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Submissions are invited at any time and, if meeting the criteria for publication, will be rapidly submitted to peer-review and carefully evaluated, selected and edited. Once accepted and edited, the papers will be published as soon as possible.

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A letter from the Editor

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The interest in publication in the Journal has significantly improved in the present year; for the current issue, five papers were accepted for publication. It comprises two original scientific papers, one research paper, and two case studies. The first paper is dealing with new theoretically well-described and experimentally proved methods of production of embossing tools by using additive manufacturing. The use of DNA-based anti-counterfeiting and identification methods in gravure and 3D printing is reported in the second paper. The influence of different films and white underlayers on the color reproduction of flexible packaging printed in the gravure technique is reported in the research paper.

The use of different digital image processing methods for approval of the authentication of Indian banknotes is presented in the first case study. The last article deals with the media literacy and information technology competencies of the students of Mizoram University, India.

The Topicalities, edited by Markéta Držková (marketa.drzkova@jpmtr.org) are bringing an overview of the reconfirmed and in the last year newly accepted standards in the field of Graphic technology, under the responsibility of ISO Technical Committee 130. As a consequence of the global pandemic, the new drupa Global Trends Report is available with a delay of more than two years. The insight into Stora Enso research on sustainability, and updated specifications for file exchange and preflight in pre-press prepared by Ghent Workgroup are also presented.

A comprehensive list of books from the fields covered by the Journal is available in the Bookshelf chapter. The list begins with a book on inkjet printing in the industry, continues with books on 3D and 4D printing, media, visual signs, and perception, followed with books on tissue engineering, contemporary materials for electronic devices, and thermoset resins.

In the same chapter also three theses are presented. Doctoral thesis on vat 3D printable materials and their application for the biomedical field was defended by Gustavo Adolfo Gonzales Flores at the Politecnico di Torino, Italy. The next presented thesis on modern Ukrainian ex-libris tradition, transformation, and achievements; it was defended by Yuliya Vyacheslavivna Kamenetska at the National Academy of Fine Arts and Architecture Kyiv. The third presented thesis on functional mechanical metamaterials was completed by Mohammad Usman Waheed at the Imperial College London.

The Events section is unfortunately still shorter due to the pandemic. The good news is that presented events are planned as live, in-person conferences, congresses, meetings, symposia, and exhibitions; however, in some cases online attendance is also an option.

After the successful iarigai International Research Conference in Greenville, some interesting original scientific or research papers for publication are expected. Even if you missed the option to attend the conference, you are invited to submit your manuscript for review and publication in the Journal. The higher number of submissions realized in past months is a good sign, and I am convinced this is also an opportunity for improvement of the quality of the papers and the status of the Journal. In the next year for all journals indexed in ECSI (by Clarivate Analytics), the desired and long expected Impact factor will be available. The quality of submitted manuscripts and the number of their recorded citations is the key to success, for the authors and for the Journal.

Ljubljana, September 2022

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Heightmap-based computing of the tool gap for additive manufacturing of paper embossing tools

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Abstract

Tools used for embossing paper and cardboard usually consist of two dies, which are inverses of each other. An important design parameter is represented by a defined gap between the fully closed dies. This is achieved by creating one of the two dies with an embossing relief that is displaced by a constant surface-normal offset. To facilitate fast data preparation for additive manufacturing of such embossing tools, a heightmap-based image data processing is developed, although the preparatory steps and resulting data may be also used for conventional manufacturing. The fundamentals of paper embossing tool layout and relief representation in heightmap images are explained and the developed process steps and their calculation bases are discussed. The focus is placed on the derivation of a heightmap with constant normal offset with respect to an input heightmap. For this purpose, image processing algorithms are elucidated to first determine the relief's surface curvature and use this information to deduce the necessary alteration to receive a derived heightmap. The generated data is reviewed and evaluated regarding its suitability for the production of additively manufactured embossing tools, which is done by examining the data as well as the derived physical dies.

Keywords: 3D printing, stereolithography, image processing, heightmaps, direct tooling

1. Introduction and background

In addition to printed texts, logos and images, embossments are used as a high-quality finish of paper, packaging and cardboard products. They do not only enable a visible change of the substrate's surface, but also add a haptic component to its design. Handling the print product, the customer can feel the embossment supporting the impression of a brand logo, writing or other features. For this reason, embossed details can be found on packages of products for the end consumer market as well as on business cards and other print media, where a high-quality finish is desired. Whereas for graphical print digital options exist, such as inkjet printing, which make them suitable for one-off and small-scale production, embossments can only be achieved with aid of embossing tools, which have to be produced for each embossment design individually (Iggesund, 2009, pp. 29–31). High cost and time consumption of the production of these tools can make them virtually unsuitable for individual or small-scale production of paper and cardboard products or make these very expensive to acquire. As shown in Figure 1, embossing tools for blind embossing consist of two halves, a female and a male die. The male die depicts the inversion of the female die and is used to drive the substrate into the desired shape by pushing it into the female die under the application of pressure (Iggesund, 2009).

In conventional manufacturing, embossing tools are often made from metals. Brass and steel tools are machined by a high resolution CNC or an engraving process (Fachverband deutscher Stanzformhersteller e.V., n.d.). Tools made of copper or magnesium can

also be created using etching processes. In contrast to metal cutting, etching processes are more cost-effective, but also limited in the achievable relief geometry of the embossing tools. Embossed reliefs, which are created by etching, usually consist of only two levels, while detailed height gradations and transitions can be achieved by milling or engraving. Further, embossing tools made of copper or magnesium are much less durable than ones machined from brass or steel (Iggesund, 2009, pp. 29–31). Depending on the paper thickness (caliper) of the intended substrate, the geometry of one of the two dies needs to be offset from the other in order to create a gap between the fully closed tool halves (Iggesund, 2009; Kirwan, 2013).

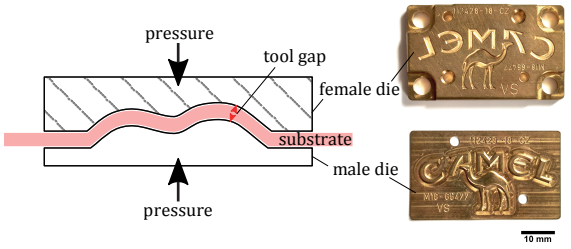


Figure 1: Schematic sectional view of a closed embossing tool with inserted substrate and an example of a conventional embossing tool made of brass

As an alternative to machining or etching both dies, the female die can also be used as a mold to cast the male die with e.g. thermoset resins. However, this approach holds a challenge. Casting of the male geometry does not allow for a large tool gap, as the only means of creating an offset between the two dies is through planned shrinkage of the thermoset resin during curing. Further, the shrinkage of the resin is hardly controllable, as it depends on the used materials, temperatures and geometries of the relief. Higher shrinkage, which is needed for thicker cardboard materials, also leads to higher residual stresses in the material and induces undesired warping (Zarrelli, Skordos and Partridge, 2002), further limiting the gap achievable using this method. A constant and defined tool gap is desirable as it allows for cleaner embossments and easier handling.

Delić, et al. (2017) investigated the suitability of additive manufacturing processes for the production of simple paper embossing tools. Therein, the Fused Filament Fabrication (FFF) process is used to fabricate two-part embossing tools. The authors conclude that, in principle, functional embossing tools can be created using this approach, but that deficiencies occur with embossing reliefs that are rich in detail and complex. Especially with increased fabrication speed, FFF produced tools show limitations in the reproduction of small elements often included in paper and cardboard embossments (Žarko, et al., 2017). However, the studies on FFF printed embossing dies show the need for a rapid tooling solution for paper embossing dies. Rapid tooling describes the additive manufacturing of tools as patterns or molds of a final part. It intends a fast and effective production launch rather than a high quantity of produced goods (Gibson, Rosen and Stucker, 2015).

Feldmann, Spiehl and Dörsam (2021) are presenting a novel approach for the production of paper embossing tools using heightmap data and masked stereolithography based additive manufacturing (MSLA). The process was shown to reduce manufacturing lead times from a full business day to approximately 2.5 hours. The MSLA can be classified as one of the additive manufacturing processes with the highest part resolution (Kim and Oh, 2008) and surface qualities (Li, et al., 2017) and has therefore proven to be a suitable manufacturing process for tools for paper embossing with a high level of detail and smooth surfaces. The presented approach allows for a cost-efficient manufacturing of prototype tools as well as for small to mid-scale production of embossed media of up to 20 000 pieces (Feldmann, Spiehl and Dörsam, 2021).

The present study focuses on the relief surface-normal tool gap, which is created by an offset of the male from the female relief. It centers on the preparation process for the computation of this gap in the geometry data, with the aim of using MSLA additive manufacturing for the tool fabrication, and evaluates the thereby created embossing tools. In the tool design a secondary gap between both fully closed die blocks outside of the relief geometry is also considered. This secondary gap is larger than the intended substrate's thickness in order to not compress and deform it where not desired. It is achieved by an additional elevation of the male relief from the die block's surface. In Figure 2 the functional features of embossing dies are shown in a schematic cross-sectional view of a closed tool.

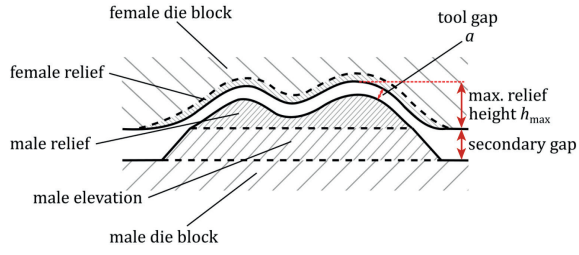


Figure 2: Diagram of the functional features of a paper embossing tool; a distinction is made between a tool gap a in the area of the embossing relief and a secondary gap outside the deformation area that serves the purpose to leave room for the substrate where it must not be deformed; the maximum relief height h_{max} is highlighted

2. Materials and methods

2.1 Heightmap images for representation of embossment reliefs

Heightmap (also *heightfield* or *displacement map*) images are usually 8-bit grayscale raster images first used by Cook (1984) to represent relief data for digital application such as rendering. Due to their small data size heightmaps are used as an efficient method to define surface data and can easily be viewed, edited and used in conventional image editors as well as transformed for use in 3D programs. A set gray value for each pixel defines the elevation of this point out of the base surface (Karhu, 2002). Using 8-bit grayscale images, elevations in a resolution of $2^8 = 256$ steps are achievable. Following Doggett (2001), conventionally, values of 0 (fully black) represent no elevation, while 255 (fully white) represent the highest points of the surface.

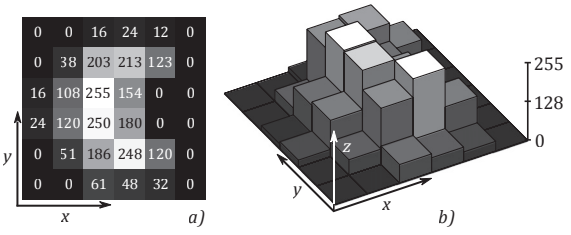


Figure 3: Exemplary illustration of a 6 × 6 pixel heightmap: elevation values are depicted as grayscale shades as well as values from 0 to 255 in (a); part (b) displays a three-dimensional representation, where pixels are raised from the image plane according to their elevation values

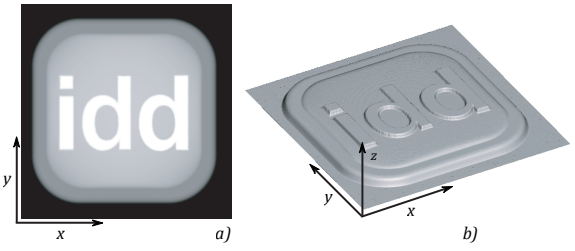


Figure 4: Comparison of an 8-bit heightmap (737 × 749 pixels, x × y) in (a), with the rendered relief derived from it (b): elevation of each point on the heightmap is represented by the brightness of the corresponding pixel; the representation of (b) is smoothed via a triangulation over the pixel values

Figure 3 shows a schematic diagram of a 6 × 6 pixel heightmap and Figure 4 displays the relief geometry of an embossment as a heightmap and as a rendered three-dimensional representation. Heightmap images are dimensionless. In order to use them for depictions of real objects, the dimensions of the image plane and the step height of the gray levels must be specified. As for each pixel on the image plane only one elevation value can be defined, heightmaps are unable to display overhangs and undercuts and are limited to surface curvature angles up to 90°. Further, due to the discretization in 256 steps, the resolution might not be sufficient in applications with shallow slopes or high elevations, as steps could be visible in the three-dimensional relief.

For the definition of embossing geometries, heightmaps are commonly used for the communication between designer and manufacturer. This is primarily the case for complex, three-dimensional designs, where elevation cannot be derived easily from 2D vector images. The aforementioned limitations in the application of heightmaps do not pose a problem for the definition of embossments, as the embossing of paper and cardboard share the same restrictions, such as the maximum surface curvature angle and the inability to display undercuts. Limits of the elevation resolution also play a subordinate role, as embossing features are usually rather flat reliefs with minor elevations of usually less than 1 mm, where 256 discrete steps serve sufficiently enough to display smooth transitions and details. Further, manufacturing methods generally pose more severe limitations in elevation resolution, which reduces the necessity for higher resolution in the images even more.

2.2 Image processing for tool gap

As mentioned before, an important design parameter in the layout of embossing tools is the gap between the reliefs of the closed female and male dies. It is desirable to manufacture corresponding dies with a uniform gap between both reliefs, which is of constant thickness along the curvature of the surface. In order to achieve such a tool gap, an image processing algorithm was developed, which can compute a fitting male relief heightmap with a predefined offset from a given female original heightmap or vice versa.

We set the originally designed heightmap to represent the relief towards the viewer and calculate either a shrunk male heightmap for an embossment, where the relief is raised out of the image plane, or an enlarged female heightmap for a debossment, where the relief is lowered into the image plane, for the die for the back side. Image processing, rather than 3D modelling, was utilized to decrease calculation time by reducing overall complexity of the calculation. For the sake of simplicity this publication will first discuss the calculation of a male heightmap-based on a female heightmap. Following, the few differences to the reverse process will be outlined. The developed image processing

algorithm was realized in *Python 3.*7 using the *NumPy* library (NumPy community, 2020). We need to define the dimensions of the desired embossing relief before commencing the image processing. Therefore, the physical image width of the heightmap, maximum relief height h_{max} and tool gap a (see Figure 1) need to be specified beforehand.

In a first step, the surface curvature at each point of the original heightmap is calculated, which is necessary to determine the surface-normal needed for the tool gap. For this a minimum filter oriented approach was used. Pixel wise the value of each pixel of the original heightmap $H_{orig,i,j}$ is compared to all other pixel values within a predefined kernel size around it. Larger kernel sizes result in smoother surfaces, albeit tending to blur details. Although the kernel size can be chosen arbitrary, we received best results with reasonable computing times when setting a kernel with a side length of approximately twice the desired tool gap. The distance $s_{i,j}$ between the kernel center pixel and the pixel with the lowest value within the kernel area is calculated (Figure 5a). If two or more pixels with equal values are found to be the lowest within the kernel area, the lowest distance between the center and one of these is considered to be $s_{i,j}$ (Figure 5b). In the case the center pixel itself has the lowest value within the area, or if all pixels within the area share the same value, the distance $s_{i,j}$ is considered to be zero (Figure 5c). All three cases are shown in Figure 5.

Further, we also determine the difference in pixel value $d_{i,j}$ between the pixel under consideration and the calculated lowest pixel in the kernel area. Again, if either the center pixel is the lowest or all pixels share the same value, the difference $d_{i,j}$ is considered to be zero.

With aid of the now known values $s_{i,j}$ and $d_{i,j}$ for each pixel, we can compute the local curvature $\theta_{i,j}$ through a trigonometric equation. Figure 6 shows a schematic representation of values needed for the determination of the curvature angle. A simplified diagram visualizing the calculation of the local curvature angle can also be seen in step 1 of Figure 8. As heightmaps represent dimensionless reliefs, we need to incorporate the real pixel size d_{px} and gray value step height h_{step}, which is calculated from the maximum relief height h_{max} divided by 255, to receive the curvature of the real surface:

$$\tan(\theta_{i,j}) = \frac{d_{i,j}}{s_{i,j}} \cdot \frac{h_{step}}{d_{px}} \quad [1]$$

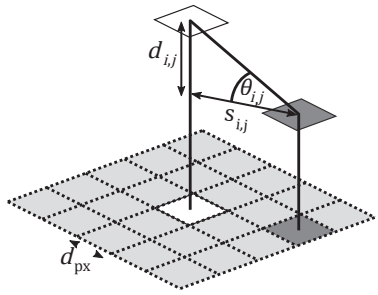


Figure 6: Schematic representation of value difference d between center and lowest pixel and pixel distance s between center and lowest pixel in a 5 × 5 kernel; curvature angle θ is calculated using a simple trigonometric equation

As an example, Figure 7 shows a plot of the surface curvature angle of the heightmap given in Figure 4. Values were calculated for each image pixel *i,j* following the above-mentioned method and Equation [1]. The maximum height of the relief h_{max} was set to 1 mm resulting in a step height of $h_{step} \approx 3.92$ µm and the image width to 50 mm resulting in a pixel size of $d_{px} \approx 67.84$ µm.

In a second processing step, the pixel grayscale values of the matching male heightmap need to be determined. In order to receive the male heightmap, the value of each pixel of the original heightmap needs to be reduced by the correct z-offset $\delta_{i,j}$ to result in the predefined surface-normal tool gap a.

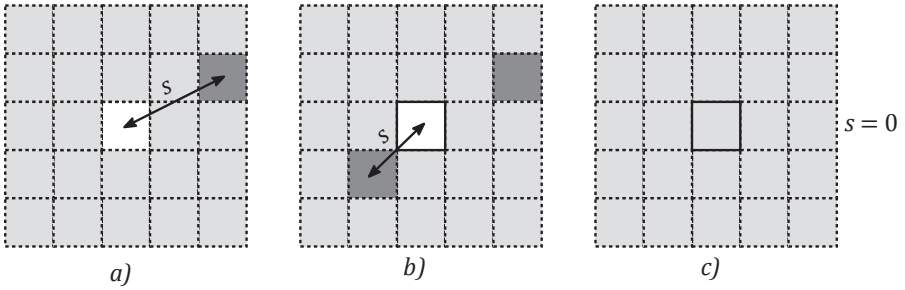


Figure 5: Schematic representation of the three cases for calculating the distance s with a 5 × 5 kernel, which is propagated for each pixel of the original heightmap image: (a) the distance s is considered to be the distance between the center pixel and the lowest (darkest) pixel of the kernel area, (b) if more than one pixel with the lowest value exists within the kernel area, the distance to the closest pixel from the center is considered, (c) if all pixels within the kernel area share the same value, the distance is considered to be zero

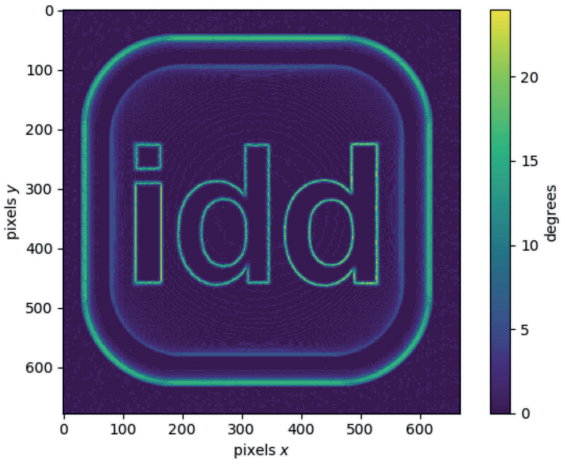


Figure 7: Calculated surface curvature of heightmap shown in Figure 4

The amount each pixel value needs to be reduced by was therefore calculated with a second trigonometric equation and the local surface curvature angle $\theta_{i,j}$ calculated by Equation [1]. Here we needed to incorporate the step height again in order to receive a value for the z-offset $\delta_{i,j}$ in dimensionless grayscale.

$$\delta_{i,j} = \left\lfloor \frac{a}{\cos(\theta_{i,j})} \cdot \frac{1}{h_{\text{step}}} \right\rfloor, \quad \delta_{i,j} \in \mathbb{Z} \qquad [2]$$

Because 8-bit heightmaps are limited to integer numbers, $\delta_{i,j}$ was rounded down by the floor function. Figure 8 shows a summary of the two processing steps in a two-dimensional representation.

As a third and final step, the male heightmap was achieved by subtracting the local value of $\delta_{i,j}$ from each pixel of the original heightmap. Where the result would be negative it was set to zero.

$$H_{\text{male},i,j} = \begin{cases} H_{\text{orig},i,j} - \delta_{i,j}, & (H_{\text{orig},i,j} - \delta_{i,j}) \geq 0 \\ 0, & (H_{\text{orig},i,j} - \delta_{i,j}) < 0 \end{cases} \qquad [3]$$

If the above-mentioned reverse process is required to create a female heightmap from a male original, a few changes must be considered.

The local surface curvature angle $\theta_{i,j}$ and the required z-offset for each pixel $\delta_{i,j}$ can be determined in the same way as shown in Equations [1] and [2] earlier. When adding $\delta_{i,j}$ to the original heightmap rather than subtracting it, we can enquire values which exceed 255, which is the largest value 8-bit grayscale is defined for. In order to avoid this problem, we reduced the original heightmap by a factor k. The largest possible value for $\delta_{i,j}$ is a/h_{step}, hence we choose

$$k = \frac{255}{255 + \frac{a}{h_{\text{step}}}} \qquad [4]$$

in order to preserve the maximum possible resolution for the resulting female heightmap, without exceeding values of 255. A female heightmap can then be calculated by adding the z-offset $\delta_{i,j}$ to the original heightmap and multiplying the result by the factor k. Values of the female heightmap were rounded to the nearest integer number.

$$H_{\text{female},i,j} = \lfloor k(H_{\text{orig},i,j} + \delta_{i,j}) + 0.5 \rfloor, \quad H_{\text{female},i,j} \in \mathbb{N}_0 \qquad [5]$$

2.3 Layer images from heightmap data

The MSLA and comparable additive manufacturing requires raster layer images (or *layer masks*), where all parts of the layer, which should be exposed to light and therefore solidified, are shown as white while all others are shown as black pixels. To receive respective layer images from previously computed heightmaps, a simple threshold function can be utilized, which incorporates each heightmap pixel value and considers layer number l as well as dimensional step h_{step} and

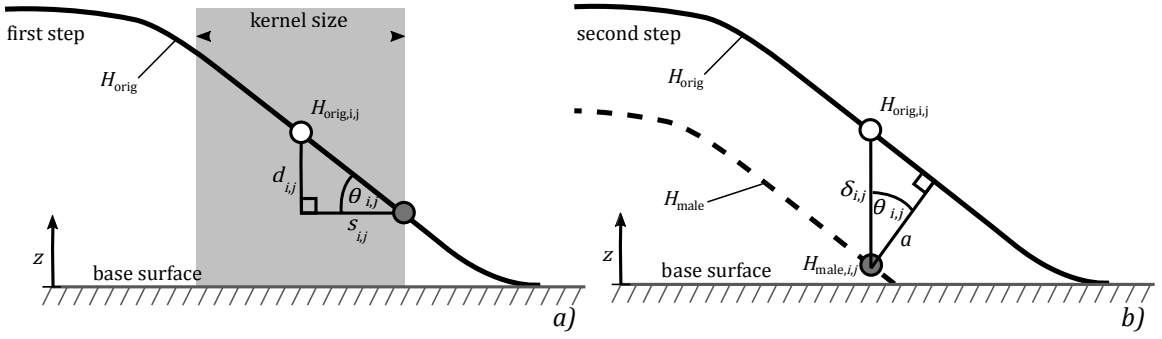
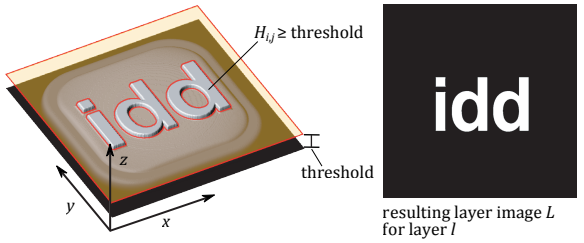


Figure 8: Graphical two-dimensional representation of the two subsequent computing steps for the calculation of the offset male heightmap H_{male}: in the first step (a), the lowest value inside the kernel size around each point on the original heightmap allows for the calculation of the surface curvature; in the second step (b), the value by which the male heightmap needs to be offset in z-direction is calculated to achieve a constant surface-normal tool gap of a

layer heights h_{layer}. The layer number l is increased by 1 for each new layer of image until the whole relief is processed. Thus, we set layer image pixels $L_{i,j}$ to either white (255) or black (0) under the following conditions, where k = 1, if not specified differently before:

$$L_{i,j} = \begin{cases} 0, & H_{i,j} < l \cdot k \cdot \dfrac{h_{layer}}{h_{step}} \\ 255, & H_{i,j} \geq l \cdot k \cdot \dfrac{h_{layer}}{h_{step}} \end{cases} \quad [6]$$

$H_{i,j}$ may be $H_{orig,i,j}$, $H_{male,i,j}$ or $H_{female,i,j}$ depending on which geometry was created. Figure 9 shows a schematic of how one respective layer image is calculated following the threshold function in Equation [6].



a) *b)*

Figure 9: Schematic visualization of the threshold algorithm for the derivation of layer images from a heightmap image: (a) the layer height is shown in opaque orange and all pixels that have a value greater than that of the respective layer threshold are kept and set to white (255), all others are set to black (0), (b) the resulting layer image

2.4 Evaluation methods

The data and results generated in the course of this research were evaluated using two methods. Firstly, the digital heightmap data obtained, which serves as the relief data basis for slicing and additive manufacturing, was examined. For this purpose, the derived heightmap's surface curvature and surface-normal tool gap to the original heightmap was calculated in analogy to the image processing algorithm described earlier. Further, a cross sectional view of both dies can be visualized by plotting the elevations of both reliefs along a defined path on the heightmap. Taking the real pixel size d_{px} and gray value step heights h_{step} into consideration the dimensions of the expected dies can be displayed.

Secondly, next to the raw data used for the generation of the layer images, the real MSLA additively manufactured tool was scanned using an optical 3D profilometer (*Keyence VR 5200*, Keyence, Japan) with an optical magnification of 12 times which results in a lateral resolution of 23.53 µm. Additive manufacturing was realized on an MSLA machine (*Zortrax Inkspire*, Zortrax, Poland) with a pixel resolution of 1 440 × 2 560 and a display size of 74.67 mm × 132.88 mm, which results in a pixel size of approximately 50 µm. The layer height was set to the minimum of 25 µm, recommended by the manufacturer. For easier measurement of the male relief elevation, the secondary gap (see Figure 2) was set to zero, in order to use the male block's top surface as a reference.

3. Results and discussion

Heightmap data created with the presented image processing workflow was successfully used for the manufacturing of fully functional additively manufactured embossing tools. Derived from a single original heightmap, corresponding reliefs for female and male tool dies could be obtained, depending on whether an embossment or debossment is desired. Figure 10 shows resulting shrunk male and enlarged female heightmaps fitting to a given original heightmap.

As the male heightmap uses the same z-scale as the original, and therefore the same step height h_{step}, it appears darker as it is reduced in elevation. Further, raised (brighter) areas appear thinner, while lower (darker) parts are broader to allow for a constant offset between original and calculated male relief. As described in section 2.2, enlarged female heightmaps are set to a new z-scale and therefore do not appear brighter, but broader raised areas as well as thinner sunken parts can be identified visually. The developed process allows for a quick design of relief data. Existing images of logos and emblems can easily be transferred into grayscale heightmaps in common graphic editing software, e.g. *GIMP* (GIMP Development Team, 2022), where an editor chooses different shades of gray for different elevation levels and brightness gradients for slopes. We differentiate between embossments, where the substrate is convexly raised towards the viewer, and debossments, where the substrate is concavely recessed by the tool. As mentioned before, we set the original heightmap to represent the relief towards the viewer and compute either a shrunk male heightmap (embossment) or an enlarged female heightmap (debossment) for the die of the back side. This also allows for the same design to be applied to different cardboard types and thicknesses. While the relief towards the viewer may remain unaltered, the die serving as an inverse for the back side can be adapted according to the requirements of the used substrate and the embossing process.

Figure 11 shows a partial cross section view of the data sets of an original heightmap and a computed offset, hence shrunk, male heightmap to realize an embossment. In the example the female relief depth h_{max} was

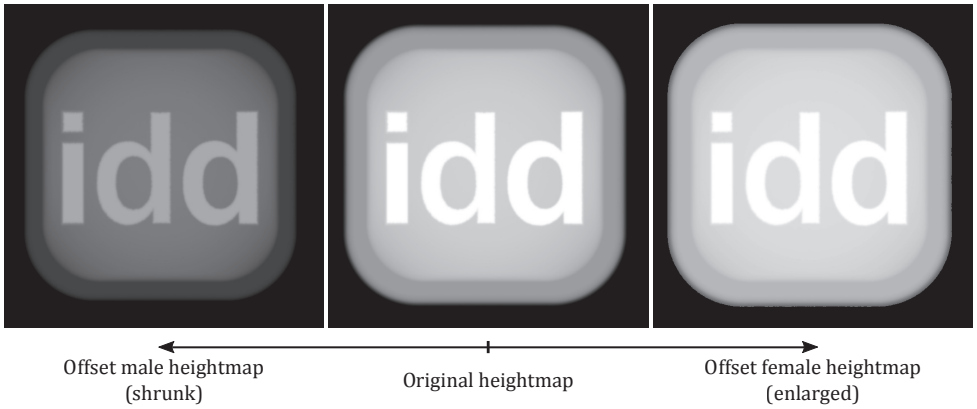


Figure 10: View of the original heightmap as well as the shrunk male and enlarged female heightmap derived from it; we choose the original to represent the relief towards the viewer and calculate either a male heightmap for an embossment or a female heightmap for a debossment for the die for the back side

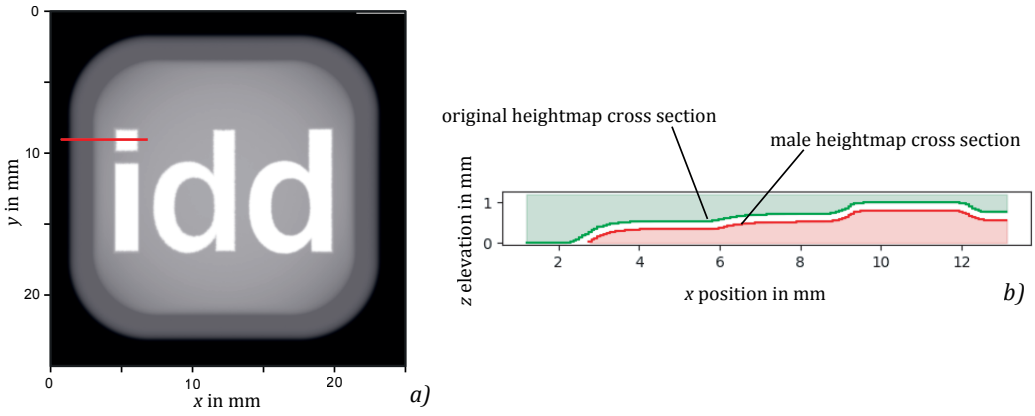


Figure 11: Cross section view of the heightmap data elevation profile along the path represented by the red line in part (a) of the figure, the profiles of original (green) and calculated male heightmap (red) are depicted in part (b)

set to 1 mm and the tool gap was chosen to be 0.1 mm. Elevation and distances in the *x*-*y*-plane were converted into unit quantities using h_{step} and d_{px}. It can be seen that a constant tool gap between both reliefs was successfully achieved with the calculated male heightmap closely following the curvature of the original heightmap, regardless of its slope angle and direction.

The error of the computed tool gap was found to be within 7 µm for a preset value of 0.1 mm for *a* and the largest deviations were identified in areas of higher surface curvatures, as can be seen in Figure 12. This implies that the approximation is error-prone in the region of large values for the quotient of $d_{i,j}$ and $s_{i,j}$. Since the technically relevant minimum resolution of additive manufacturing systems in question is in the order of 25 µm, such expected deviations of the tool gap are only of minor importance and can be accepted as sufficiently precise. Such resolutions were found to be sufficient for the intended use case for paper and cardboard embossing, as the layer pattern resulting from the stair casing effect in additive manufacturing could not be identified with the unaided eye (Feldmann, Spiehl and Dörsam, 2021).

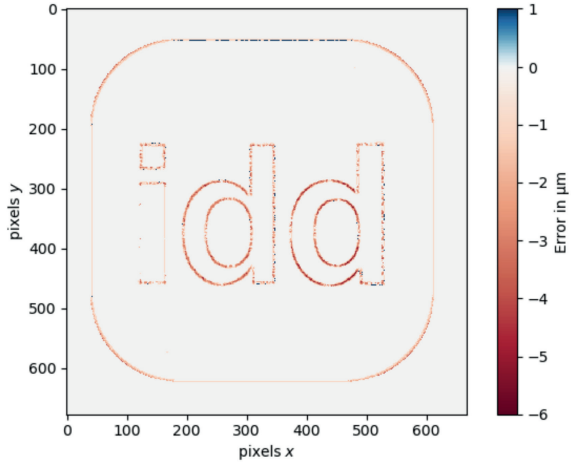


Figure 12: Plot of local tool gap deviation from the desired preset value of a = 0.1 mm between original and male heightmap data

The tool dies were set to the aforementioned dimensions (1 mm depth, 50 mm image width and 0.1 mm tool gap), in addition a secondary gap of 0.7 mm was chosen to not compress the paper where not intended and a rough paper with a grammage of 150 g/m^2 was embossed with 15 kN force.

When examining the additively manufactured embossing dies, which were fabricated based on the calculated data, it can be demonstrated that the set tool gap is also carried over onto the physical tool. A scan of the tool surface via 3D optical profilometry is shown in Figure 13. Although the tool gap is present over the whole layout of the relief and is especially very uniform as well as of the desired thickness of 0.1 mm in even and flat areas, larger deviations than in the heightmap data mentioned before can be found at high surface curvatures, where the surface-normal tool gap was found to be up to 0.14 mm. These can be explained by the coarser resolution of the used additive manufacturing system, which becomes particularly apparent in the area of gradients. While the defined female relief height h_{max} of 1 mm could be depicted in 255 discrete steps in the heightmap, in the physical tool it is created with only 40 layers of 25 µm height. Furthermore, inaccuracies in the building process as well as handling can cause rounding along sharp edges, which can be seen along the rim of the female relief in the cross-section view of Figure 13. However, deviations were found to be small enough to not cause major deficiencies in the embossing process or in the embossing results. An embossment created using an embossing tool designed and manufactured in the here described process is shown in Figure 14.

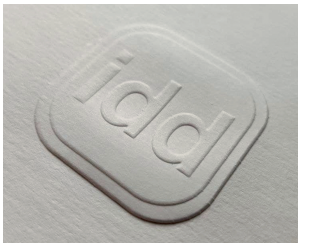


Figure 14: Embossing result in rough paper of 150 g/m^2 grammage by an additively manufactured embossing tool of 1 mm depth with a 0.1 mm tool gap, a force of 15 kN was applied to emboss the substrate; the embossment has a size of 38 mm × 38 mm

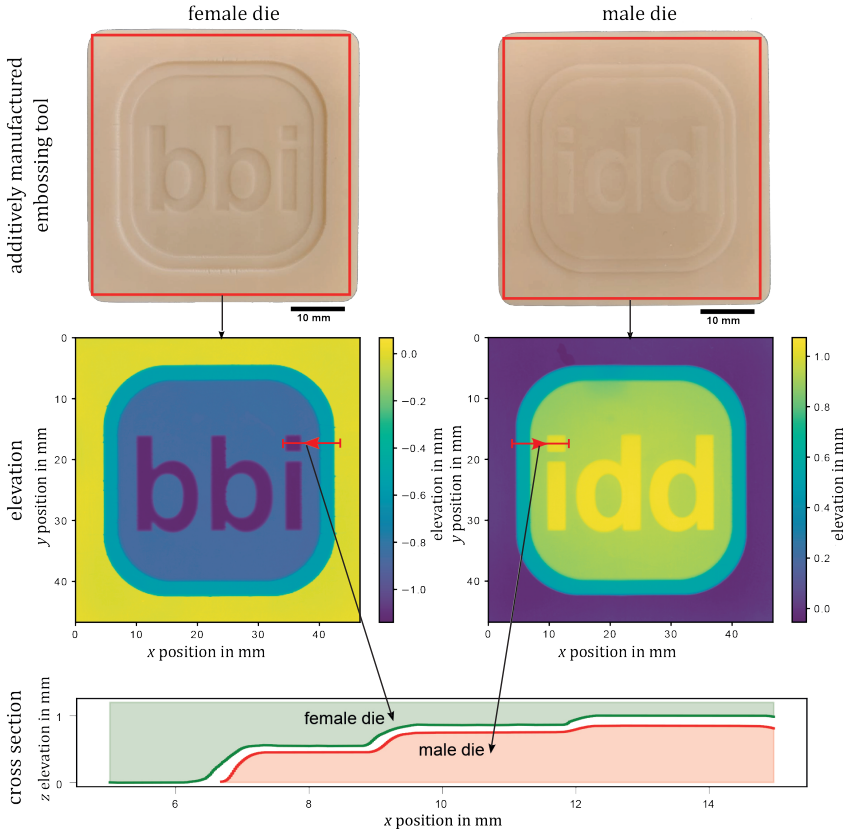


Figure 13: Display of a relief analysis of the additively manufactured embossing tool; 3D scans of the relief surfaces of both dies were realized using an optical profilometer, the figure shows images of the manufactured female and male embossing die, where the area of the scan is highlighted in red; the scanned surface elevation as well as a cross section view of the closed dies are displayed below

4. Conclusions and outlook

The investigation shows that heightmap data is suited for direct processing into layer images for additive manufacturing of embossing tools without the need for other preparatory 3D modelling software. Embossing reliefs can be derived from images used for graphic print and can therefore be easily and quickly processed in the same work environment. The method, thus, has the potential not only to reduce the production time of embossing tools, but also to enable faster provision of processable data. It was further shown, that the relief of a complementary die of a two-part tool with a defined surface-normal offset can be calculated using the presented algorithm. The derived complementary die exhibited minor deviations from the desired size (< 7 µm), which is smaller than the resolution of conventional additive manufacturing technologies and thus neglectable. A 3D surface scan of the additively manufactured tool showed that the largest deviations arise from the manufacturing process rather than from the data preparation, which could possibly be reduced by choosing an MSLA system with a higher resolution and further improvement of the setup and workflow. Nevertheless, these deviations are small enough to not cause deficiencies in the embossing process or result.

Experience shows that during embossing the substrate experiences particularly high stresses in areas that exhibit high degrees of deformation. These are prone to result in failures of the embossment. Therefore, determining these areas of high degrees of deformation based on the surface curvature angle and dynamic adjustment of the tool gap could be possible content of future research. This could distribute loads more evenly over the substrate and reduce stress peaks, which would potentially have a positive effect on process reliability and the achievable maximum embossing depth. Finally, 3D scanning of the embossing result on the substrate and comparison with the original heightmap data could allow for a regulated adjustment of the relief data and tool gap. It could also provide a deeper understanding of the embossing deviations in comparison to the original data, which may allow general rules on embossing transfer to be derived.

Future work is therefore aimed at the estimation of an embossing result based on gathered information gained from a comparison between the original heightmap and the 3D scanned embossing result. This could potentially not only reduce production times per iteration, but reduce the necessity for iterations and trial embossings overall.

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Use of *Bacillus subtilis* spores in printing and additive manufacturing as a robust, DNA-based anti-counterfeiting and identification feature: stresses, processing and evaluation

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Abstract

Part labeling is a crucial security feature as it can prevent product counterfeiting. Deoxyribonucleic acid (DNA), the information carrier of life, is started to be explored as an engineered information molecule with immense potential in respect to information density and encryption. Most research in this direction is concerned with how to encode binary data into DNA and read the stored information from this DNA. Little to no effort is made on how to apply DNA and the information stored within as an identification label for counterfeit protection. In this study, we explore DNA in various printing processes for its suitability as an anti-counterfeiting and identification tag. DNA is sensitive to environmental influences, which is why we compare the suitability of free DNA against using the spores of the bacterium *Bacillus subtilis* as a naturally evolved DNA protective shell. To integrate these two DNA species into products, we aim to use both conventional printing methods and additive manufacturing processes. Foremost we investigate the stresses on the DNA as well as spores, then derive suitable printing techniques and assess the practical application – processing, extraction and subsequent detection via polymerase chain reaction (PCR). The stresses are differentiated into four groups – solvents, UV irradiation, temperature and shear stress, to which both DNA species are exposed and characterized. In actual printing processes several kinds of stresses are combined and thus we test two exemplary and complementary methods. Namely gravure printing as a conventional 2D– and masked stereolithography as a 3D printing method. We were able to show that both free DNA as well as DNA encapsulated in spores can be readily integrated into printing processes and detected using PCR where there are some significant advantages for DNA protected in spores. Consequently, spores, which can be applied economically, fast and in large quantities using printing, offer great potential for counterfeit protection, for example on drug packaging.

Keywords: gravure printing, 3D printing, masked stereolithography, product piracy, counterfeit protection

1. Introduction

Product piracy is a global economic concern. According to OECD data of 2019, around 2.5 % of all products in international trade are counterfeit, which corresponds to a value of 414 billion EUR (OECD/EUIPO, 2021). Counterfeit products not only have a negative impact on sales revenue for companies, but also damage the reputation of the brand. In addition, low-quality products or harmful materials pose risks for the customer (Kennedy, 2020). This is especially true for counterfeit pharmaceuticals. It is estimated that about half of all medicines worldwide are counterfeits, resulting in several hundred thousand deaths per year due to substandard drugs (Glass, 2014; Shipalana, Matema and van der Westhuizen, 2020). Therefore, there is an industry-independent effort to provide products worth protecting with anti-counterfeiting features. Among the best-known and most widely used security features are holograms, seals and QR-codes, however, protection is limited as these can be imitated by product counterfeiters (Sung, et al., 2015; Fernandes, 2019).

We present a novel approach to anti-counterfeiting by applying deoxyribonucleic acid (DNA) protected in spores using 2D and 3D printing. We compare it with free, unprotected DNA to emphasize the advantages of our "DNA vault" concept. In addition to the potential for product counterfeit protection, it also offers the ability for product identification due to the possibility of storing information as a biological storage device.

The potential for commercial application of DNA as an anti-counterfeiting label had been described by Outwater and Tullis (2000). Preliminary work also exists on the application of DNA-tags in inks, e.g., by Hashiyada (2004). Even though the potential of DNA markers has been proven in many publications, DNA's lack of stability – and thus its suitability for long-term use under sometimes harsh environmental conditions – is still the greatest obstacle (Hashiyada, 2004; Altamimi, et al., 2019; Berk, et al., 2021; Sharief, Chahal and Alocilja, 2021). Embedding DNA in a protective shell (such as silica or nanomaterials) appears promising, but is accompanied by high manufacturing costs and an extensive extraction process (Sharief, Chahal and Alocilja, 2021). Nevertheless, a single commercialized DNA identifier appears to be resistant to high temperatures and UV radiation, but the technical implementation of this protection has not been described (Hayward and Meraglia, 2011).

Instead of the previously described approaches of providing DNA with an artificial protective layer, we take the approach of exploiting the ability of *Bacillus subtilis* to form so-called endospores and use these spores as a "DNA vault". The Gram-positive bacterium *B. subtilis* is one of the best studied microorganisms and widely used in industrial biotechnology (van Dijl and Hecker, 2013). It is able to differentiate between vegetative, i.e., normally reproducing cells, as well as a dormant state, the so-called spores. The process leading to this state is called sporulation and is the ultimate answer of the cell to harsh situations (Setlow, 2006). The cell copies its DNA and packs it into a protective shell equipped with many mechanisms to ensure the DNAs integrity (Nicholson, et al., 2000). Upon completion of this process, the spore destroys its mother-cell and is released. Spores can remain inactive due to their low water content for thousands of years (Sneath, 1962) while retaining their ability to germinate to vegetative cells within hours upon receiving the appropriate environmental signals (Setlow, 2014).

Next to these highly intricate physiological features, *B. subtilis* spores are already produced in large scale industrial processes for agriculture (El-Bendary, 2006) and can also be used for various biotechnological applications (Setlow, 2006; Karava, Gockel and Kabisch, 2021). The safe use of spores is underlined by the fact that *B. subtilis* spores are prescribed as probiotics (Hong, Duc and Cutting, 2005). The use of spores has as well been demonstrated as 3D printable living materials (González, Mukhitov and Voigt, 2020).

Free genomic DNA can be applied to products using printing processes (see Figure 1a), but it may be damaged by the printing ink, processing or environmental influences. Our approach, shown in Figure 1b, is based on the fact that DNA as an ID is protected by *B. subtilis* in spores in such a way that it can be processed by industrial printing processes and is enduring on the products. Samples can then be taken from the protected product and the DNA ID of interest can be detected by a variety of methods. In this work, detection using polymerase chain reaction (PCR) was chosen as the method of choice, as it is well established in the lab. For future application in the field, a lower instrumented method such as loop-mediated isothermal amplification (LAMP) or even an instrumentation-free, on-site detection of the DNA could be established, using different lateral flow assays which have been developed to detect pathogenic bacteria (Lee, et al., 2016) and viruses (Piepenburg, et al., 2006).

Printing processes, such as gravure printing used in this work, seem suitable for the commercial application of spore-protected DNA identification features to products, as they are quick and cost-effective (Kipphan, 2001). However, in addition to the stresses to which the identification feature is subjected during storage, transport and use of the product, printing causes further stresses to be applied to the spores. Printing inks consist of various components, including

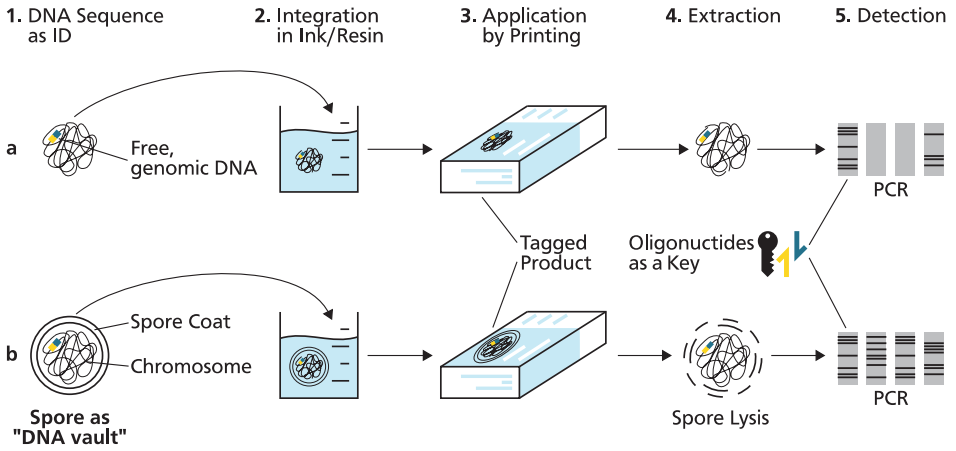

Figure 1: Process for the integration of DNA into an ink, subsequent processing by printing and later extraction and validation of the DNA for free genomic DNA (a), compared to the "DNA vault" concept, in which DNA is protected in spores (b); in this work, detection was performed by PCR; lateral flow assays represent a simpler solution in the field for future application

solvents, which are important for the inks' processability, the drying process or for dissolving additives (Kipphan, 2001). When spores are added to printing inks, they remain in contact with solvents for extended periods of time. The potentially damaging effect of the solvents on the investigated DNA must therefore be examined. Furthermore, in conventional printing, UV-curing inks may be used, in which polymerization is triggered by UV radiation (Kipphan, 2001). Likewise, UV-crosslinking resins are used in 3D printing by vat photopolymerization, including stereolithography (SLA) or digital light processing (DLP). Accordingly, to use spores as a counterfeit protection, they must withstand irradiation by UV light. Thermal stress poses a further challenge. It can occur both in conventional printing, such as for drying the inks, and in 3D printing, for example for melting the filament in fused filament fabrication (FFF). For instance, polylactic acid (PLA), a polymer frequently used as a 3D printing material, is processed at a temperature of 200 °C (Nienhaus, et al., 2019). Among the mechanical loads, shear is the dominant mechanical stress on inks in conventional printing processes. The range of values for typical shear rates varies heavily, depending on the printing process. In offset printing, shear rates of 1 000/s to 10 000/s can be assumed (Mewis and Dobbels, 1981; Pangalos, Dealy and Lyne, 1985), in flexographic printing, the range is between 1 000/s and 100 000/s (Lorenz, et al., 2013), and in gravure printing, shear rates as high as 1×10^6/s may be achieved (Jabrane, et al., 2008).

The processing of spores in printing inks and resins does not require any special machinery or processes. The size of *B. subtilis* spores, with a diameter of about 480 nm and a length of about 1070 nm (Carrera, et al., 2007), barely differs from ink pigments, which are usually in the range of 500 nm to 1500 nm (Szabo, 2002). In contrast to pigments, however, even very low concentrations of spores are sufficient, which we will discuss further below. The challenge rather is not to damage the DNA contained in the organism by processing it using printing methods, which is what we are addressing in this work. The fact that – as previously mentioned – *B. subtilis* is commercially available as a probiotic dietary supplement underlines its safe use. As long as no genetically modified organisms (GMO) are used, there are no special legal restrictions on their use, for example in commercial printshops. As a result of this, we use genetically non-modified wild type strains for producing the spores in order not to consider legislation for GMO in our work. The genetic diversity, i.e., different DNA sequences required to provide individual safety encoding can still be achieved this way by either using different locations to be detected on the strains genome or using strains with differing genomes.

Consequently, in this work we aimed to investigate the feasibility of different printing methods – including conventional printing and additive manufacturing using gravure printing and mask stereolithography (mSLA), respectively – for processing free DNA versus DNA protected by *B. subtilis* spores. Foremost we investigated the influence of the mentioned stresses on both DNA species.

2. Materials and methods

2.1 *Bacillus subtilis* spore and isolated genomic DNA preparation

Spores of *B. subtilis* were prepared as described in Karava, Gockel and Kabisch (2021) with the following modification. Strain S02003 was incubated for 48 h at

37 °C with 200 rpm shaking in Difco Sporulation Media (DSM; 8 g of Bacto nutrient broth, provided by Difco, Franklin Lakes, United States), 10 ml of 10 % KCl solution, 10 ml of 1.2 % $MgSO_4 \cdot 7H_2O$ solution and 0.5 ml of 1 M NaOH were dissolved in 1 l of deionized water and sterilized by autoclaving). For harvesting the spores, the culture broth was centrifuged for 15 minutes at 3 500 × g and the pellet resuspended in deionized water to yield an optical density measured at 600 nm (OD_{600}) of 0.1.

A custom washing solution (9 g/l dissolved by pipetting in deionized water, provided by NeoFroxx GmbH, Einhausen, Germany, available upon request), which safeguards integrity of the spores while eliminating free DNA, was used. This step was necessary to ensure that only spore DNA is detected in subsequent experiments. Therefore, the OD_{600} = 0.1 spore solution was mixed with 5 ml washing solution and incubated at 20 °C for 120 minutes with an agitation of 350 rpm. After this incubation the solution was washed three times with a double volume of deionized water by repeated centrifugation (5 minutes, 20 °C, 3 500 × g) and resuspension. The sample was finally concentrated by centrifugation as described above following a resuspension of the final pelleted spores in 1 ml of deionized water.

Free, genomic DNA (gDNA) from vegetative grown *B. subtilis* was isolated using the High Pure PCR Template Preparation Kit (Roche Diagnostics GmbH, Mannheim, Germany) according to the manufacturer's instructions with the following modifications. In order to ensure full lysis of the cell wall, the cells were incubated in the resuspension buffer with 10 µl of 10 mg/ml lysozyme (Sigma-Aldrich, St. Louis, USA) dissolved in deionized water for 60 minutes at 37 °C.

2.2 DNA detection

The DNA from spores was detected using colony PCR. Colony PCR involves cultivation on a growth medium, during which *B. subtilis* colonies are formed and subsequent PCR, during which a specific section of the DNA is amplified to such an extent that the detection limit is exceeded.

For this the spores in solution, e.g., organic solvents or from sample taking as described in the corresponding printing processes, were plated to LB-agar plates (7.5 g agar, 5 g tryptone, 5 g sodium chloride and 2.5 g yeast extract, autoclaved in 500 ml of deionized water) and germinated to colonies of vegetative cells in 16 hours at 37 °C. A pipette tip was used to transfer a minimal amount of cells to a 20 µl of *Taq* polymerase reaction mix (EURx, Gdańsk, Poland) and resuspended by pipetting. For gDNA, in contrast to spores, the cultivation step could be omitted.

Presence of sufficiently intact DNA was detected using PCR with the primers listed in Table 1 using *Taq* polymerase and thermocycling protocols as suggested by the manufacturer. The detected DNA sequence was a 424 bp stretch in the *amyE* gene of *B. subtilis*. PCR was evaluated by DNA gel electrophoresis.

Table 1: Oligonucleotides used in this study

Primer-ID	Used for	Sequence (5'→3')
14207	amplification of *amyE* reverse	CAGCGTGTAAATTCCGTCTGC
66032	amplification of *amyE* forward	GATGCGAATACAACAAAAGCCG

2.3 Stresses

Printing processes – regardless of whether they are conventional printing processes or 3D printing processes – have in common that stresses due to solvents, temperature, irradiation and shear occur when ink, resin or molten plastic filament is applied. These sometimes interacting stresses may have a negative effect on the free DNA as well as on the spores. Therefore, the different stresses are first analyzed individually in order to determine whether individual stresses already lead to damage to the DNA sequences to be detected. For all of the experiments described below regarding stresses, three independent experiments, each with spores and gDNA, were performed (n = 3). In addition, a negative control (samples containing neither spores nor gDNA) was included and analyzed.

2.3.1 Ambient conditions I: solvents

The solvents investigated in this work were selected because they are commonly found in commercially available inks and resins. Different groups of solvents were considered (alcohols, ketones, ethers, glycol ethers, aromatic hydrocarbons, esters, glycol esters, chlorinated hydrocarbons and water) resulting in the selection shown in Table 2.

Table 2: List of solvents used in this work to investigate the endurance of spores and gDNA

Solvent
Ethanol
Acetone
Tetrahydrofuran
2-Methoxyethanol
Toluene
Ethyl acetate
2-Methoxyethylacetate
Dichloromethane
Water

Two separate series of experiments were conducted, one with gDNA and one with *B. subtilis* spores. The spores were each provided in 100 µl of fully demineralized water with an optical density OD_{600} of approximately 0.1. According to Karava (2021), OD_{600} = 0.1 corresponds to about 10^7 – 10^8 spores per ml, resulting in 10^6 – 10^7 spores per sample. For gDNA, 10 µl of gDNA was provided in Tris-HCl buffer at a concentration of 30 µg/µl.

The samples were first dried under ambient conditions and then resuspended in the respective solvent (see Table 2). The exposure time to the corresponding solvent was 24 hours, including the time required for evaporation of the solvent under ambient conditions. This was achieved by initiating the evaporation of the solvents at different times to obtain samples that were finally dried after 24 hours. The spores respectively the gDNA, now again in dry condition, were then resuspended in fully demineralized water to their original concentrations and passed on to colony PCR as described in section 2.2. First, colonies are formed on LB-agar plates, and the effect of solvents on the ability of spores to germinate back into replicating cells can be evaluated at the same time.

To unambiguously assign the grown colonies to *B. Subtilis*, a PCR follows, which is evaluated by gel electrophoresis.

2.3.2 Ambient conditions II: irradiation

The energy input into inks and resins as a result of UV radiation varies with the process used. Therefore, two different scenarios were investigated.

First, UV irradiation in a conveyor drying system for printing inks (IST Metz GmbH, Nürtingen, Germany) with a power of 8 000 W (mercury-vapor lamps) distributed over a width of 40 cm at a wavelength spectrum of 180–450 nm and 5 m/min throughput speed was tested. This corresponds to a typical cross-linking process condition for an UV-curable ink.

On the other hand, a post-curing UV chamber for SLA components (Form Cure, Formlabs, Somerville, USA) was used. The device has a power of 9.1 W (from LEDs) at a wavelength of 405 nm. The selected exposure time to UV irradiation was 30 minutes at room temperature, which is a typical post-curing process for 3D printed parts.

Both spores (100 µl at an OD_{600} of 0.1 in demineralized water, corresponding to approximately 10^6 – 10^7 spores per sample) and gDNA (10 µl with a concentration of 30 µg/µl in Tris-HCl) were dried in aluminum trays at room temperature and then exposed to UV irradiation in the respective device. Samples were subsequently resuspended in 100 µl or 10 µl of demineralized water, respectively, and submitted for colony PCR.

2.3.3 Ambient conditions III: temperature

In printing processes, both for conventional and 3D printing, it can be assumed that the temperature exposure is only of short duration. Therefore, we consider that an exposure to heat of 60 seconds is appropriate. Again, 100 µl of spores with an OD_{600} of 0.1 in demineralized water were used corresponding to approximately 10^6 – 10^7 spores per sample. Similarly, 10 µl of gDNA with a concentration of 30 µg/µl in Tris-HCl buffer was examined. Both are first dried under ambient conditions in an aluminum tray. The aluminum tray was then placed on a hot plate and held at 200 °C for a period of 60 seconds. Finally, the dry sample was resuspended with 100 µl or10 µl of demineralized water, respectively, and transferred for colony PCR.

2.3.4 Mechanical loads: shear stress

A rotary rheometer (Malvern Kinexus lab+, Malvern Instruments, Malvern, United Kingdom) with cone-and-plate geometry (cone angle 1°) was used to apply defined shear rates to the liquid samples. In between the cone and plate geometry, 1 002 µl of spores in fully demineralized water with an OD_{600} of 0.1 were dispensed, corresponding to approximately 10^7 – 10^8 spores (Karava, 2021). The value of 1 002 µl results from the necessity to completely fill the gap between cone and plate. Similarly, the same volume of liquid containing gDNA in Tris-HCl buffer with a concentration of 3 µg/µl was assayed. After dispensing the liquid between the cone-plate geometry, the shear rate was incrementally increased over 400 s to the maximum possible value of 6 000/s and held at this rate for 20 seconds. At 6 000/s, the shear rate is within a typical range for offset and flexographic printing, as previously noted. The temperature of the liquid was kept constant at 25 °C. After the measurement the samples were submitted to colony PCR.

The higher shear rates found in gravure printing and their effect on spores and gDNA were tested on a printability tester (IGT G1-5, IGT Testing Systems, Almere, Netherlands, see Figure 4). Tests were carried out using a gravure cylinder with a screen ruling of 40 lines/cm, a cell volume of 20 ml/m^2, a speed of 0.6 m/s and a printing force of 700 N, which is distributed over a width of 40 mm. A sheet of 125 µm thick polyethylene naphthalate film (PEN, Teonex Q65 HA, DuPont Teijin Films, Luxembourg) was used as a substrate for printing tests. The PEN sheet is provided with a surface treatment, not further specified by the manufacturer, which is intended to facilitate printing. The smooth

plastic film facilitates the extraction of spores or gDNA after printing. For the test, 100 µl of liquid (spores in demineralized water, OD_{600} = 0.1 or gDNA in Tris-HCl, 30 µg/µl) was applied between the gravure cylinder and the doctor blade and printed onto the substrate.

Extraction of the dried layer with spores or gDNA was performed by pipetting 100 µl of demineralized water onto the plastic film, then rubbing with the pipette tip and pipetting back again. The sample concentration is subject to fluctuations, however, in preliminary experiments we proved that the extracted sample amount was always sufficient for the subsequent colony PCR.

2.4 Gravure printing

Since gravure printing has the highest shear rates (Jabrane, et al., 2008) as well as the highest surface pressure (Kipphan, 2001) compared to other printing techniques such as offset or flexographic printing, we use it to investigate the processability of spores and gDNA.

For printing tests by rotogravure, the same IGT G1-5 printability tester as used in section 2.3.4 for the investigation of shear forces was chosen; the principle is shown in Figure 2.

For this purpose, the spores or gDNA were applied to the printing inks. Two different commercially available inks were investigated: a water-based coating (Senolith WB Gloss Coating FP DC, WEILBURGER Graphics, Gerhardshofen, Germany) and a solvent-based ink (Solvaplast P HR Cyan, SunChemical, Parsippany, US). For this purpose, 300 µl of spores in demineralized water (OD_{600} of 0.1, approx. $10^7 - 10^8$ spores) were dried and mixed with 300 µl of the respective coating or ink. Likewise, 100 µl of gDNA in Tris-HCl (30 µg/µl) were dried and mixed in 100 µl of coating or ink and printed on the PEN substrate (as specified in 2.3.4). In all cases, gravure printing was done as described previously (printing force of 700 N which is distributed over a width of 40 mm, substrate speed of 0.6 m/s, screen ruling of 40 lines/cm, cell volume of 20 ml/m²) on a 125 µm thick PEN substrate. Drying took place at room temperature. The changes in the rheological properties of the ink tagged with spores or gDNA were not further investigated due to the proof-of-concept scope of this work.

To assess whether the spores or gDNA embedded in the inks have withstood the loads, but also for later practical use to verify the authenticity of a spore-protected product, it is necessary to extract the spores or gDNA from the gravure printed substrate. Extraction was done as described in the previous section by pipetting 100 µl of demineralized water onto the dried film, dissolving the ink containing spores or gDNA and pipetting it back. For the solvent-based ink, the same procedure was performed using 100 µl of ethanol. In this case, the solvent subsequently needed to be evaporated at room temperature and then the extract to be resuspended with the same amount of demineralized water. Specimens were then transferred to subsequent colony PCR.

Again, three tests were performed for each ink with spores or gDNA, respectively. A thorough cleaning of all components in contact with spores or gDNA was performed between experiments to ensure independent tests, including the use of strong UV radiation for cleaning. Similarly, negative samples (ink/coating without gDNA or spores) were included and tested.

2.5 Additive manufacturing

Based on the results from the previous experiments with UV radiation in section 2.3.2, mSLA was chosen as a suitable 3D printing technique. The setup of an mSLA 3D printer can be seen in Figure 3.

A commercially available mSLA printer (Zortrax Inkspire, Zortrax, Olsztyn, Poland) and a common epoxy methacrylate based resin (Tough Transparent, Prusa Research, Prague, Czech Republic) were used. The

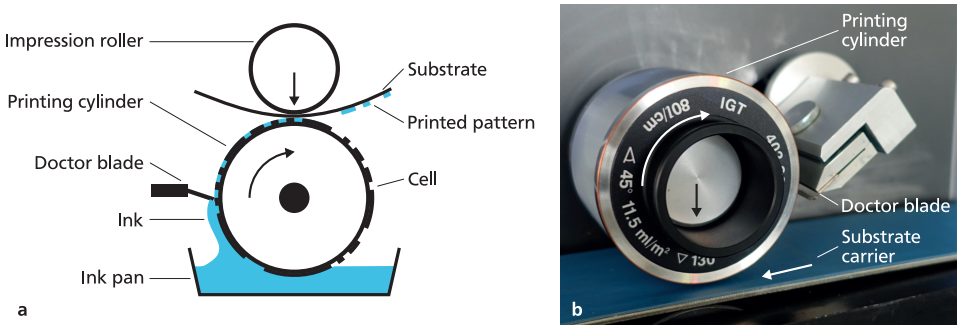

Figure 2: Principle of gravure printing as used in rotogravure printing machines (a); the printability tester used in this work (b), on the other hand, is slightly different in design, in particular the ink is applied to the doctor blade using a pipette

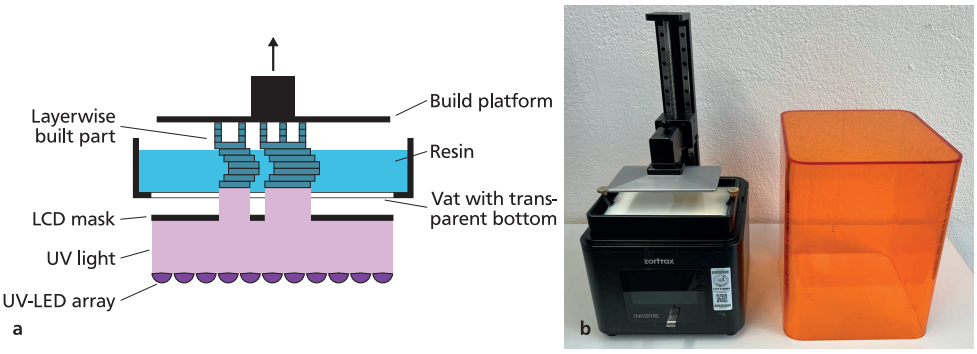

Figure 3: Principle of operation of an mSLA 3D printer (a), which is characterized in particular by the use of an LCD mask that allows the UV light to pass selectively so the resin polymerizes in the desired locations; Zortrax Inkspire mSLA-printer (b), as used by the authors

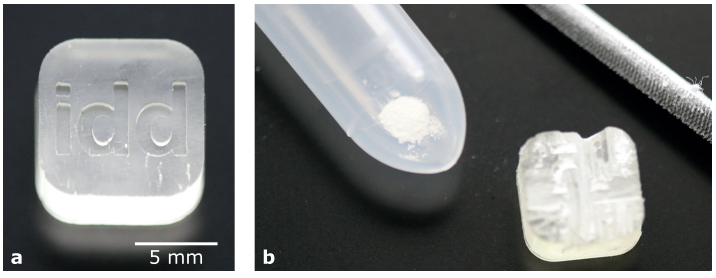

Figure 4: Specimen produced using mSLA (dimensions 10 mm × 10 mm × 5 mm) incorporating DNA protected in spores over its entire volume (a), specimen after sample extraction using a file, the resulting powder is passed to colony PCR in a microcentifuge tube (b)

printer manufacturer's software (Z-Suite) was used together with typical settings (layer thickness of 50 µm, layer exposure time of 10 s, five bottom layers with 120 s exposure time). These constraints were deliberately chosen to demonstrate the practical application of the spores as an anti-counterfeiting device without modifications to the equipment and the processing parameters. To fill the resin vat of the printer sufficiently, 10 ml of spores with $OD_{600} = 1$ were dried at room temperature, mixed with 100 ml of resin and poured into the vat. Three identical specimen geometries (10 mm × 10 mm × 5 mm, see Figure 4) were manufactured. Because of the good resistance to solvents of the cured resin, a different procedure was chosen than for the samples produced by gravure printing and the sample was extracted mechanically using a file. The resulting powder was passed to colony PCR in 100 µl of demineralized water. Due to the high amount of material required, no experiments were performed with gDNA in this case.

3. Results and discussion

The complete results of the PCR and corresponding gel electrophoresis can be found in supplemental data, Table S1 <https://doi.org/10.48328/tudatalib-977>.

First, the stress due to contact with solvents was evaluated for spores and gDNA. Nine different representatives of solvents frequently used in printing inks including water were tested. After 24 hours in contact with the respective solvents, *B. subtilis* spores were able to germinate thereafter, regardless of the solvent, and the DNA sequence was detected by PCR. An example of the formation of colonies can be seen in Figure 5. Only very few outliers not showing a corresponding signal after gel-electrophoresis occurred (i.e., see Figure 6 "spores in Ethanol"). This is likely due to a pipetting error while setting up the PCR reactions, but is mitigated by using appropriate numbers (i.e., $n = 3$) of technical replicates. There is an uncertainty about the absolute amount of DNA tested in PCR. The amounts of free DNA used vary significantly, as there is 30 µg/µl of free gDNA versus ~10–15 ng of DNA from spores per sample. However, germinating the spores results in replicating cells, which in turn results in additional DNA material. Therefore, amounts of gDNA as well as spores utilized were chosen based on their ease of application in a technical process. The sensitivity of PCR allows detection of as little as 35 molecules of DNA (Purcell, et al., 2016), which are well surpassed in any sample taken by several orders of magnitude, thus allowing us to make qualitative statements. When testing for resistance to solvents, spores were shown to be

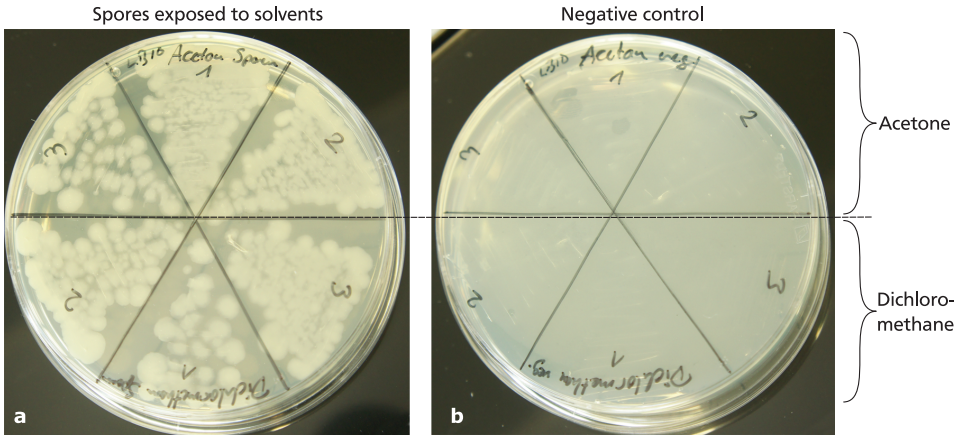

Figure 5: The formation of colonies on a growth medium (LB-agar, see section 2.2) shows in (a) that the spores were able to germinate and grow after contact with solvents (top: acetone, bottom: dichloromethane), while the negative samples (no spores) can be seen on the right side (b); each sample was in triplicate indicated by the intersecting lines between them

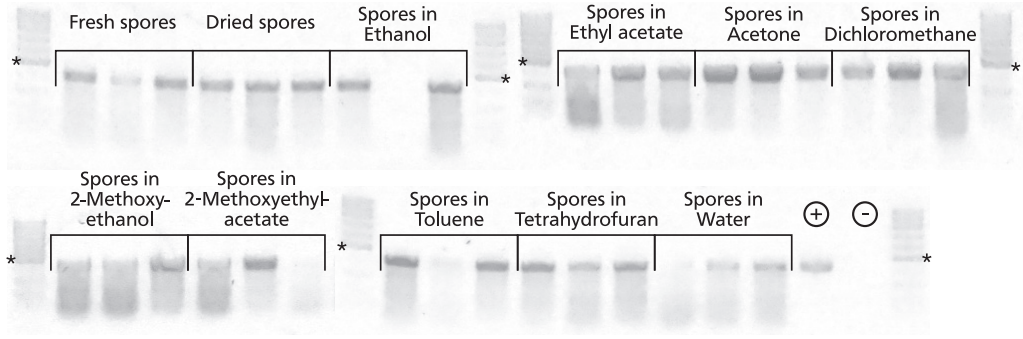

*Figure 6: Gel electrophoresis image of the detection of specific spore DNA with PCR after the labeled treatment; *: reference DNA band at 500 bp; ⊕: positive control of untreated DNA; ⊖: negative control not containing any added DNA (n = 3)*

unaffected by the substances studied for the selected period of time. For gDNA, resistance could also be shown, with the exception of 2-Methoxyethanol. It can therefore be concluded that spores are suitable for use in printing inks. This also applies to gDNA, however, with the exception mentioned.

The resistance against UV irradiation was investigated with two different intensities. In the post-curing chamber ("UV low" in Table 3), the DNA sequence from both spores and gDNA could be detected after irradiation. For the higher UV exposure of the continuous dryer ("UV high" in Table 3), no DNA sequence could be detected for either spores or gDNA. The different results indicate that for UV exposure of spores and gDNA, respectively, there seem to be threshold values up to which a DNA sequence can be detected by PCR. Thresholds were not investigated within the scope of this work, but it has been shown that the performance of commercially available drying units for UV-crosslinking coatings appears to be too high for spores and gDNA in a dry, non-embedded condition. Therefore, processing of spores or gDNA in UV-curing coatings does not seem to be appropriate, whereas processing by 3D printing using mSLA appears to be feasible.

Short-term exposure to elevated temperatures (200 °C, 60 s, "Temperature" in Table 3) also resulted in no DNA sequence being detected for either spores or gDNA. This suggests that damage or destruction of the DNA segments occurred during the heat treatment. Therefore, the use of spores or gDNA in processes where the investigated temperatures may occur (for example, in 3D printing using FFF) should not be considered.

Mechanical stress, on the other hand, was well endured by both spores and gDNA, as in both cases the detection of the DNA sequence was successful – for low as well as for high shear rates ("Shear low" and "Shear high" in Table 3). Hence, it can be concluded that conventional printing processes, which involve high shear rates, are suitable for processing both spores and gDNA.

The combination of different loads was investigated in actual printing tests. In conventional gravure printing with water- and solvent-based inks, samples of spores were extracted from the printed film and DNA sequences were detected by PCR. Spores could also be taken from components produced by additive manufacturing (mSLA) and DNA detection could be performed successfully (see "Gravure" and "mSLA" in Table 3). However, using gDNA, only printing tests with water-based coatings were carried out, but already at this stage no DNA sequence could be detected.

The complete list of all tests on single and combined loads on spores as well as on gDNA can be found in Table 3. An exemplary figure of the PCR results analyzed by gel electrophoresis which form the basis for Table 3 is depicted in Figure 6.

Table 3: Detection of DNA after stresses on free genomic DNA (gDNA) and spore-protected DNA (spores) after PCR; due to the qualitative nature of the measurement, successful detection (●) or partially successful detection with a single outlier (●[1]) is distinguished from unsuccessful detection (○) resp. not tested (–); corresponding gel electrophoresis images can be found in supplementary data (n = 3)

			Spores	gDNA
Single stress	**Solvents**	Ethanol	●[1]	●
		Acetone	●	●
		Tetrahydrofuran	●	●
		2-Methoxyethanol	●	○
		Toluene	●	●
		Ethyl acetate	●	●
		2-Methoxyethylacetate	●[1]	●
		Dichloromethane	●	●
		Water	●[1]	●
	UV	UV low	●	●
		UV high	○	○
		Temperature	○	○
	Mech. stress	Shear low	●	●
		Shear high	●	●
Comb. stresses	**Printing**	Gravure (water)	●	○
		Gravure (solvent)	●	–
		mSLA	●	–

So far, based on the previous experiments, no particular benefit of spores as a "DNA vault" has emerged in comparison to gDNA, assuming that only individual stresses are investigated. Only for 2-Methoxyethanol an advantage of DNA protected in spores is found for individual stresses. This assumption could be refuted in the printing experiments, where combined loads are present. In the case of gravure printing, it can be seen that gDNA was no longer detectable after processing in water-based coating, while DNA extracted from spores could be detected. This also suggests that a simple superposition of the results from the previous experiments is not possible.

In addition, the potential of DNA protected in spores as an anti-counterfeiting agent has also been demonstrated in additively manufactured components. The DNA extracted from spores could be detected despite the combined exposure to resin ingredients and UV radiation. However, the spores in the mSLA-manufactured specimens are distributed over the entire volume of the part, making it seem inappropriate in terms of cost-effectiveness and the number of spores required. A local application of resin incorporating spores, for example by using two-component mSLA, might be appropriate.

4. Conclusion

We accomplished the processing of DNA protected in spores using gravure and 3D printing, and successfully detected the DNA after extraction from the sample. To demonstrate the benefit of spores and the potential of spores as an anti-counterfeiting feature applied by printing, all experiments were also performed and compared with free, genomic DNA.

Single stresses that can occur in conventional and 3D-printing (solvents, UV irradiation, temperature and mechanical stress as shear) were applied to spores and gDNA. For a single solvent (2-Methoxyethanol), an advantage in terms of resistance of the DNA protected in spores compared to gDNA could be shown. For other individual stresses, whether solvents, UV radiation, temperature or shear stress, no advantage has been found for DNA protected in spores compared to free DNA. The knowledge about the resistance of the spores to environmental conditions obtained in this work allows, in reverse, recommendations for cleaning, which is also relevant for an application in print shops. Spore-protected DNA can be successfully removed by high UV irradiation and elevated temperatures. However, in the case of combined loads, such as those found in actual printing processes, the advantage of DNA protected in spores is more evident. In gravure printing of a water-based coating, no DNA segments from unprotected gDNA could be detected by PCR. Though, when spores were used, detection by colony PCR was successful, thus demonstrating that not only the DNA but the complete spore survived. This allows using germination to "amplify" the DNA signal by natural DNA replication of growing cells. In addition, the usability of spores in a solvent based ink applied via gravure printing was shown. Likewise, the suitability of spores for processing by mSLA has been proven. In particular, it could be demonstrated that spores – unlike free genomic DNA – offer a significant advantage under

realistic processing conditions due to their robustness. In future studies, other printing techniques with a wider range of inks should be investigated.

Spores as a "DNA vault" thus offer great potential for use as counterfeit protection when applied using inexpensive and productive industrial 2D- and 3D-printing processes. Especially in conventional printing techniques, such as gravure printing shown in this work, spores may be applied locally and thus economically. This does not require any modifications to the machinery, which facilitates the future implementation of this technology. Because of the non-pathogenic nature of *Bacillus subtilis*, it may be used without concern in print shops and additive manufacturing facilities. In fact, they are already used in e.g. agriculture and are commercially available as a probiotic dietary supplement. Genetically modified organisms are restricted in use, so a special designed DNA sequence is not possible under current legislation. Right now, this is not needed, as the natural sequence length in *B. subtilis* already provides a high number of possible variants by using different locations to be detected on the strains genome or using strains with differing genomes. The detection and validation of the DNA right now needs equipment and knowledge (PCR, etc.), but should in future approaches be realized by e.g. lateral flow assays, which can be used by untrained users.

Supplemental data

Supplemental data (Table S1 including gel electrophoresis images) can be accessed through DOI <https://doi.org/10.48328/tudatalib-977>.

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Characterizing the influence of white ink coating weight and print layer film type on chromaticity in gravure printed flexible packaging

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Abstract

When printing transparent substrates, a white ink underlayer is frequently required to reproduce saturated colors. Nevertheless, the cost of adding this underlayer makes it a potentially attractive cost reduction opportunity. The primary objective of this study was to investigate the influence of white underlayer coating weight (g/m^2) and print layer film type on the chromaticity of reverse printed structures representative of those found in gravure printed flexible packaging. To analyze the influence of white ink coating weight (Ctg Wt) and print layer film type on chromaticity, six design of experiments (DOEs) were conducted. Each DOE explored the relationship between three levels of white ink coating weight and three print layer film types for one ink (Magenta, Cyan, Yellow, Orange, Violet, or Black). The DOE results showed that both coating weight and film type have a statistically significant effect on chromaticity ($P < 0.005$). For Magenta, Cyan, Yellow and Orange inks, white underlayer coating weight had the dominant effect on chroma (the values of ΔC^*_{ab} typically between 4 and 7) while the effect of print layer film type was relatively minor (the value of ΔC^*_{ab} is typically < 1). For Violet ink, white ink Ctg Wt was still the dominant effect (the value of ΔC^*_{ab} was 7), but print layer film type had a more pronounced effect (the value of ΔC^*_{ab} was 3). The relationship between coating weight and chroma over the range from 0.49 g/m^2 to 1.95 g/m^2 was linear for all inks ($R^2 > 0.99$). Finally, when printing Magenta, Cyan, or Orange ink a coating weight reduction of 1 g/m^2 (from 1.95 g/m^2 to 0.98 g/m^2) resulted in a color shift of the ΔE_{00} ~2.5, and a 1.5 g/m^2 reduction (from 1.95 g/m^2 to 0.49 g/m^2) resulted in a color shift of ΔE_{00} ~3.5. Yellow, the weakest ink, was more affected (the ΔE_{00} ~4 for 1 g/m^2, and ΔE_{00} ~5 for 1.5 g/m^2), while Violet, a hue where the human visual system has less sensitivity to chroma differences, was less affected (the ΔE_{00} ~1.5 for 1 g/m^2, and ΔE_{00} ~2 for 1.5 g/m^2). For achromatic Black ink, lightness (L^*) was chosen as the response variable. Although white ink Ctg Wt and print layer film type had statistically significant effects on L^*, the differences attributable to these effects were at or below the threshold of visual detection.

Keywords: white ink underlayer, color saturation, ΔE_{00}, rotogravure

1. Introduction

In flexible packaging, reverse printed laminates are frequently used to package products such as potato chips, tortillas, extruded snacks, popcorn, and pretzels (InterFlex, 2021). A typical laminate is shown in Figure 1. In this laminate, a clear print web is reverse printed with directly applied chromatic inks. In many cases, these inks are subsequently overprinted with a white ink underlayer to enhance the saturation of the printed colors (Flexographic Technical Association, 2020). The use of the term "underlayer" reflects the fact that, from the viewpoint of the consumer, the white ink film underlays the chromatic inks. Finally, the finished bag structure is assembled by laminating a barrier web to the print web. In this structure, the colorfulness (chromaticity) of the graphic design is potentially affected by the interaction of the chromatic inks with the print web, and by the quality of the white underlayer (Flexographic Technical Association, 2020). Although a white underlayer is often required to achieve high levels of color saturation in eye catching graphics, the cost of adding white ink can be substantial, especially when graphic coverage is high. As a result, reducing white underlayer coating weight is a potentially attractive cost reduction opportunity for package printers.

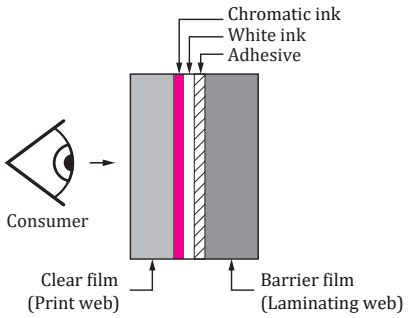

Figure 1: Typical flexible packaging laminate for salty snack bags

The principle problem associated with reducing white ink coating weight (Ctg Wt) is to ensure that the colors printed on the resulting underlayer retain their colorfulness (chromaticity). Chung and Hsu (2006) created a framework for optimizing the color gamut of gravure printed packaging, but the framework did not include optimizing a white ink underlayer. Other researchers have investigated the influence of substrate properties on printed colors (e.g. Valdec, Miljković and Auguštin, 2017) but their studies were restricted to opaque white substrates which do not require the use of a white ink underlayer. Finally, a number of other researchers have studied the properties of white ink underlayers (Argent, 2008; Rich, 2021), but always with a view toward optimizing the properties of the white ink layer (e.g. opacity, density, contrast) instead of optimizing the properties of chromatic inks backed by these underlayers. In fact, an extensive search of the literature failed to uncover any papers investigating how white underlayer coating weight affects the chromaticity of inks backed by the underlayer.

The primary objective of this study was to investigate the influence of white underlayer coating weight (g/m^2) and print layer film type on the chromaticity of reverse printed structures representative of those found in gravure printed flexible packaging.

2. Methods

To analyze the influence of white ink Ctg Wt and film type on chromaticity, six design of experiments (DOEs) were carried out using the materials and methods described below. Each DOE explored the relationship between three levels of white ink Ctg Wt and three print layer film types for one of six ink colors (Magenta, Cyan, Yellow, Orange, Violet or Black). Chroma (C^*_{ab}) was selected as the response variable for experiments involving chromatic inks (Cyan, Magenta, Yellow, Orange, and Violet). Lightness (L^*) was chosen as the response variable for the Black ink experiment since Black ink is designed to be as achromatic as possible.

2.1 Materials

Solvent based gravure inks supplied by Flint Group were used in the experiment. All inks were formulated to an efflux time of 19 seconds using a Zahn 2 cup before printing. Test swatches of each ink were printed on three films: 75 ga Oriented Polypropylene (75 OPP), 92 ga Cellophane (92 Cello), and 80 ga TIPA® 318 (80 TIPA) (the film thicknesses given in ga (gauge) correspond to 19 µm, 23 µm, and 20 µm, respectively). Swatches were printed using an RK Industries K Printing Proofer operating in direct gravure printing mode. The proofer used an electromechanically engraved plate (500 lpi, 37° compression angle, 130° stylus) to print 100 % solid color swatches. Three replicates of each ink / film type combination were printed for a total of 54 swatches (6 inks, 3 film types and 3 replicates). The inks and films used in the experiment are described in Table 1. For additional information, please see the weblinks associated with the references.

White underlayer samples were printed on a commercial gravure press using cylinders engraved to print nominal coating weights of 1.95 g/m^2, 0.98 g/m^2, and 0.49 g/m^2. All underlayers were printed on 75 OPP film. The coating weights used in the experiment

Table 1: Inks and films used in the experiment

Inks			**Films**	
Ink color	**Supplier**	**Grade**	**Film type**	**Supplier**
Cyan	Flint Group[1]	XCEL GS CF Blue	75 OPP	Tagleef Ind.[2]
Magenta	Flint Group[1]	2.2234R37CRLA2027 Bon Rubine	92 Cello	Futamura[3]
Yellow	Flint Group[1]	PluriBase V1 HS NC Yellow	80 TIPA	TIPA Corp.[4]
Black	Flint Group[1]	PluriBase Black		
Orange	Flint Group[1]	PluriStar RTV 37078 Orange		
Violet	Flint Group[1]	XCEL Carb Violet		

[1]Flint Group, Anniston, AL, USA (Flint Group, 2022)
[2]Tagleef Industries, Newark, DE, USA (Tagleef Industries, 2022)
[3]Futamura North America, Tecumseh, KS, USA (Futamura, 2022)
[4]TIPA North America, Jersey City, NJ, USA (TIPA, 2021)

were chosen to represent a typical white underlayer used in commercial printing (1.95 g/m^2), a half thickness underlayer (0.98 g/m^2), and a quarter thickness underlayer (0.49 g/m^2).

2.2 Data generation

Each DOE was a 3^2 full factorial design with three replicates. In this design, two variables (the exponent in 3^2) were evaluated at three levels (the base in 3^2) and replicated three times. Thus, each DOE consisted of three identical replicates printed using a single color of ink. Table 2 shows the design table for one replicate of the Magenta DOE.

Table 2: Design table for one replicate of the magenta ink experiment; the full experiment consists of three identical replicates

Run	Ink color	Film type	White ink Ctg Wt (g/m^2)
1	Magenta	75 OPP	1.95
2	Magenta	92 Cello	1.95
3	Magenta	80 TIPA	1.95
4	Magenta	75 OPP	0.98
5	Magenta	92 Cello	0.98
6	Magenta	80 TIPA	0.98
7	Magenta	75 OPP	0.49
8	Magenta	92 Cello	0.49
9	Magenta	80 TIPA	0.49

For each ink color / film type combination shown in this table, a sandwich consisting of the printed swatch and specified white underlayer was measured using a Techkon SpectroDens on an X-Rite black backing tile. In all cases, the swatch was placed print side down on a white underlayer positioned with its print side up. The resulting structure simulates a reverse printed flexible package (print film / chromatic ink / white ink / underlayer film). Figure 2 shows a test sample as printed and as sandwiched for measurement.

All measurements were collected using the following settings: D50 Illuminant, 2° Observer, No Polarization, Absolute Colorimetric, and M1 Measurement Condition. Nine sets of CIELAB values were collected from each test structure by superimposing a 3 × 3 grid on the printed swatch and taking one measurement in each grid square. The average of these values was used to represent the CIELAB values for the test condition specified in the design table. The response variables for the experiment, chroma (C^*_{ab}) for chromatic inks and lightness (L^*) for black swatches were calculated from the CIELAB values.

2.3 Statistical analysis

Three analyses were conducted to assess the influence of white underlayer coating weight (g/m^2) and print layer film type on chroma (or lightness in the case of Black ink). First, an analysis of variance (ANOVA) was conducted to assess the statistical significance of each variable in isolation and of the interaction between these variables. Second, regression models were created to predict chromaticity based on white underlayer coating weight for each film type. Finally, CIELAB data was analyzed to assess the visual impact of changing film type and/or coating weight in terms of ΔE_{00}. Each analysis is discussed in a separate section. For the ANOVA and regression analyses, the section opens with a detailed discussion of the Magenta analysis, followed by a discussion of how the remaining analyses (for Cyan, Yellow, Orange, Violet and Black) conform to or differ from the results discussed in the Magenta example.

Analysis of variance was used to assess the statistical significance of the relationships between sources of variation (coating weight, film type, coating weight × film type), and a response variable (chroma or lightness). In this analysis a linear model estimates the response variable as a function of source values. This permits the total observed variation of the response

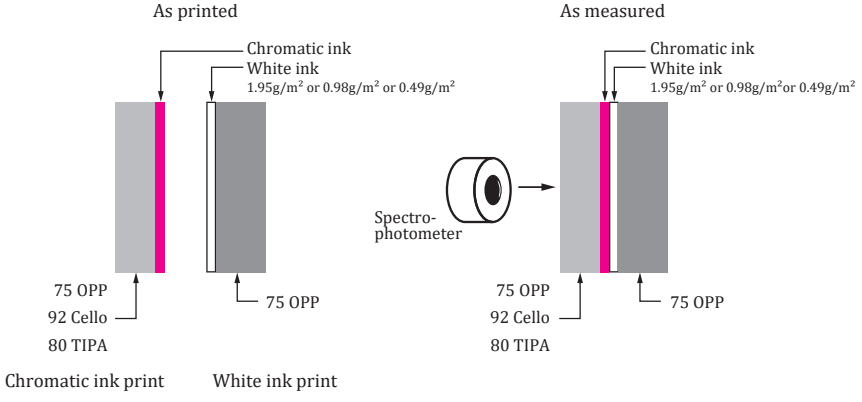

Figure 2: Test samples as printed (a), and as assembled for measurement (b)

variable to be divided into four components: 1) the amount due to changes in coating weight, 2) the amount due to differences in film type, 3) the amount due to the coating weight × film type interaction, and 4) residual error. Under the null hypothesis, coating weight, film type, and the coating weight × film type interaction have no effect on the response variable. An *F*-test is then used to compare the observed variation due to each source (film type, coating weight, and film type × coating weight) to the variation due to residual error. If *F*-value has a probability less than a critical value (0.05 in this study), we reject the null hypothesis and accept the alternative hypothesis that the source has a statistically significant effect on the response variable.

The ANOVA results are summarized in Tables 3 to 7. In these tables, the first column lists the sources of variation. The second lists the degrees of freedom (DF) associated with each source. As an example, the experiment as a whole has 26 degrees of freedom (the DF entry next to Total). In the experiment, 27 data points (3 film types, 3 coating weights and 3 replicates) are compared to the grand average to calculate the adjusted sum of squares (Adj SS). Once the grand average is calculated, only 26 datapoints are free to take on any value (the value of the 27th datapoint must equal the grand average times 27 minus the sum of the first 26 values), so the experiment is said to have 26 degrees of freedom. Variance is proportional to the sum of squares of the differences between the group means and the datapoints in each group (Adj SS). In this context, "Adjusted" (Adj) means the sum of squares calculation is performed in a way that does not depend on the order in which the terms are introduced into the model. The next column, mean sum of squares, (Adj MS) divides Adj SS by DF to compensate for differences in group size. An *F*-statistic (*F*-value) is calculated by dividing the Adj MS value for the source by the Adj MS value of error. The *P*-value is the probability of getting the observed *F*-value when the null hypothesis is true. As stated above, we interpret *P*-values less than 0.05 as being statistically significant.

3. Results and discussion

3.1 Statistical analysis of the Magenta DOE

Table 3 summarizes the results of conducting an ANOVA on the Magenta DOE data.

Throughout the experiment, close attention was placed on reducing sources of random variation in the data. The resulting level of random error in the data reflects the effectiveness of these measures: less than 1 % of the total variation is attributed to random error. The majority of the observed variation is attributed to white ink Ctg Wt, with a smaller amount attributed to film type. When these effects were tested to determine their significance, the probability of obtaining the observed results through random chance (the *P*-value) was 0.000. Equivalently, the statistical significance of coating weight and film type on chroma exceeds 99.9 %. When the effect of the coating weight × film type interaction was tested, it was found to be statistically insignificant with a *P*-value (0.476) greatly exceeding the maximum *P*-value for a significant effect (0.05). The low level of random error in the experiment ensures that the signal (the interaction) is not being obscured by noise (error).

Main effects plots show the relative magnitude of each effect. Figure 3 is a main effects plot showing the relative impact of coating weight and film type on chroma. As expected, coating weight is the dominant factor with a total impact of ΔC^*_{ab} nearly 6, while film type contributes ΔC^*_{ab} to chroma variation a little less than 1.

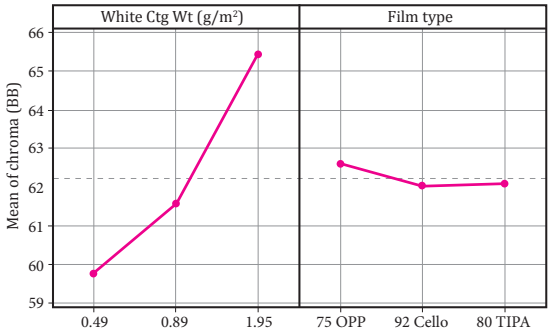

Figure 3: Main effects plot for magenta ink chroma measured with black backing (BB) vs white coating weight (Ctg Wt) and film type

Figure 4 is an interaction plot for coating weight × film type. To interpret this chart, start with the chroma of a specific film type and coating weight combination. For example, the C^*_{ab} of the 75 OPP Magenta swatch measured on a 0.49 g/m^2 white underlayer was approximately 60. Now assume we change the film type to 80 TIPA and the coating weight to 1.95 g/m^2. Based on the main effects plot, a change from 75 OPP to 80 TIPA has an effect on ΔC^*_{ab} of approximately −0.5. Similarly, a change from 0.49 g/m^2 to 1.95 g/m^2 has an effect on ΔC^*_{ab} of approximately +6.0. In the absence of an interaction, the predicted result for 80 TIPA on a 1.95 g/m^2 white underlayer is simply the starting point plus the individual effects of ΔC^*_{ab} values: 60 − 0.5 + 6.0 = 65.5. Since this closely matches the observed result for 80 TIPA measured on a 1.95 g/m^2 white backing, we conclude that there is no interaction. If an interaction were present, the observed effect would be significantly larger or smaller than the starting point plus the main effects. On the plot in Figure 4, if all of the observed

Table 3: Analysis of variance for magenta ink chroma vs white coating weight and film type

Source	DF	Adj SS	Adj MS	*F*-value	*P*-value
Model	8	153.44	19.18	1 256.37	0.000
Linear	4	153.39	38.35	2 511.82	0.000
White ink coating weight	2	151.62	75.81	4 965.68	0.000
Film type	2	1.77	0.88	57.96	0.000
2-Way interactions	4	0.06	0.01	0.92	0.476
White ink Ctg Wt × Film type	4	0.06	0.01	0.92	0.476
Error	18	0.28	0.02		
Total	26	153.72			

effects closely correspond to the starting point plus the main effects, then the lines for the three film types will be approximately parallel. Turning our attention to Figure 4, we observe that this is the case. Thus, Figure 4 indicates that no interaction is present (which agrees with the ANOVA result that the coating weight × film type interaction is not statistically significant).

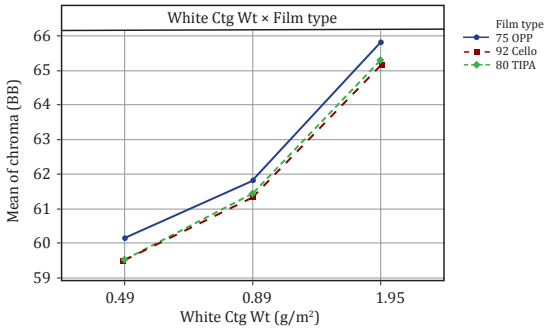

Figure 4: Interaction plot for magenta ink chroma measured with black backing (BB) vs white coating weight × film type

3.1.1 Statistical analysis of DOE data for the remaining experiments

The ANOVA results for the remaining chromatic colors (Cyan, Yellow, Orange, and Violet) are summarized in Tables 4 through 7. As the tables show, the results for these colors are strikingly similar to the results for Magenta. In all cases, random error accounts for less than 2 % of the total variation, again reflecting the high level of repeatability achieved in these experiments. White ink Ctg Wt is always statistically significant with a significance level exceeding 99.9 %. Film type is also a highly significant factor with a significance level exceeding 99.5 %. Finally, the *P*-value of the coating weight × film type interaction never comes close to the *P*-value required to be statistically significant (0.05).

The ANOVA results for Black are summarized in Table 8. Results for Black differed in several aspects from those just discussed. The response variable chosen for Black (an achromatic ink) was lightness (L^*). A perfect Black has an L^* value of 0. The combination of gravure printing and high quality Black ink yielded L^* values in the 5 to 6 range. The small magnitude of these L^* values (less than 10 % of the C^*_{ab} values just discussed) resulted in an exceedingly small total variation for Black: slightly more than 2 (compared to 65 to 260 for the chromatic inks). Since the magnitude of random variation for L^* values is similar to the magnitude for C^*_{ab} values (a fraction of a unit), random error in the Black ANOVA contributes 12 % of the total variation (compared to less than 2 % for the chromatic inks).

Despite this difference (which reduces the sensitivity of the analysis), *P*-values remained exceptionally low: 0.001 for coating weight and 0.000 for film type. This means that both factors are statistically significant at a level of 99.9 %. As with the chromatic colors, the coating weight × film type interaction is not statistically significant. On the other hand, the variation in L^* attributable to film type greatly exceeded the variation attributable to coating weight. This result is due to the fact that the 80 TIPA film has a distinct haze which significantly lightened the 80 TIPA samples compared to the other film types.

Figure 5 shows the main effects plots for Cyan, Yellow, Orange, Violet, and Black. The main effects plot for Magenta is repeated in the upper left position to facilitate comparison. Once again, the plots for the remaining chromatic colors (Cyan, Yellow, Orange, and Violet) bear significant similarities to the Magenta plot. In all cases, the effect of coating weight outweighs the effect of film type. The effect of film type on chroma, on the other hand, exhibits some differences between colors.

Magenta, Cyan, and Yellow film type plots are virtually identical: the magnitude of film type's impact on chroma is small compared to the impact of coating weight, 75 OPP exhibits higher chroma than the other two films, and the chroma of 92 Cello and 80 TIPA are generally similar. Orange exhibits this pattern with the exception that 92 Cello chroma is closer to 75 OPP than 80 TIPA. Violet, on the other hand exhibits a different pattern. For Violet, the impact of film type on chroma

Table 4: Analysis of variance for cyan ink chroma vs white coating weight and film type

Source	DF	Adj SS	Adj MS	*F*-value	*P*-value
Model	8	67.49	8.44	127.42	0.000
Linear	4	67.46	16.86	254.72	0.000
White ink coating weight	2	65.33	32.67	493.38	0.000
Film type	2	2.13	1.06	16.07	0.000
2-Way interactions	4	0.03	0.01	0.12	0.972
White ink Ctg Wt × Film type	4	0.03	0.01	0.12	0.972
Error	18	1.19	0.06		
Total	26	68.68			

Table 5: Analysis of variance for yellow ink chroma vs white coating weight and film type

Source	DF	Adj SS	Adj MS	*F*-value	*P*-value
Model	8	215.89	26.99	158.39	0.000
Linear	4	215.74	53.94	316.57	0.000
White ink coating weight	2	231.18	106.59	625.61	0.000
Film type	2	2.57	1.29	7.54	0.004
2-Way interactions	4	0.14	0.04	0.21	0.931
White ink Ctg Wt × Film type	4	0.14	0.04	0.21	0.931
Error	18	3.07	0.17		
Total	26	218.95			

Table 6: Analysis of variance for orange ink chroma vs white coating weight and film type

Source	DF	Adj SS	Adj MS	*F*-value	*P*-value
Model	8	216.06	27.01	1 134.39	0.000
Linear	4	215.94	53.99	2 267.58	0.000
White ink coating weight	2	212.07	106.04	4 453.92	0.000
Film type	2	3.87	1.93	81.24	0.000
2-Way interactions	4	0.11	0.03	1.20	0.346
White ink Ctg Wt × Film type	4	0.11	0.03	1.20	0.346
Error	18	0.43	0.02		
Total	26	216.49			

Table 7: Analysis of variance for violet ink chroma vs white coating weight and film type

Source	DF	Adj SS	Adj MS	*F*-value	*P*-value
Model	8	262.80	32.85	974.24	0.000
Linear	4	262.78	65.70	1 948.37	0.000
White ink coating weight	2	227.56	113.78	3 374.40	0.000
Film type	2	35.23	17.61	522.33	0.004
2-Way interactions	4	0.02	0.00	0.11	0.978
White ink Ctg Wt × Film type	4	0.02	0.00	0.11	0.978
Error	18	0.61	0.03		
Total	26	263.41			

is much larger than for the remaining chromatic inks (ΔC^*_{ab} ~3 versus ΔC^*_{ab} ~1). In addition, there is a clear difference in the effects of the individual films on chromaticity: 75 OPP has the greatest effect, 80 TIPA has the least, and 92 Cello is almost exactly in the middle.

The Black main effect plot is much different than the plots for the chromatic colors (which is wholly consistent with the ANOVA results discussed previously). Unlike the chromatic inks, the impact of film type on lightness exceeds the impact of coating weight. In addi-

Table 8: Analysis of variance for black ink lightness vs white coating weight and film type

Source	DF	Adj SS	Adj MS	*F*-value	*P*-value
Model	8	2.0536	0.25670	16.75	0.000
Linear	4	2.0375	0.50937	33.23	0.000
White ink coating weight	2	0.3021	0.15103	9.85	0.001
Film type	2	1.7354	0.86772	56.60	0.000
2-Way interactions	4	0.0161	0.00403	0.26	0.898
White ink Ctg Wt × Film type	4	0.0161	0.00403	0.26	0.898
Error	18	0.2759	0.01533		
Total	26	2.3295			

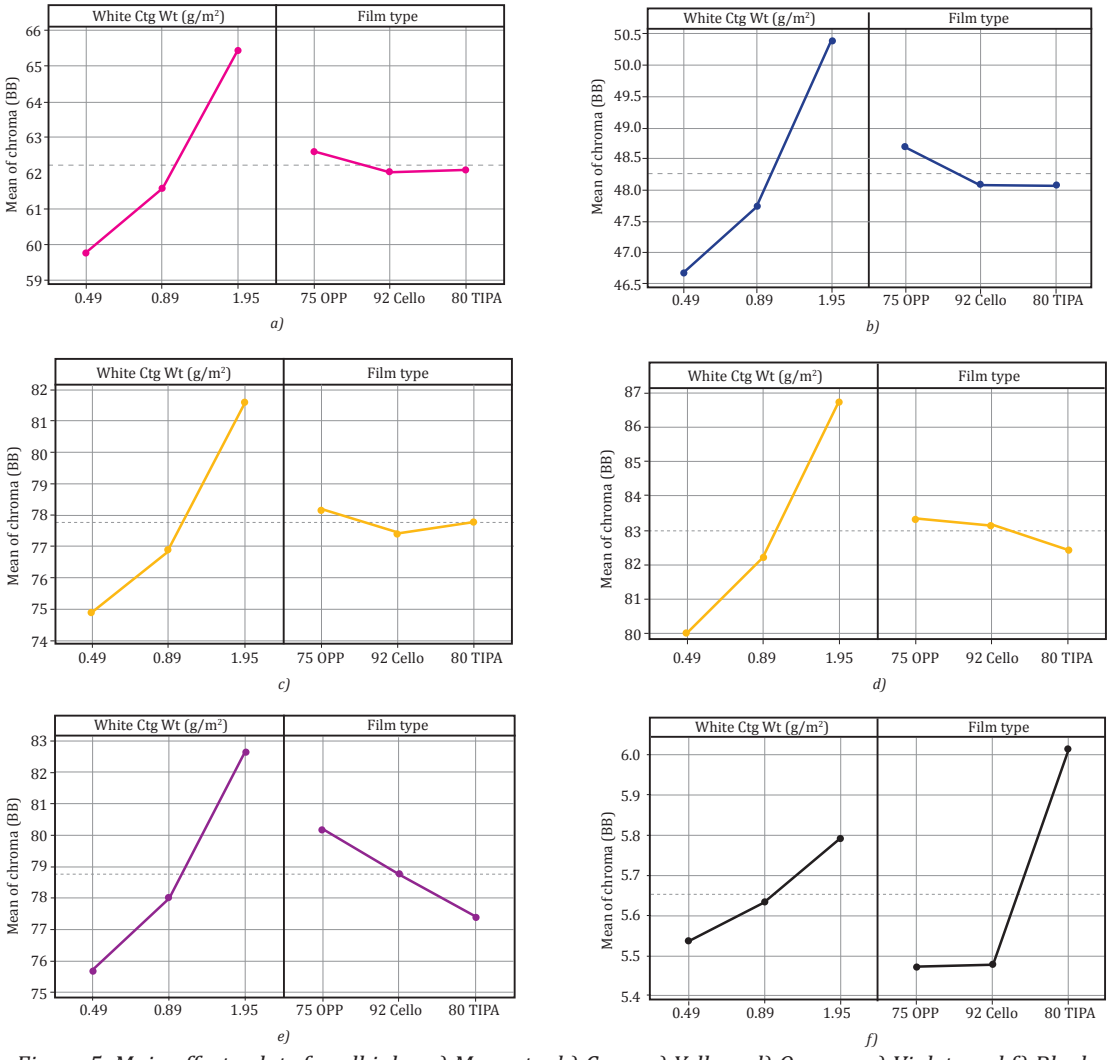

Figure 5: Main effects plots for all inks: a) Magenta, b) Cyan, c) Yellow, d) Orange, e) Violet, and f) Black, measured on black backing (BB)

tion, 80 TIPA stands apart from 75 OPP and 92 Cello in its impact on lightness. It should also be pointed out that lightness differences among the black samples are either visually undetectable or at the very threshold of detectability. This contrasts strongly with the chromatic inks where chroma differences are highly visible.

3.2 Regression analysis of experimental data

Having established that the relationships between coating weight, film type, and chromaticity parameters are statistically significant (i.e. real and repeatable), the next step is to develop quantitative, predictive

models for chromaticity. To realize this end, linear and nonlinear regression models were used to develop quantitative relationships based on the data collected.

3.2.1 Regression analysis of Magenta data

For purposes of generating regressions, the chroma values of the replicates were averaged and the average was used as a single data point representing the film type / coating weight combination. In addition to the data presented in the previous section, chromaticity was measured on unprinted 75 OPP. Table 9 shows the Magenta dataset used for the regression analysis.

Table 9: Magenta chroma versus film type and coating weight

	Chroma (C^*_{ab})		
White ink Ctg Wt	**75 OPP**	**92 Cello**	**80 TIPA**
1.95 g/m^2	65.79	65.11	65.40
0.98 g/m^2	61.82	61.36	61.44
0.49 g/m^2	60.14	59.52	59.52
0.00 g/m^2	25.31	25.87	25.27

A separate regression model (chroma as a function of coating weight) was created for each film type. A logarithmic transformation of the data resulted in a regression models that fit the data reasonably well. The result for 75 OPP is shown in Figure 6.

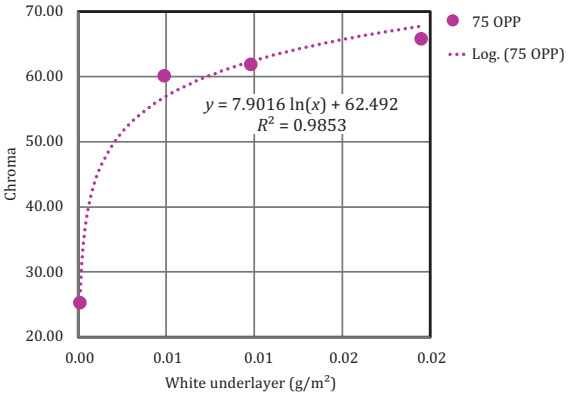

Figure 6: Logarithmic regression of chroma vs white underlayer coating weight for Magenta ink on 75 OPP film

Although the logarithmic regression curve has an R^2 of 0.9853, it still significantly underestimates the chroma value of the 0.49 g/m^2 underlayer and overestimates chroma of the 1.95 g/m^2 underlayer.

Since the plot points in the region of interest (0.49 g/m^2 to 1.95 g/m^2) look approximately linear, the next step was to assess the fit of a linear regression to these points. Figure 7 shows the results.

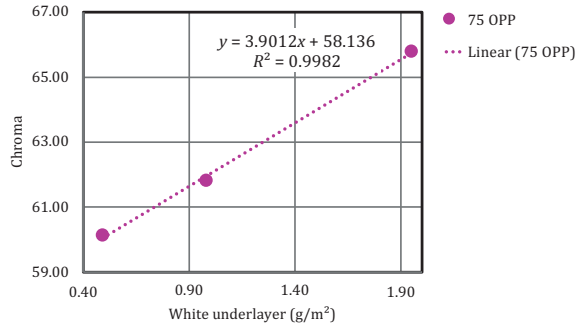

Figure 7: Linear regression of chroma vs white underlayer coating weight for Magenta ink on 75 OPP film

As the figure shows, a linear regression with an intercept C^*_{ab} of 58 and a slope C^*_{ab}/g/m^2 of 3.9 is a near perfect fit with an R^2 of 0.9982. The intercept, slope, and R^2 are the key results of this analysis. To save space, the remaining regressions are presented in tabular form and graphs are omitted. Table 10 presents the Magenta regression results. Intercept data shows that the swatches printed on 75 OPP are slightly more chromatic than those printed on the other films. The slopes (chroma gain per 1.0 g/m^2 increase in coating weight) are grouped around C^*_{ab}/g/m^2 of +3.9. Finally, R^2 values of 0.99+ demonstrate that between 0.49 and 1.95 g/m^2 coating weight, the regression is a near perfect fit to the data.

Table 10: Regression results for the chroma of magenta ink printed on 75 OPP, 92 Cello, and 80 TIPA measured on white underlayers with coating weights between 0.49 g/m^2 and 1.95 g/m^2

Film type	**Intercept**	**Slope**	R^2
75 OPP	58.1	3.90	0.9982
92 Cello	57.6	3.83	0.9999
80 TIPA	57.5	4.03	0.9999

3.2.2 Regression analysis of the remaining data

Table 11 compares the regression results for the remaining chromatic colors. Magenta results are included for ease of comparison. As Table 11 shows, linear regressions provide near perfect fits to the data (R^2 values between 0.9947 and 0.9999) for all combinations of chromatic inks and film types. The intercept data is consistent with the main effect analyses for film types: choice of film type has a minor effect on chroma ($C^*_{ab} \leq 1$) for all inks except Violet, where film type has a C^*_{ab} effect of 3. Slopes are closely grouped within each ink, but vary significantly between inks. The slope (% intercept/g/m^2) adjusts for this difference by dividing the slope (in C^*_{ab}/g/m^2) by the value of the intercept (in C^*_{ab}). After making this

Table 11: Regression results for chroma of chromatic inks printed on 75 OPP, 92 Cello, and 80 TIPA measured on white underlayers with coating weights between 0.49 g/m² and 1.95 g/m²

Ink	Film type	Intercept	Slope (C^*_{ab}/g/m²)	Slope (% Intercept/g/m²)	R^2
Magenta	75 OPP	58.1	3.90	6.7 %	0.9982
	92 Cello	57.6	3.83	6.6 %	0.9999
	80 TIPA	57.5	4.03	7.0 %	0.9999
Cyan	75 OPP	45.7	2.60	5.7 %	0.9996
	92 Cello	45.3	2.42	5.3 %	0.9971
	80 TIPA	45.0	2.74	6.1 %	0.9963
Yellow	75 OPP	73.0	4.54	6.2 %	0.9947
	92 Cello	72.0	4.67	6.5 %	0.9983
	80 TIPA	72.5	4.66	6.4 %	0.9997
Orange	75 OPP	78.0	4.67	6.0 %	0.9999
	92 Cello	78.0	4.50	5.8 %	0.9992
	80 TIPA	77.0	4.69	6.1 %	0.9994
Violet	75 OPP	74.7	4.79	6.4 %	0.9998
	92 Cello	72.1	5.47	7.6 %	0.9895
	80 TIPA	71.8	4.81	6.7 %	0.9997

adjustment, we can observe that all slopes fall between 5.3 % and 7.6 % per 1.0 g/m² increase in white ink Ctg Wt with two thirds of the slopes falling between 6.0 % and 6.9 % per 1.0 g/m². Black results have been excluded from this analysis since the L^* (lightness) differences among the black samples are visually insignificant and a predictive model is, therefore, meaningless.

3.3 Relationship between chroma loss and CIEDE2000

Chroma is only one aspect of color perception. To understand the visual impact of changing coating weights and film types, CIEDE2000 color difference values were calculated from the underlying CIELAB data. The CIELAB values of ink swatches printed on 75 OPP and measured on a 1.95 g/m² white underlayer were used as color references since 75 OPP is a standard packaging film and 1.95 g/m² is a standard white ink Ctg Wt.

Unlike the previous two sections, Magenta results will not be discussed separately. Instead, it is more instructive to examine the results for all colors, film types, and coating weights simultaneously. Table 12 summarizes the results of the ΔE_{00} analysis. Black ΔE_{00} values are all less than 1 (i.e. visually undetectable or barely detectable). Thus, Black results have been excluded from the table since they have no visual significance.

Table 12: CIEDE2000 color differences vs reference CIELAB values for each ink (i.e. CIELAB values of each ink printed on 75 OPP and measured over a 1.95 g/m² white underlayer); values below 2 ΔE_{00} are shown in normal text, values between 2 and 3 ΔE_{00} are italicized, values above 3 ΔE_{00} are italicized and shown in bold

Ink	Film type	ΔE_{00} on 1.95 g/m² White	ΔE_{00} on 0.98 g/m² White	ΔE_{00} on 0.49 g/m² White
Magenta	75 OPP	0.00	*2.48*	***3.41***
	92 Cello	0.55	*2.58*	***3.86***
	80 TIPA	0.27	*2.34*	***3.53***
Cyan	75 OPP	0.00	*2.34*	***3.42***
	92 Cello	0.38	*2.64*	***3.71***
	80 TIPA	0.37	*2.56*	***3.53***
Yellow	75 OPP	0.00	***3.50***	***5.10***
	92 Cello	0.93	***4.35***	***5.41***
	80 TIPA	0.24	***3.66***	***5.39***
Orange	75 OPP	0.00	*2.46*	***3.65***
	92 Cello	0.10	*2.31*	***3.50***
	80 TIPA	0.23	*2.35*	***3.56***
Violet	75 OPP	0.00	1.21	1.80
	92 Cello	0.35	1.57	*2.17*
	80 TIPA	0.60	1.69	*2.27*

As this table shows, white ink Ctg Wt is the dominant factor influencing the observed ΔE_{00} values with print layer film type having a secondary effect, a finding that is consistent with the ANOVA results. The range of variation due to film type is less than ΔE_{00} of 1 for all ink color / Ctg Wt combinations. The white ink Ctg Wt, on the other hand, has a pronounced effect on perceived color. For Magenta, Cyan, and Orange inks, cutting white ink Ctg Wt from 1.95 g/m^2 to 0.98 g/m^2 results in a ΔE_{00} of ~2.5 color difference; a further reduction to 0.49 g/m^2 results in a ΔE_{00} of ~3.5 color difference. For Yellow, color difference is magnified. Reducing white ink Ctg Wt to 0.98 g/m^2 results in a ΔE_{00} of 3.5 – 4.5 color difference, and further reducing coating weight to 0.49 g/m^2 results in a ΔE_{00} of 5.0 – 5.5 color difference. This effect is attributable to the fact that Yellow has the least blocking power of all inks. As a result, Yellow is more dependent on the white underlayer to block background colors (in this case the black backing) than the remaining inks. Violet, on the other hand, shows less sensitivity to reductions in white ink Ctg Wt. In this case, a 0.98 g/m^2 white underlayer is a ΔE_{00} of ~1.5 color difference versus a 1.95 g/m^2 underlayer, while a 0.49 g/m^2 underlayer results in a ΔE_{00} of ~2.0 color difference. This effect is most likely attributable to the fact that the human visual system is less sensitive to chroma changes in the Blue-Violet region than in other color regions. The ΔE_{00} calculation introduced a rotational factor to account for this difference and improve the agreement between ΔE values and human color judgements (Habekost, 2013).

4. Conclusions

The results of six DOEs assessing the impact of white underlayer coating weight and print layer film type on the chromaticity of gravure printed Magenta, Cyan, Yellow, Orange, and Violet swatches showed that both coating weight and film type have a statistically significant effect on chromaticity ($P < 0.005$). For Magenta, Cyan, Yellow, and Orange inks, white underlayer coating weight had the dominant effect while the effect of print layer film type was relatively minor. Violet ink followed this general pattern, but the difference between the effect of white ink Ctg Wt and print layer film type was less pronounced. The relationship between coating weight and chroma over the range from 0.49 g/m^2 to 1.95 g/m^2 was linear for all inks ($R^2 > 0.99$). Finally, when printing Magenta, Cyan, or Orange, a coating weight reduction of 1 g/m^2 (from 1.95 to 0.98 g/m^2) resulted in a color shift ΔE_{00} of ~2.5, and a 1.5 g/m^2 reduction (from 1.95 to 0.49 g/m^2) resulted in a color shift ΔE_{00} of ~3.5. Yellow, the weakest ink, was more affected, while Violet, a hue where the human visual system is less sensitive to chroma differences than it is when judging other hues, was less affected.

For achromatic Black ink, lightness was chosen as the response variable. Although white ink Ctg Wt and print layer film type had statistically significant effects on L^*, the differences attributable to these effects were at or below the threshold of visual detection.

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Authentication of Indian paper currency using digital image processing

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Abstract

Counterfeit currency notes create serious threat to the economy as it reduces the value of genuine currency and hampers the financial system due to inflation. Hence to limit the circulation of fake currency notes a system needs to be designed which can authenticate a banknote more efficiently. The aim of this present investigation is to differentiate between real and fake currency notes by considering various elements of digital image processing (IP). This methodology when applied on MATLAB software gives a striking contrast between the real and fake Indian currency notes. The advantage of this technique is that the currency image can be captured by any type of simple scanner or digital camera in any lighting condition as well as can recognize the currency note from any direction and angle. From the output of the MATLAB programming the clear disparities obtained between genuine and counterfeit banknotes helps to detect a fake currency note very efficiently. The proposed approach for processing Indian currencies using IP seems to be a very simple and novel method and also open up entirely new application area for comparison of genuine and fake notes that have not previously been feasible or cost effective.

Keywords: Indian currency notes, counterfeit, compare, MATLAB programming

1. Introduction

In every country an automatic system is required to detect counterfeit currency notes in order to eliminate the circulation of black money and fake currency notes used for funding illicit activities. Therefore, a system should be introduced which is convenient, user-friendly, cost effective, fast and reliable approach for the identification of genuine and fake Indian currency notes. Hence the need for an automatic banknote recognition system has offered many researchers to make up robust and dependable techniques. Speed and accuracy of processing are the key factors in such detection systems. Digital image processing (IP) involves changing the character of an image to boost its visual information for human interpretation. The proposed methodology consists of various steps that are performed when genuine and fake currency notes undergo in the stage of image acquisition. After some preprocessing methods applied to the currency images it then gets converted from red, green, and blue (RGB) to hue saturation value (HSV) form. Several other IP techniques such as image enhancement, edge detection using Canny, Sobel and Prewitt filter, image segmentation, histogram of an image and number of objects detection are used in the present investigation. The clear disparities between the genuine and fake banknotes can be ultimately compared with each other.

Some works in the domain of IP had been done by various researchers. Chakraborty, et al. (2013) proposed a paper that presented an extensive survey of research on various developments in identification of currency denomination in recent years. This paper primarily focused on currency detection system including various steps involved in it like image acquisition, feature extraction and classification system by using various algorithms of IP. Yadav, et al. (2014) proposed a fake currency note detection technique using MATLAB and feature extraction with HSV color space and other applications of IP. Ismail and Makone (2014) investigated an automated recognition of currency notes that was introduced with the help of feature extraction and classification based on IP. Ballado, et al. (2015) investigated the Phillipine currency paper bill counterfeit detection techniques through image processing using Canny

edge technology. Edge detection is the most important process in IP, and the detection results directly influences the image. Semary, et al. (2015) presented a paper where a currency recognition system was applied to Egyptian banknotes. The basic techniques utilized in their proposed system included image foreground segmentation, histogram enhancement, region of interest extraction and finally template matching. Zeggeye and Assabie (2016) presented a paper on automatic recognition and counterfeit detection of Ethiopian paper currency. Suresh and Narwade (2016) mentioned the approach which consisted of a number of components of IP including edge detection, image segmentation, characteristic extraction and comparison of images to check the validity of fake or genuineness of currency notes. Sawant and More (2016) introduced a paper based on recognition and detection method for Indian currency using IP based on a set of unique non-discriminating security features. Agasti, et al. (2017) suggested the design of a system that detected fake currency notes in less time and in a more efficient manner with the help of IP. Barman, Saha and Bandyopadhyay (2018) proposed a method for identification of different objects present in the Indian currency note using IP. Alnowaini, Alabsi and Ali investigated an approach based on Yemeni counterfeit paper currency detection system. This study provides a solution for every Yemeni denomination with the help of IP and machine learning techniques. Sharan and Kaur (2019) proposed a system to differentiate between a real and fake note which was based on the IP technique and was implemented on MATLAB. Mangayarkarasi, et al. (2020) proposed an approach that consisted of multiple element transactions like image acquisition, feature extraction and comparison, texture features, and voice output. In the present investigation a new framework has been designed on the basis of various digital IP techniques for the detection and authentication of Indian currency notes by obtaining several MATLAB programming outputs and analyzing the clear disparities among the genuine and counterfeit notes.

2. Overview of digital image processing-based currency recognition

For multidimensional systems having two or multiple dimensions of an image, digital IP plays an important role. It permits extensive range of algorithms to take part at the input side along with avoiding complexities of noise and distortion during the processing. The IP takes into consideration the initial step of image acquisition tools where the images are imported. The second step focuses on images being examined and manipulated. The final step is based on scrutinizing an image the output is generated in which altered results for the images are displayed.

The various IP techniques (Gonzalez and Woods, 2002) that are used in the present study are discussed below for ready reference and easy convenience.

Image pre-processing: The goal of image pre-processing is to enhance the image data that restricts distortions present in an image or improves image characteristics for further examining and processing task (Agasti, et al., 2017). The operations which are included during pre-processing helps to decrease the information content from an image only if entropy is the measurement of information. Image pre-processing uses the set of operations that generalizes an image at its lowest level. Four different kinds of image pre-processing techniques are segmentation and image filtering technique, image restoration and Fourier transform technique, brightness correction or pixel brightness transformation technique and geometric transformation technique.

Image enhancement: The process of eliminating any unwanted or unnecessary information from an image according to particular needs is done by image enhancement (Iwasokun and Akinyokun, 2014). It also highlights the required parts of an image. For instance, to highlight features of an image it adjusts the levels, eliminates unwanted noise and displays the blurred details of an image. Image enhancement techniques are divided into spatial domain and frequency domain. The operations executed by spatial domain procedures are directly applied on the pixels of an image. It separates an image on the basis of uniform pixels with a definite resolution with respect to its spatial domain coordinates. However, the operations executed by frequency domain procedures are indirectly applied on the pixels of an image. The improved quality of an image is acquired by using Fourier transform to the spatial domain.

Edge detection: The groups of pixels that are connected to each other and create a boundary between two disconnected regions are determined as edges. In a digital image the considerable changes of intensity are represented by edges. The three types of edges that are present in an image are: diagonal edges, horizontal edges and vertical edges. Edge detection always decreases the number of data present in an image as well as maintains the structural attributes of an image. It is a technique of segregating an image into the regions of discontinuity. Edge detection permits the users to examine the characteristics of an image by creating a noticeable transition in the gray level (Sonka, Hlavac and Boyle, 2014).

Sobel operator: The Sobel operator is also known as Sobel filter or the Sobel-Feldman operator. In the domain of computer vision and IP, Sobel operators take

into account the edge detection algorithms in order to highlight the edges present in an image (Kanopoulos, Vasanthavada and Baker, 1988). At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. It is formulated on rotating the image with a distinguishable integer valued filter horizontal as well as vertical directions. Therefore, in terms of calculations it is comparatively low-cost and reasonable.

Prewitt operator: Prewitt operators detect edges with the help of a mask whenever there is an abrupt transition in the pixel intensities (Dong and Shisheng, 2008). By applying the method of differentiation, the edges present in an image can be clearly interpreted. In the graphical illustration of Prewitt mask's result, the edges are described by the local maxima or minima where the mask is a first order derivative type. Prewitt operators detect two types of edges and they are horizontal edges and vertical edges.

Canny operator: These types of operators use Canny edge detection which is a method to lessen the quantity of data that needs to be processed and only select the necessary information from different objects (Ballado, et al., 2015). The applications of Canny edge detection are extensively used in computer vision system where in a wide range of situations the detection method can be executed.

Image segmentation: This technique changes as well as simplifies the characterization of an image into something that is simple to understand and analyze (Suresh and Narwade, 2016). Image segmentation as the name suggests separates a digital image into its numerous segments which are referred as image objects or image regions. It is normally used in an image in order to trace boundaries such as curves, lines, etc. and objects. This technique is widely used in IP and computer vision where the image pixels that have common characteristics between them and share certain attributes are allotted a particular characterization in case of every pixel.

Image histogram: Histogram of an image corresponds to a function that is discrete in nature having gray levels in the range [0, L–1]. The relative frequency of occurrence of different gray levels can be depicted by the histogram of an image. The required information of an image acquired by the histogram is always wide-ranging in nature. Usually, histogram provides an overview of the overall appearance of an image. The horizontal axis of a histogram determines the variation of tonal ranges of an image whereas the vertical axis determines the aggregate number of pixels present in a specific tone. Histograms have diverse applications in the field of IP as it helps to scrutinize an image by just viewing at its histogram. For modifying the contrast of an image histograms are used along with brightness purposes as required. Equalization of an image is also done by the application of histograms (Thomas, Flores-Tapia and Pistorius, 2011).

Object detection: In digital videos and images this technique is associated to digital IP and computer vision that allows recognition of occurrence between objects connected with a certain class like such as buildings, cars or humans. Classification of objects is based on its unique characteristics, for example all rectangles are quadrilateral with adjacent equal sides. Therefore, when searching for rectangles, objects that are having four adjacent equal sides are looked for. Again, in case of triangles, objects that are having three edges and three vertices are detected. A similar perspective is applied in case of identifying the features of a face in which facial features can be pointed out along with color of the skin as well as distance between eyes. These are the special characteristics that object class recognition uses (Hussin, et al., 2012).

3. Proposed methodology

The methods that are used in this study are presented on MATLAB software with the help of MATLAB programming. Dummy or fake currency notes taken here are generally used for playing monopoly, business games and other board games for kids and all.

The IP algorithm which is applied for the detection of counterfeit Indian currency notes is depicted in Figure 1 representing the flowchart of proposed methodology. The algorithm consists of various elements of IP.

Images of genuine and fake currency notes are acquired by a HP Ink Tank Wireless 419 scanner having optical scanning resolution 1200 × 1200 spi. All the scanned images of the currency notes are in jpg extension. Image acquisitions have been done for both the genuine and fake banknotes simultaneously. Preprocessing is applied to both the images and then it transforms the RGB images into its corresponding HSV form. Image enhancement has been performed in order to improve the quality of the image for better inspection by enhancing the intensity and improving the contrast. It also eliminates noise from the image for better visibility. The edge detection technique is also performed by considering various operators such as Canny, Sobel and Prewitt operators. The process of image segmentation has been executed to create a subdivision of numerous image segments to convert the representation of the image. The outcome of an image segmentation operation is a group of segments that identifies boundaries such as lines, curves, etc. as well as certain objects that share the same characteristics.

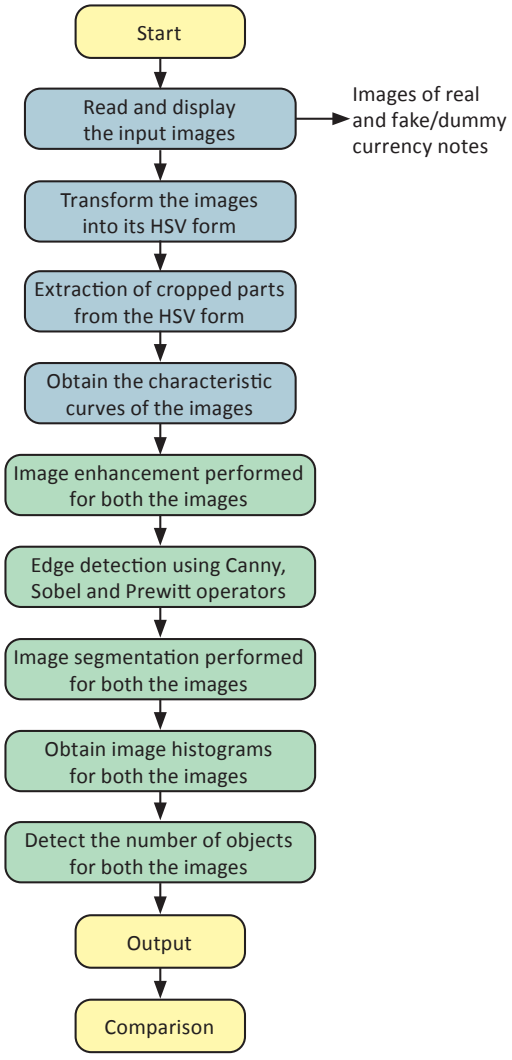


Figure 1: Flowchart of present methodology

Histograms of the images determine the brightness measure by representing the tonal values on a bar chart. The horizontal axis ranges from black on left hand side having 0 % brightness to white on the right-hand side having 100 % brightness. The frequency of each tone present in the image is represented with the vertical axis. Finally, the last technique which has been applied is known as the object detection where the number of objects obtained from the images are calculated and shown in the numerical form. Thus, after the application of various elements of IP, the processed images of the genuine and fake banknotes are then compared where the difference can be perfectly identified. In order to test the efficiency and validity of the proposed system, MATLAB programming is implemented using a Lenovo G50-70 laptop which has the following features: Intel (R) Core (TM) i3 4030U CPU @ 1.90GHz, and 4.00GB of RAM, 64-bit Windows 7 and the MATLAB version of R2009a. Based on the flowchart as illustrated the various techniques of IP used in this investigation are presented by developing corresponding algorithm of various elements of IP which is given in detail in Figure 2.

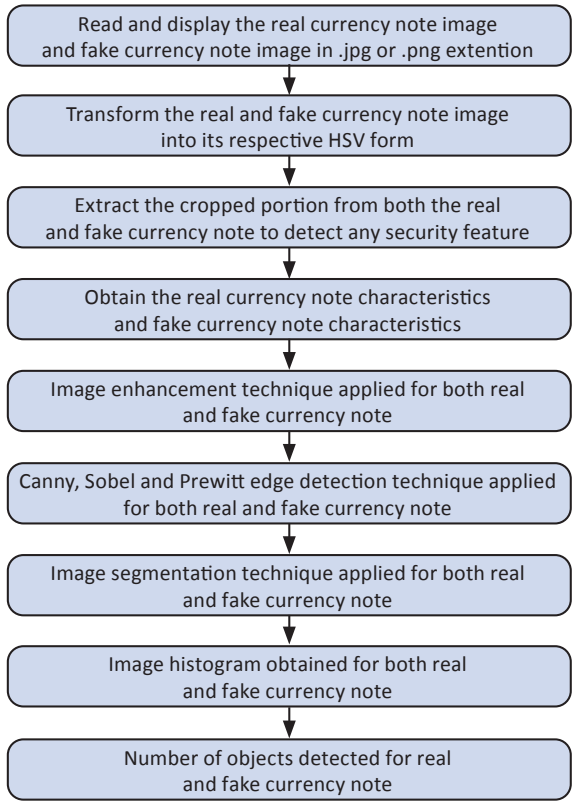


Figure 2: Algorithm of present methodology

Several outputs have been generated with the help of MATLAB programming. The programming codes have been developed in such a way that it can detect the currency note from any direction and from any angle. Also, the images can be read in both .jpg and .png extension.

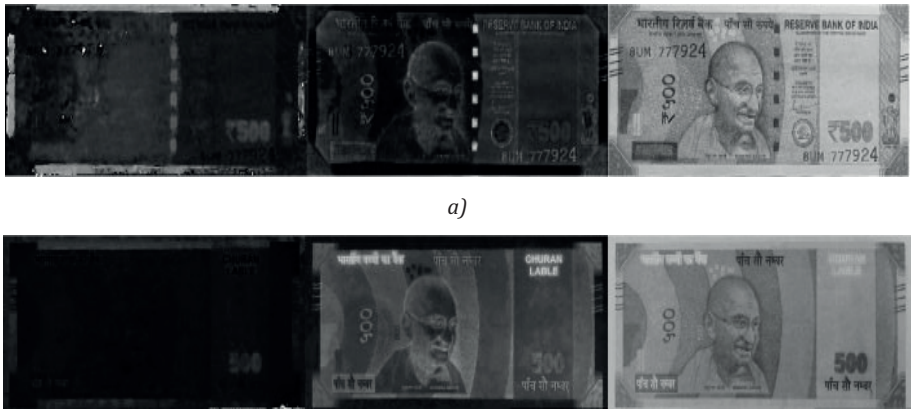
4. Experimental results and analysis

Ten genuine and two fake/dummy currency notes in values of 10, 20, 50, 100, and 500 Indian rupees were used in this study. The size and aspect ratio of the genuine currency paper notes are found to be constant for each denomination i.e, standardized values set by Reserve Bank of India, Government of India. On the other hand, in case of dummy paper notes the size and aspect ratio are not standardized.

Figure 3 shows the output of the real currency note and fake/dummy currency note when the images have been acquired. In Figure 4 the RGB to HSV conversion has been depicted for a real currency note and a dummy currency note. A difference can be seen between the images obtained after the RGB to HSV transformation.

a) *b)*

Figure 3: Images of currency notes: (a) real, and (b) dummy



a)

b)

Figure 4: RGB to HSV form of real and dummy currency note: (a) real, and (b) dummy

The left side of the images for both real and dummy notes represent the Hue part, the right side of the images represent Value part whereas the middle portion of the images designate the Saturation part as shown in Figure 4. The security thread illuminates in case of real currency note but no such case in case of fake currency note.

a) *b)*

Figure 5: Cropped part from the HSV form of real and dummy currency note: (a) real, and (b) dummy

The cropped images of HSV form of real currency note and dummy currency note have been illustrated in Figure 5. The cropping is generally done to remove unwanted object or irrelevant noise of an image. When the cropped image for a real currency note has been extracted, in case of a genuine currency note it portrays the security thread feature whereas the cropped image for a dummy note is completely black, no security feature obtained. It indicates that the most common security features like security thread cannot be extracted in case of a dummy note.

a) *b)*

Figure 6: Rotated 90 degrees solid line image for real currency note and broken line image for dummy currency note: (a) real, and (b) dummy

The solid line image and the broken line image have been portrayed in Figure 6 for real and dummy currency note, respectively. Here the images for both the notes have been rotated by 90 degrees so that the significant changes between a genuine and dummy note

can be analyzed from any angle in any direction by the use of any lighting condition. As the aspect ratio of the dummy notes does not follow any standardization, the size of the real currency notes differs with that of dummy notes. The solid line image for genuine currency note is much more bright and enhanced compared to the fake currency note which remains dull and blackish.

Figure 7 represents the characteristics of a real currency note and the characteristics of a fake/dummy currency note. Here the pixel values of the region of interest (ROI) of the image are normalized between 0 and 1. In order to develop the characteristics of the images of both real and fake/dummy currency, the peak-to-peak normalized pixel intensities of the images along the scanned distance have been obtained and illustrated in Figure 7. The normalized pixel intensity distributions along the distance of the images generated at the output for a genuine currency note and a dummy currency note give a clear distinction between the two currency notes by considering the threshold values of a currency note.

Figure 8 depicts the enhanced images for a real currency note and a dummy currency note, respectively. In case of image enhancement, the genuine currency note gives an enhanced image in the dark background whereas there is no such enhanced image in case of dummy note.

Figure 9 represents Canny edge detection when applied on a real currency note and a fake currency note. The Canny edge detection gives detailed edges for a genuine currency note whereas the edge detection in case of dummy note is blurred.

Figure 10 illustrates the Sobel edge detection when used on a real currency note and dummy currency note, respectively. A sharp contrast arises in case of Sobel edge detection for the genuine currency note where the edges are sharp and clear, however, in fake/dummy note the edges still remain unclear.

Prewitt edge detection has been portrayed in Figure 11 for a real currency note and for a fake currency note. The Prewitt edge detection shows the perfect edges in case of real currency note but fails to detect proper edges for a dummy note.

Figure 12 shows image segmentation for a real currency note and dummy currency note. With respect to a dark background the clear segmented parts of a real

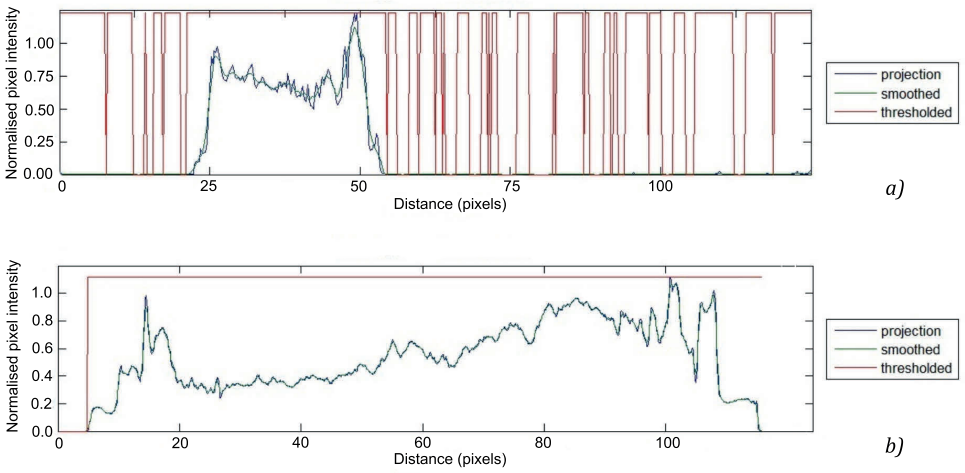
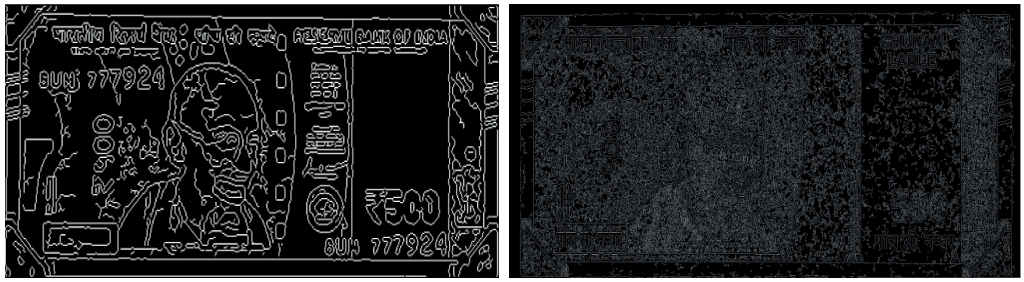


Figure 7: Characteristic curves of real and fake/dummy currency note: (a) real, and (b) dummy

a) *b)*

Figure 8: Enhanced image of real and dummy currency note: (a) real, and (b) dummy

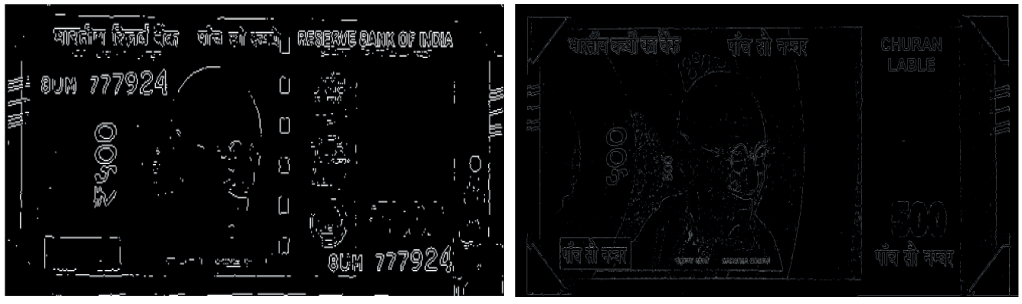


a) *b)*

Figure 9: Canny edge detection of real and dummy currency note: (a) real, and (b) dummy

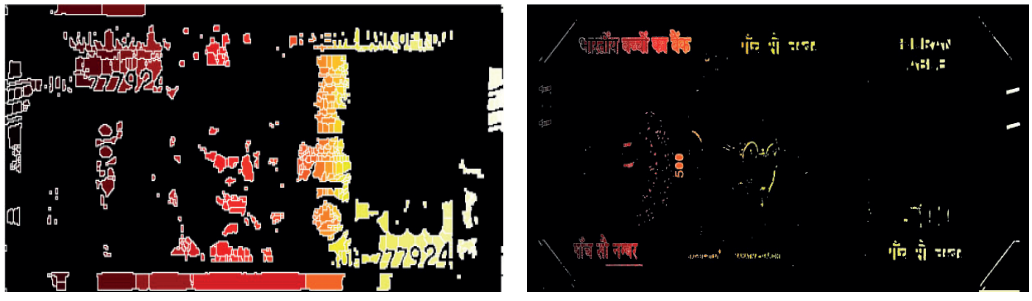
a) *b)*

Figure 10: Sobel edge detection of real and dummy currency note: (a) real, and (b) dummy



a) *b)*

Figure 11: Prewitt edge detection of real and dummy currency note: (a) real, and (b) dummy



a) *b)*

Figure 12: Image segmentation (dark background) of real and dummy currency note: (a) real, and (b) dummy

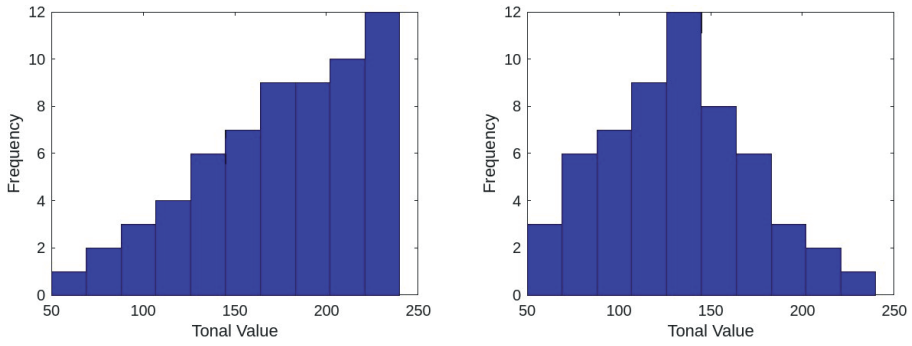
currency note can be noticed but no such proper segmentation takes place in case of dummy currency note.

The final segmented image for a real currency note and a dummy currency note has been in Figure 13. In image segmentation the blue lines that are present on the genuine note determine the segmented portions of a genuine currency note, however, it cannot segment any such portions in the case of a dummy note.

Image histograms for a real currency note and a dummy currency note has been illustrated in Figure 14.

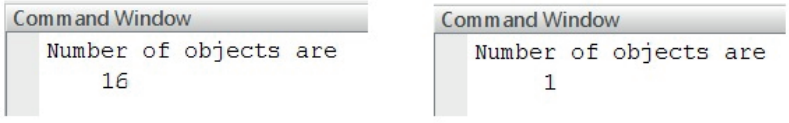
a) *b)*

Figure 13: Image segmentation (light background) of real and dummy currency note: (a) real, and (b) dummy



a) *b)*

Figure 14: Image histogram of real and dummy currency note: (a) real, and (b) dummy



a) *b)*

Figure 15: Number of objects detected in real and dummy currency note: (a) real, and (b) dummy

Here the *x*-axis represents the tonal gradation of the image and the *y*-axis represents the frequency of pixels present in a particular tone. It is observed that in the case of real currency note the number of pixels or tonal values is more in the high-key region than in the case of the low-key region. On the other hand, the fake/dummy note portrays a maximum number of pixels or the tonal values in the mid-key region of the histogram.

Figure 15 shows the number of objects detected in a real currency note and the number of objects detected in a dummy currency note. The number of objects detected for the genuine currency note is 16 whereas it is 1 in case of dummy currency note.

The results shown from Figure 3 to Figure 15 have been obtained for the Indian paper currency (both genuine and dummy) note of value 500. Similar kinds of observations have been noticed for other values of Indian currency notes.

5. Conclusion

Developed MATLAB programming codes have been applied to both genuine and fake currency notes. It is observed that the results obtained from IP analysis on the real Indian paper currency notes are distinct from that of the dummy notes. A clear contrast between a genuine currency note and a fake currency note has been obtained by considering several IP techniques such as image enhancement, edge detection using Canny, Sobel, and Prewitt operators, image segmentation, histogram of an image, and a number of objects detection. The results give accurate disparities between both images that are obtained from the output.

This proposed system focuses on the approach for authentication of Indian banknotes. Since the framework is based upon a generalized concept therefore it is not limited only to Indian currency notes but it can also authenticate any currency notes across the world.

This research work may be expanded to an application-based system to detect the characteristics of a genuine currency note by just capturing the image of a banknote. Moreover, for better authentication functionality image processing can be used with machine learning as an attempt to automate the image analysis process. On the basis of published research results available in references and authors' previous and the present research, the authors assume this methodology can also be adapted to detect fake notes which are close to the original. The advantage of this method is that the image of the currency can be captured by a simple scanner or digital camera in any lighting conditions which can recognize the currency note from any angle in any direction. Moreover, a smartphone-based application system can also be developed to detect the characteristics of genuine currency notes which may be useful for the common people.

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Assessing and fostering media literacy education among undergraduate students: the competence in information retrieval and usability

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Abstract

The purpose of the present study is to provide the insight into media literacy awareness and practice among undergraduate students of Arts and Science disciplines at Pachhunga University College, Aizawl, followed by the emphasis on student's skills of using the application of various media platforms for academic purposes. The random (purposive) sampling method has been used for collecting the required information. Many research studies have been conducted in the past with information literacy as the primary research topic. However, a review of the literature revealed that just a few studies have been conducted using media literacy as a primary focus. Consequently, this research contributes new knowledge to this less explored area of research. Paper concludes with suggestions to strengthen the awareness of media literacy among users.

Keywords: information literacy, media literacy, electronic media, print media, digital media

1. Introduction

Information literacy has become one of the most important skills of modern society in the 21st century; various definitions have been developed in the past by library professionals, associations, and organizations. According to the American Library Association, information literacy is a set of abilities requiring individuals to "recognize when information is needed and can locate, evaluate, and use effectively the needed information" (ACRL, 1989).

The Chartered Institute of Library and Information Professionals defined information literacy in 2004 as "information literacy knows when and why you need information, where to find it, and how to evaluate, use and communicate it in an ethical manner" (Goldstein, 2018). Therefore, information literacy is more than just a set of skills and knowing when and why information is needed, where to obtain it, and how to successfully search, assess, and apply that information. Media literacy in the 21st century refers to the ability to recognise various types of media and comprehend multimedia formats such as audio-visual media, social media, and so on. Audio-visual has a significant impact on school curriculum and teacher teaching style in today's educational system. Students nowadays are increasingly reliant on multimedia, and they use the internet to access study materials.

In the past, literacy used to be defined as the ability to read, write, communicate, use, and analyse information in a meaningful way. Literacy nowadays refers to the ability to read and write, as well as comprehend and communicate ideas through numerous media formats such as radio, television, newspapers, magazines, websites, social media, etc.

The United Nation Educational, Scientific and Cultural Organisation defined literacy as "the ability to recognise, comprehend, interpret, produce, communicate, and compute utilising printed and written materials in a variety of circumstances" (Montoya, 2018). Literacy is a lifelong process of learning that allows a person to attain his or her goals, expand his or her knowledge and potential, and fully participate in society. Finally, liter-

acy is about the ability to use and acquire information in various formats, as well as interpret and generate it. It also refers to communicating in society through the use of media tools (Aufderheide, 1993). Literacy has a critical role in social practice and relationships, as well as knowledge, language, and culture. The concept of media literacy has attracted the researchers from different disciplines to undertake various studies related to the dimension of the area of study.

2. Information literacy

People must master critical thinking skills and information gathering procedures in order to access, store, organise, evaluate, and use information successfully in the twenty-first century information society. In today's world of rapid technological change, information literacy is becoming increasingly vital. Individuals with information literacy are better able to seek, locate, analyse, produce, and apply information and digital technology to attain their personal, educational, occupational, and societal goals. There are different types of information literacy (Lisbdnetwork, 2022), which include:

Visual literacy: Visual communication is one of the most popular communication processes, to communicate by using visual elements, both words and pictures such as images, videotapes, films, drawings, maps, symbols, signs, logos, gestures, photographs, etc.

Computer literacy: Communication by using the process of computer is also the essential need of people. For this purpose, people need some skills and ability. Computer literacy is defined as the ability to create and manipulate documents and data via word processing, spreadsheets, databases and other software tools.

Electronic literacy: The term electronic literacy (e-literacy) refers to the ability to use electronic means such as computers, videos, web pages and the like and to make efficient use of all the materials, tools and resources that are available in the electronic form.

Digital literacy: Digital literacy is the ability to understand and use information in multiple data formats.

Network literacy: Network literacy is closely similar to computer literacy, but it is the ability to locate, access and use information in a networked environment such as the World Wide Web.

Media literacy: Media literacy is defined as the ability to access, analyse and produce information for specific outcomes. Media literacy is the skills and knowledge to understand all the media and formats of information.

3. Media literacy

The term media is the plural form of 'medium' that comes from the Latin word 'medius', whose meaning is 'middle' or 'between two things'. Marshall McLuhan (1911–1980), a Canadian, was the first to coin the phrase "the medium is the message" (McLuhan, 1964), which was further developed to "media as a vehicle or means of communication" (Team Leverage Edu, 2022). As a result, the term 'media' refers to a variety of communication tools, such as an instrument or a transmission channel that people use to store, transmit, and retrieve data or messages (Figure 1).

Figure 1: Steps involved in the transmission channel

In the past, the term media referred to mass media such as newspapers, books, magazines, radio, films and television. In modern days digital technology has become increasingly important day by day, resulting in the emergence of digital media.

As a result, the term 'digital media' can refer to social networking platforms, the internet, smartphone applications, and other types of communication that are sent electronically throughout the world via a computer network. Print and non-print media such as books, newspapers, magazines, television, and radio, mobile phone, computer, social media are examples of modern types of media. There are several forms of media available today, which can be classified as follows.

Traditional media: This includes newspapers, journals, radio, television, magazines, etc. Traditional media is broadly divided into two sub-categories, print media and broadcast media. *Print media* is the oldest form of media and includes all types of printed paper publications such as newspapers, magazines, books, reports, journals, etc. *Broadcast media,* such as radio and later television, was first introduced at the turn of the twentieth century. Although television and radio are crucial means of communication for those seeking information, broadcast television is beginning to slip behind as online media sources take control.

Digital media: Digital media is making various changes in modern communication. Modern digital media encompasses the internet as a whole, but media also refers to websites, blogs, podcasts, videos, digital radio stations, mobile phones, and the communication methods used to send data, such as instant messaging, video chats, and emails.

Computer media: This term is used to describe the electronic devices used to store data such as hard drives, USB drives, DVDs, CD-ROMs, and floppy disks. It also refers to the transmission media used to link workstations. Moreover, technologies used to communicate information such as videos, pictures, sounds and presentations are often referred to as media or multimedia.

Mass media: All media that can reach a huge number of people at the same time are considered mass media. Television, radio, and print media are examples of traditional mass media, whereas social media and internet platforms are examples of digital mass media.

Social media: Both the mass media and digital media categories include social media outlets. They are made up of apps and websites that allow people to exchange content in real time via their computer or smart phone.

Media literacy indicates the ability to access, analyse and evaluate the variety of media messages presented through the mass media. In the past few decades, the meaning of media literacy refers to the ability of reading and writing. Nowadays, media literacy is not only the ability to read and write but also to understand the concept, instructions, functions, ways of communication and to know how to use the various media of communication. However, in this study media literacy refers to the skills including skills of using media, creating media content, critical evaluation of media structure and analysis of media text.

This study emphasises the student's skills of using the application of various media platforms, studied previously by Yildiz Durak and Saritepaci (2019). According to the Centre for Media Literacy, (Thoman and Jolls, 2005), "Media literacy is a 21st century approach to education. It provides a framework to access, analyse, evaluate, create, and participate with messages in a variety of forms – from print to video to the internet. Media literacy builds an understanding of the role of media in society as well as essential skills of inquiry and self-expression necessary for citizens of a democracy." In the field of education, students require media literacy instructions for their education and personal growth, and they must grasp how media strategies influence their vision and thinking, as well as how media operate, how they can be used, and how to evaluate the information they give.

4. A look on media in Mizoram

Mizoram is one of Northeast India's seven sister states. It is surrounded by a hilly mountains with a diverse range of forest resources. The scheduled tribes, i.e. tribal communities or a group within such tribes or tribal communities as under Article 342 of the Indian constitution (The Constitution of India 2022) make up the majority of the population in Mizoram. The state of Mizoram is divided into ten districts, including three autonomous district councils: Lai Autonomous District Council, Mara Autonomous District Council, and Chakma Autonomous District Council. In the state of Mizoram, various ethnic groups live and speak different languages and have their own culture, tradition, and way of life.

The literacy rate has been used to measure who has developed and grown in terms of education, occupation, job opportunity, industry, etc. In India, literacy is widespread; a person who is seven years of age or older and can both read and write with understanding any language is treated as literate. According to the overall country literacy rate is 74.04 %; for males it is 82.14 % and for females 65.46 %. Kerala state has taken the first position with a 93.91 % literacy rate followed by Lakshadweep with 92.28 %. Mizoram has also grown the literacy rate and occupied the third position in the 2011 census, i.e. 91.58 %. (India/Bharat, 2020)

In term of the growth and development of mass communication and journalism, it is noticed that there is tremendous potential among the Mizo society. With the rapid growth of communication technology, different types of media can be noticed. They include print media, which is the first form of communication through media. According to the Office of Registrar of Newspapers for India (2022), there are a total number of 204 titles registered in Mizoram. Out of a total number of 108 newspapers and periodicals, 36 are daily, 43 weekly and 29 are monthly periodicals newspapers and magazines. Some of the frequently published newspapers include 14 from Lunglei, 6 from Mamit, 11 from Saiha, 7 from Lawngtlai, 9 from Champhai District, 9 from Serchhip and 6 from Kolasib District; Aizawl District has the most newspapers publications with 34 newspapers (Vanamamalai, 2018). In Mizoram, there are many print media (newspapers) such as Aizawl Post, Mizo Aw, Mizo Arsi, Dingdi, Vanglaini, Romei, Sunday Times, Zalen, Zozam and other. Highlander, News Link and Mizoram Post are published in English.

Along with the growth of print media, the electronic media are also playing a vital role in its own pace of development. It includes TV and radio as the fastest growing communication channels in Mizoram. The All India Radio is the main station in Mizoram; it was started in the 1960s. The Ministry of Information and Broadcasting has made a minimum wave transmitter and set up a station in Aizawl and it started to function in 1966 with a 150 Watt medium wave frequency. In 1995, the FM radio station was launched with 6 KW and FM radio has become one of the most popular

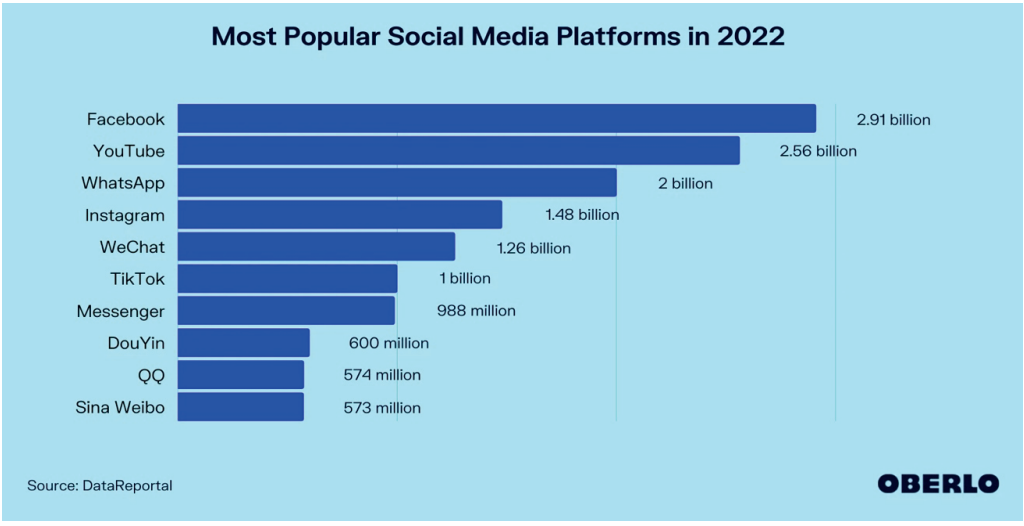


Figure 2: Most popular social media platforms in 2022 (Oberlo, 2022)

radio programmes in Mizoram (Mizoram, 2021; Baruah, 1983). On 20 March 1995, Prasar Bharati has set up an FM transmitter in Lunglei. The All India Radio covers a total percentage of 75 % of the population of Mizoram through five transmitters such as medium wave, short wave and FM. The All India Radio Aizawl and Lunglei broadcast programmes in different languages such as Mizo, English and Hindi languages, and also in other ethnic languages such as Hmar, Paomih, Mara, Chakma (Prasar Bharati, 2022). Doordarshan Kendra Aizawl is the first television channel in Mizoram, and its headquarters is located in Tuikhuahtlang Aizawl. Apart from the Doordarshan channel, 29 cable operators have been functioning in urban and rural areas. LPS and ZONET are the major cable channels in Mizoram. The use of technology, the internet, computers, and social media, among other things, has resulted in a significant change from an automated to a virtual world. Nowadays, social media has more users among young people, with 90 % of 18 to 29 years old using at least one social media programme (Vanamamalai, 2018). Social media began as a platform for sharing personal information, documents, videos and photos, activities, and events with friends and family in real-time, but it has since been adopted for business, marketing to reach out to customers, advertisement and promotion, extension service, and the development of a new educational system. The most popular social media platforms in 2022 are shown in Figure 2.

5. Application of media and social media in libraries

People's daily lives have been made easier with the growth of information and communication technology (ICT) and its associated devices. In terms of economy, culture, education, and research development, it introduces numerous changes to our society. Millions of people use various media platforms for their everyday activities and other objectives in today's globe, making media and social media one of the most popular communication tools.

At the same time, a growing number of libraries throughout the world are utilising various social networking platforms, and many librarians are utilising social networking to create a virtual platform that allows library users to access and share their information requirements with other users (Figure 3). Some libraries utilise it to promote library resources and services, as well as to communicate with its patrons, including those who live in rural areas.

As a result, in this age of information explosion, everyone is running and living behind knowledge and people's thinking and mindsets are changing as well. Many people lack media literacy knowledge and abilities, and they do not know how to successfully utilise social media, therefore they should grasp the fundamentals and concepts of media activities and functions. Similarly, library professionals should prepare for new difficulties and problems that may arise in their fields. They should improve their media literacy skills and expertise in order to meet the requirements and desires of their library customers in the future.

Modern technology has brought many multimedia applications, such as audio-visual media, social media, online platforms, the internet, and others, to our doorstep, making education possible. The library also has a specific role, and it should organise learning classes, training, orientation programmes, and other learning courses in the field of media literacy skills for its patrons.

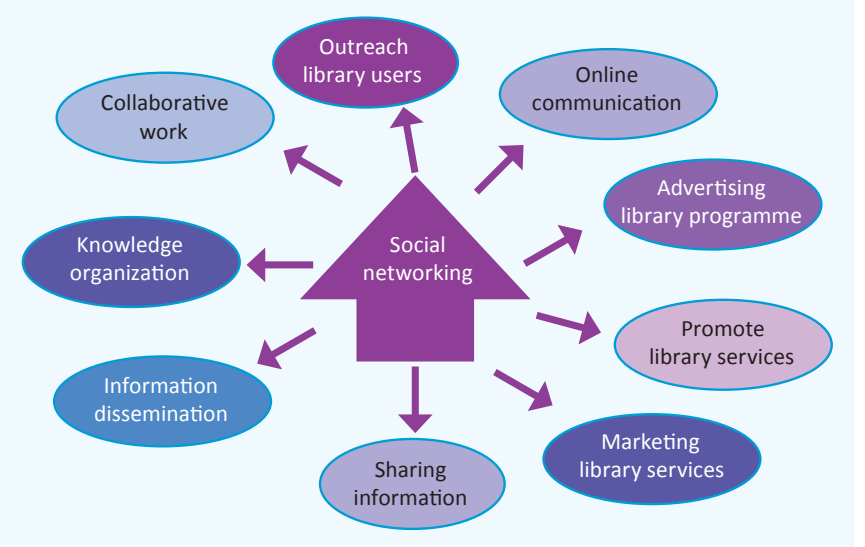


Figure 3: Social networking tools in library

6. Pachhunga University College

Pachhunga University College (PUC) is a constituent college of Mizoram University and one of the leading institutions in Aizawl. The college was founded as 'Aijal College' on August 15, 1958, and is now Mizoram's oldest and largest college. The college is located in College Veng, a neighbourhood in Aizawl's eastern outskirts (PUC, 2019). The college offers undergraduate and postgraduate courses, as well as diploma and certificate programmes. Seminars, workshops, conferences, and training at various levels were held at the college on an international, national, and state level.

The National Assessment and Accreditation Council has given the college an A+ grade, indicating that it is now nationally recognised (NAAC). In 2016, the college was honoured with the 'Indira Gandhi NSS Awards' for its exceptional contributions to community service at various levels. From 2016 to 2019, the college won the title of 'Overall Champion' in the MZU Sports meet for four years. In 2008, the college celebrated its Golden Jubilee, and on August 17, 2018, the college commemorated its Diamond Jubilee.

7. Significance and scope of the study

The study is basically confined to undergraduate students of Arts and Science disciplines at PUC, Aizawl. As today's information world is moving rapidly, media literacy seeks its attention in the society. Because online-mode education, web learning, cloud education, and many class lectures are conducted through online, audio-video media, students cannot rely on classroom teaching to keep up with this advancement in the education system. Students must be able to deal with the information working cycle, information anxiety, and changes in formats and retrieval strategies in a variety of media. The undergraduate students were taken into consideration rather than the general public of Mizoram as the students seem to have differentiation of knowledge about media literacy or skills.

8. A look into the previous studies/literature

To understand the core area of media literacy and its impacts on society some of the relevant kinds of literature were considered for the study such as Rasi, Vuojärvi and Ruokamo (2019) who examine the current condition of media literacy for various age groups, as well as existing and future needs. They emphasize the importance of continuing development, particularly in the area of media literacy instruction for older persons. Omar (2018) believes that media literacy has changed the concept of literacy from knowing how to read and write into knowing how to read and write and using media for analyzing and responding to messages and information. Durak and Saritepeci (2019) studied the increasing problems of internet usage among high school students and find out the importance of different variables, such as social media usage status, usage purposes, and new media literacy. Boruah and Bora (2017) and Boruah (2019) in their studies highlight the significance of critical media literacy in the media education curriculum where teaching-learning techniques among Assamese postgraduate students are increasingly centered on understanding media as a medium, with students learning how to create media contexts, analyze,

and evaluate media content. In the study of Bahramian and Amidi Mazaheri (2018), the scale development process was carried out in nine steps, and after conducting an analysis they found out that media literacy skills, which consist of 45 items gathered under the four main factors of 'access, analyze, evaluate and communicate', is a reliable and valid measurement instrument. Austin and Pinkleton (2016) studied the effect and importance of media literacy on young people thinking skills. According to their study, it has strong potential and they also suggested to conduct more media literacy training programmes to the specific needs of the members. Gretter and Yadav (2016) studied the development of 21st-century skills, creativity critical thinking, and problem-solving in our globalization and ICT society. In their finding, the advancement and accessibility of computing technologies have a great impact on the students and other people. The educator shall truly be benefited from developing technical skills, which shall enhance the complementary relationship between computational thinking and media and information literacy. Media literacy education shall evolve the spectrum of professional and personal abilities in the promotion of digital citizenship. These sets of students shall bridge the digital gap and apply the most affordable means to communicate and challenges modern-day issue. Zhang and Zhu (2016) examined the digital media literacy of primary school students in 5th and 6th grade in Beijing. The finding is most of the students in the 5th and 6th grades have high critical thinking understanding and technical skills. The study by Schmidt (2013) has attempted to analyze the importance of media literacy education among all levels of educational background and found that the focus group of students is most conceived within the higher education level despite several research and policies keeping media literacy as the focal point. On the other hand, a comprehensive study made by Valtonen, Tedre, and Makitalo (2019) has analyzed of connection between media literacy education and algorithms and automation of computerization of media learning environment where it was reported that there are different ways for intertwining media literacy education complementing computer education that led to improvement of latest technological innovation among students, which shall develop interest to cope up the modern media and be a skilled professional to locate themselves in the contemporary media scenario. An assessment made by Hobbs (2004) on the implementation of media literacy in K-12 education focusing teacher's motivations in elementary education, secondary English language arts, and media production to drive student attention toward critical-thinking skills, political activism, communication skills, and many more. One more important study to be noted is that of Kahne, Lee and Feezell (2012) wherein they attempted to understand the relation between digital media literacy education and civic and political participation via online mode and the results reveal that media literacy is not only closely associated with demographic variables but also other variables that boost the active online participation in the diverse fields, which are having close associates with each other where the present study also seek to understand the importance of media literacy on active political and social participation of the youth in the development of society and nation as a whole.

9. Objectives of the study

To accomplish the study, the following five objectives were set.

1. Understanding the use and application of media literacy among the undergraduate students of PUC, Aizawl.
2. Student perception about media literacy for the academic and personal development.
3. Satisfaction of the students in seeking information from various types of media available to them.
4. Finding out the strategies adopted and the mechanism to be designed to encounter the problems in seeking media literacy.
5. Suggesting ways to strengthen media literacy.

10. Research methodology

Table 1: Students' response rate

Department name	Questionnaire Distributed	Received	Percentage (%)
Department of Education	10	10	10.4
Department of Economics	10	10	10.4
Department of English	10	9	9.4
Department of Geography	10	10	10.4
Department of History	10	10	10.4
Department of Biotechnology	10	8	8.4
Department of Botany	10	10	10.4
Department of Chemistry	10	10	10.4
Department of Environmental Science	10	10	10.4
Department of Geology	10	9	9.4
Total	100	96	100.0

The present study is undertaken by surveying the students and the primary data is collected through a questionnaire. For sampling, the random (purposive) sampling method has been used for collecting the required information. The sample selected were students from Arts and Science disciplines. From altogether 20 (11 Arts and 9 Science) departments in PUC, 5 departments from Arts discipline, and 5 from Science discipline were selected for the study. From both disciplines, 10 students from each departement have been randomly selected to answer the questionnaires. Therefore, 100 questionnaires were distributed to the selected students. The data analysis and interpretation were based on the objective of the study; the calculated percentages in tables are based on received questionnaires. The primary data collected were analysed and interpreted with the help of Microsoft Excel 2010 and SPSS software package (Table 1).

11. Analysis and interpretation of data

The data received from the respondents is analysed and interpreted in six parts according to the research objectives such as personal information, media literacy, use and application of media literacy, student perception about media literacy, satisfaction of seeking information sources, and strategies and mechanism.

11.1 Personal information

The general information was collected from the students on the basis of gender, age and residential area. The data are reported in Tables 2, 3, and 4, respectively. Table 2 represents the number of male and female questionnaire respondents in the research study, divided into Arts and Science stream.

Table 2: Gender-wise analysis of the students

Streams	Gender	No. of students	Percentage (%)	Total
Arts	Male	24	49.0	49
	Female	25	51.0	
Science	Male	22	46.8	47
	Female	25	53.2	
Total		96	100.0	96

The study data of age group among the students were analysed into two streams as well, as given in Table 3. This study result shows that most of the students of PUC are between the ages of 19 to 21 years.

The residential area of the students was based on three different categories comprising urban, semi-urban and rural areas. This parameter is taken into consideration due to geographical factors as the state is hilly by nature and factors such as connectivity, electricity and other elements should be taken into account. The detailed information is presented in Table 4.

Table 3: Age group of Arts and Science students

Streams		Age 16–18	19–21	22–24	Total
Arts	No. of students	1	36	12	49
	Percentage (%)	2.0	73.5	24.5	
Science	No. of students	0	34	13	47
	Percentage (%)	0.0	72.3	27.7	
Total	Students	1	70	25	96

Table 4: Residential area of the students

Area	No. of students	Percentage (%)
Urban	54	56.2
Semi-urban	11	11.5
Rural	31	32.3
Total	96	100.0

11.2 Media literacy

Table 5 represents student's opinion, i.e., yes or no, on their media literacy. From the students who opted yes option, the student's media literacy skills were also analysed further.

Table 5: Opinion on the term media literacy

Option	Respondents (No.)	Percentage (%)
Yes	78	81.3
No	18	18.7
Total	96	100.0

The term 'media literacy' indicates the perceptions of students' media literacy skills rather than their actual professional literacy skills.

From Table 6 it can be observed that out of 96 student respondents the majority of students' media literacy skills are self-ranked average or good. Among the students of PUC media literacy skills are not considered too low.

Table 6: Rating on the media literacy skills

Option	Respondents (No.)	Percentage (%)
Excellent	2	2.1
Good	31	32.3
Average	61	63.5
Poor	2	2.1
Total	96	100.0

11.3 Use and application of media literacy

Media literacy is occupying the role of players in today's era of conversation among the youth where its vital role can be noticed in our daily life activities. The third part of the analysis discusses its use and application of media literacy among the undergraduate students of PUC both Arts and Science. Figure 4 shows that a majority of the respondents have stated that they prefer to use media at home.

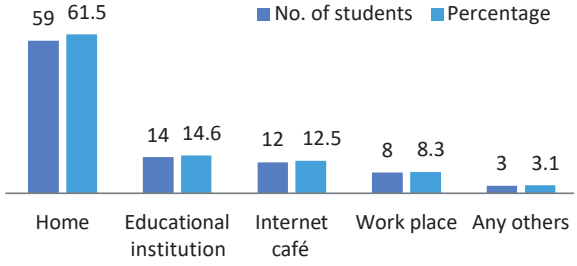


Figure 4: Students preference on location of media access

In Figure 5a frequency of access in a week is presented, where a majority of the respondents had access to social media around 6–7 days a week. Figure 5b shows the use of media platforms provided by the opinion of the student respondents about the duration of use of different media in a day and the time spent. This diagram shows that social media occupied first and most frequently access among the students. Social media plays the most important role in shaping the society and it is to be noted that the students' perception as per the survey had stated that they remain updated and aware about the recent information occurring across the globe because of which the opines they retrieve more information as compared to other print and electronic media. It is interesting to be noted that social media refers to use of internet-based form of communication, which allows the users to converse, share and create the web content while on the other hand electronic media can be stated as the use and applications of electronics means for assessing the content from web. This finding shows that during 24 hours in a day more than 4 hours is used for accessing social media.

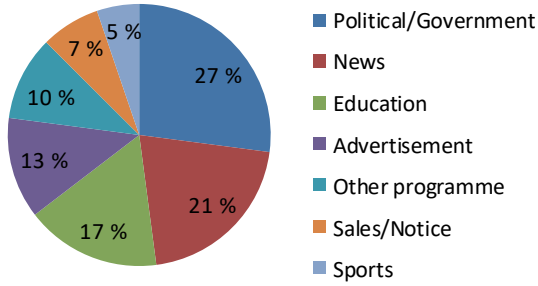


Figure 6: Graphical representation of media access on media programme

The graphical political/government programme are the most accessed programmes among the students, out of 96 respondents a total number of 26 (27 %) respondents accessed this programme (Figure 6).

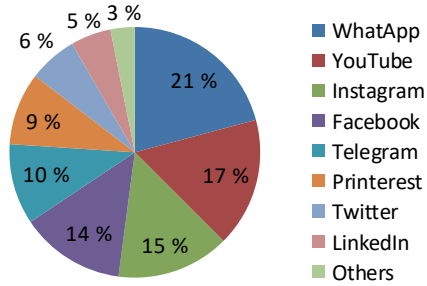
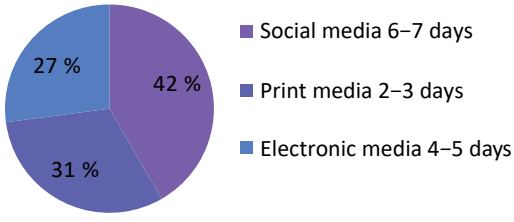


Figure 7: Most visited social media

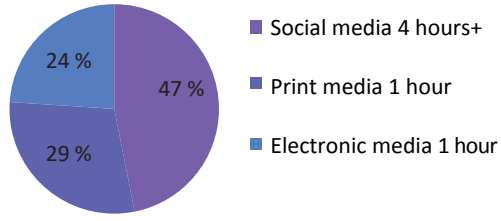
According to the student's preference on the most visited social media as reported in Figure 7, among the WhatsApp, YouTube and Instagram were the top 3 which are mostly visited by the undergraduate students of PUC.

11.4 Students' perception of media literacy

This part studied the students' perception of media literacy importance for the academic and personal development. For this study the question was designed in different categories exploring study parameters of media literate person, whether media literacy skills are helpful, study which media is convenient and helpful for learning and education.



a)



b)

Figure 5: Use of media platform: (a) weekly access, and (b) daily time spent

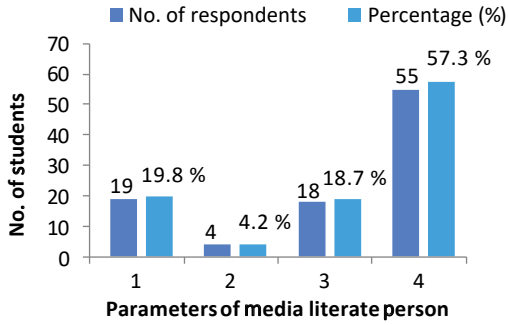


Figure 8: Parameters characteristic of media literate person: (1) dealing with information in different formats, (2) dealing with different information as it evolves, (3) knowing the information retrieval techniques, (4) identifying, locating, retrieving and using information

Figure 8 represents students' opinions on media literacy person. It was found that the majority of the students, i.e. 55, believed that media literate persons can be able to identify, locate, retrieve and use information and thus they can also deal with information retrieval techniques and others. Another 19 students believed that media literate person should be able to identify, locate, retrieve and use the information available in different formats. Further, 18 believed that media literate persons should know the information retrieval techniques whereas only 4 believed that media literate persons can deal with the various information evolves.

Figure 9 represent students' preference on types of media; a question was asked among the students whether they find various media convenient to access information and helpful for learning and educational purposes. From this study among these three types of media, social media was selected for the most convenient and helpful access. This study finds that social media occupied the most important place for students' educational development.

Table 7 reveals the students' opinion on the value of media literacy skills, in which a question was asked among the students whether they believe media literacy skills are helpful or not for their educational and personal development. Different options were given from strongly agree, to agree, strongly disagree or do not know. The study reveals that the students of PUC are much aware of media literacy skills and they also believe these skills are very helpful for their educational development.

Table 7: Students' perception that media literacy skills are beneficial

Option	Opinion	Respondents (No.)	Percentage (%)
1	Strongly agree	36	37.5
2	Agree	59	61.5
3	Disagree	–	0.0
4	Strongly disagree	–	0.0
5	Do not know	1	1.0
Total		96	100.0

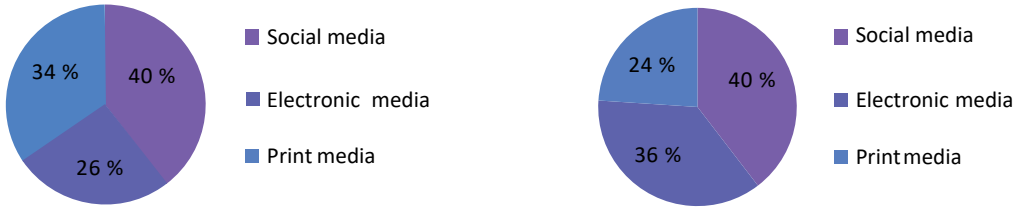
11.5 Satisfaction with seeking information

Satisfaction of seeking information on different types of media is becoming important for the students. Each student was asked a question if they were satisfied or not (Table 8).

Table 8: Satisfaction/dissatisfaction about the access to resources

Opinion	Respondents (No.)	Percentage (%)
Yes	57	59.4
No	9	9.4
Not sure	30	31.2
Total	96	100.0

Therefore, students were also asked which media they regularly visited for seeking information. The students' response about impact of electronic media on literacy awareness was also recorded as well as students' opinion on overall satisfaction and dissatisfaction with the access to print and digital resources. The dissatisfaction was due to lack of awareness of the possibilities offered by the institution and library.



a) *b)*

Figure 9: Access to media for learning and education: (a) convenient access to media, and (b) helpful media access

Table 9 reveals students' preference for media for seeking and accessing information. Question was split into five groups of types of media. It is to be mentioned that many of the students during the survey have intertwined perceptions with respect to the internet, social media and digital media. The research was conducted in this manner to assess the students' ability to identify and differentiate among the terms.

Table 9: Media for seeking information

Option	Types of media	Respondents (No.)	Percentage (%)
1	Internet	78	81.2
2	Social media	9	9.4
3	Digital media	5	5.2
4	Print media	2	2.1
5	TV, radio	2	2.1
Total		96	100.0

The results show that out of 96 students 78 students are using internet to do their assignments and thus most of the students are using it as a source of education. Internet and social networking made our life easier and quicker; now when it is impossible to attend regular courses due to some reasons, online programmes and courses are organised by the institution so that the students can attend courses and programmes while sitting at home and prepare their assignments and works using internet.

Table 10 indicates that electronic resources have different impact on students.

Table 10: Impact of electronic media on students

Option	Respondents (No.)	Percentage (%)
Positive impact	36	37.5
Negative impact	6	6.2
Both, positive and negative impact	54	56.3
Total	96	100.0

The analysis also reveals that there is a lot to do with the positive aspects of media literacy in the educational processes as it provides ample amount of opportunity to keep trends with the latest technological developments. Though there might have some negative impact on the educational perspective, it is less present there and carries a lot of positive qualities.

11.6 Strategies and mechanisms

In this part students were asked what type of strategies and mechanisms they adopted to face their media literacy seeking solutions for problems.

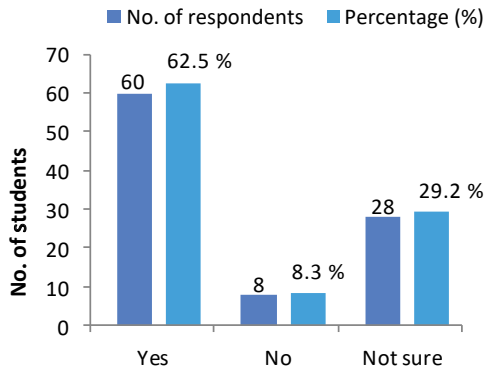


Figure 10: Needs of media literacy education in curriculum and syllabus

The students were asked whether there is a need for media literacy education as a part of the school curriculum and syllabus. Out of 96 respondents, 60 students responded media literacy is a required part of the school curriculum and syllabus whereas 8 of the respondents said that it is not. On the other hand, 28 respondents are not sure about the need for media literacy in their school curriculum and syllabus. Students' responses to this question reveal the need to include media literacy in school curriculum and syllabus.

Strategies and mechanisms are the basic requirements for understanding and developing the media literacy skills of students. Therefore some questions were asked on how the students to develop their media literacy skills (Table 11).

Table 11: Strategies and mechanisms

Option	Strategies	Respondents (No.)	Percentage (%)
1	Self-learning	30	31.3
2	Training programme	20	20.8
3	Seminars/workshops	18	18.8
4	Library induction programme	13	13.5
5	TV, radio	8	8.3
6	Lectures/demonstrations	5	5.2
7	Other programme	2	2.1
Total		96	100.0

Table 11 shows strategies and mechanisms that students preferred for developing media literacy skills. Self-learning has placed the highest rank, i.e. 30 respondents selected self-learning for their literacy skills improvement. Training programme place the second highest rank with 20 respondents who preferred to take part in training programme of media literacy skills, while 18 respondents suggested seminars/workshops to be organised in order to improve students' media literacy skills. Library induction programme was preferred

by 13 respondents; it shows that library plays a very important role in the academic and educational development. Further, 8 respondents selected education curriculum/syllabus, 5 preferred lectures/demonstrations strategies and 2 respondents choose a programme other than these 6 strategies and mechanisms. The overall result shows that from all participants, more than half of the students preferred some kind of self-learning.

Table 12: Areas of media literacy programmes

Option	Areas	Respondents (No.)	Percentage (%)
1	Use of electronic media, internet, social media for educational purposes	35	36.5
2	How to access electronic books/articles online, on internet, websites, etc.	28	29.2
3	Use and evaluation of media information	18	18.7
4	Retrieval/access of media information using search strategies	15	15.6
Total		96	100.0

A media literacy programme is very important to inform how to use effectively various types of media to the students. In this area, the study has focused on finding which area is best to conduct a media literacy programme for the students' literacy skills development. Students were asked to give their opinion on which area they felt to need to take part in a media literacy programme. The results are given in Table 12.

Conducting a media literacy programme among students has become one of the most important steps in media education and for this, the first step is to find out what problems can affect students learning literacy in education development. For this barrier, a question was asked to the students about what barriers they are facing in their media literacy development and analyse (Table 13).

Table 13: Barriers to media literacy programmes

Option	Barriers	Respondents (No.)	Percentage (%)
1	Lack of internet/Wi-Fi connection	35	36.5
2	Lack of infrastructure	22	22.9
3	Lack of awareness about literacy	15	15.6
4	Lack of ICT education	14	14.6
5	Technical difficulty	10	10.4
Total		96	100.0

This study discovered that many college students were facing some problems in building up their media literacy skills; those barriers were greatly affecting the effect of media literacy programme among the students.

12. Discussion, conclusion and recommendations

In recent years, the mass media, including the digital ones, has risen to prominence as one of the most essential communication channels for accessing a wide range of information, and a large number of people rely on it when seeking information. Media has gradually changed the way we live and learn, and it has become our primary cultural tool for finding, selecting, accumulating, storing, and transferring knowledge. The growth of mass media has both positive and harmful consequences for societies, particularly youths. Individuals in society are subjected to a barrage of messages from the media, and being media literate is critical to resolving these issues. As a result, it is very significant for individuals to achieve media literacy so that they can effectively use a variety of media and interpret and process a variety of media messages. For students at PUC, having the requisite media literacy competencies and knowledge, as well as receiving media literacy education is critical. In this context, activities such as seminars, conferences, lectures, and training programmes can be used to improve students' literacy knowledge, and it is critical to teach and assess students' knowledge and skills levels, as well as their opinions and readiness about media literacy while organising programmes.

Media literacy is important because of its beneficial and harmful effects on the young generation and society. It is important to understand and analyze its curial impact in both individual perspectives and society as a whole. The present world has become a global village and ICT world, where everyone can access the internet and can also communicate with each other via various social media. Literacy education also becomes important to the daily life of people activities. The librarians and library professionals are creating a bridge between library users and library sources, and services through social networking tools.

Media literacy and social networking are now the most potent tools available to students and the general public. To support their studies, daily activities, and future development, the majority of students use numerous media and social networking sites. The study has sketched out many findings about media literacy along with some constructive remedial for better development. The suggestion includes the incorporation of

media literacy education into school curricula and syllabi where the institution should reserve at least one period/class a week for the students and inform on the positive effect of using various media and the importance of media literacy for educational and academic purposes. Teachers and staff should have to explore their students' problems regarding media literacy and try to help them whenever they need it. The institution should build high and free bandwidth connections and build infrastructures like internet, computer, and other ICT facilities to enhance media literacy skills. The electronic and social media cannot fully satisfy the students' information needs. Therefore, teachers and library staff are needed to develop their teaching methods and library services and sources. Social media is the most popular social networking tool, surpassing both print and electronic media among PUC students and the institution should provide better and most updated media literacy education possible. There is a need for as much public awareness as possible so that people are aware of the need for media literacy. Programmes such as seminars, conferences, and orientation may be held by the institution and the library regarding the best use of electronic media, social media, and the internet for college students. This will assist students in developing and improving their media literacy skills. Media literacy should contribute for the betterment of mankind and make the world a good place to live in.

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TOPICALITIES

Edited by Markéta Držková

CONTENTS

News & more

Recent changes in ISO standards for graphic technology

This regular summary is focused on standards developed under the direct responsibility of ISO/TC 130 and brings an overview of the changes that have, or have not, taken place during the last year.

Based on the systematic review made every five years, six standards were reconfirmed and thus remain current, although published more than ten years ago. All deal either with printing inks or prepress data. Namely, they include ISO 2834-3:2008 Graphic technology – Laboratory preparation of test prints – Part 3: Screen printing inks, ISO 12040:1997 Graphic technology – Prints and printing inks – Assessment of light fastness using filtered xenon arc light, ISO 12640-4:2011 Graphic technology – Prepress digital data exchange – Part 4: Wide gamut display-referred standard colour image data [Adobe RGB (1998)/SCID], ISO 12642-1:2011 Graphic technology – Input data for characterization of four-colour process printing – Part 1: Initial data set, ISO 12644:1996 Graphic technology – Determination of rheological properties of paste inks and vehicles by the falling rod viscometer, and ISO 15930-1:2001 Graphic technology – Prepress digital data exchange – Use of PDF – Part 1: Complete exchange using CMYK data (PDF/X-1 and PDF/X-1a). The oldest one from this list, ISO 12644, was confirmed for the fifth time.

The more recent standards, which were confirmed for the first time, include ISO 12646:2015 Graphic technology – Displays for colour proofing – Characteristics, ISO 12647-7:2016 Graphic technology – Process control for the production of halftone colour separations, proof and production prints – Part 7: Proofing processes working directly from digital data, ISO 16762:2016 Graphic technology – Post-press – General requirements for transfer, handling and storage, ISO 17972-2:2016 Graphic technology – Colour data exchange format (CxF/X) – Part 2: Scanner target data (CxF/X-2), ISO 18620:2016 Graphic technology – Prepress data exchange – Tone adjustment curves exchange, ISO 19594:2017 Graphic technology – Test method for the determination of the binding strength for perfect-bound products – Page-pull test working upwards, and also two Technical Specification documents, ISO/TS 15311-2:2018 Graphic technology – Print quality requirements for printed matter – Part 2: Commercial print applications utilizing digital printing technologies, and ISO/TS 21830:2018 Image technology colour management – Black point compensation for n-colour ICC profiles.

In addition, two standards were confirmed, but soon the committee decided on their revision. For ISO 12641-1:2016 Graphic technology – Prepress digital data exchange – Colour targets for input scanner calibration – Part 1: Colour targets for input scanner calibration, the second edition is now in the draft stage. In the case of ISO 19445:2016 Graphic technology – Metadata for graphic arts workflow – XMP metadata for image and document proofing, the process was quick, and the second edition was published in 2022; see the next page.

Among more than 20 standards in different stages of development, a new project dealing with the evaluation of colour graininess was registered in September 2021 to be published as Part 22 within the ISO/TS 18621 series.

The 8th edition of the drupa Global Trends report

This series of reports that monitor key developments across the print industry was regularly published each year in spring from 2014 to 2020 and then had to be paused as a consequence of the COVID-19 pandemic. Now, after two and a half years, the 8th drupa Global Trends report was published at the end of this September. Due to the lack of opportunity to recruit panel members among visitors of the drupa fair, the number of printers and suppliers participating in the survey has noticeably decreased. The analysis is based on the answers of over 500 senior decision makers who completed the expanded online survey in spring 2022. The reliability of regional results for North America and Africa is low, and in the case of Australia/Oceania and the Middle East, the data sets were too small; however, overall, the report again brings valuable insight.

In spite of many significant and unexpected disruptions, the global net balance of economic confidence remained positive. That is also true when examining the expectations for the next year, but in this case, the European printers are considerably more cautious. The finding that stands out from the previous trends is the unprecedented number of printers raising prices in most regions and markets, and the result is similar among suppliers. When comparing the major printing technologies, the volume of commercial print produced by sheetfed offset strongly decreased, but it was almost compensated by a growth in packaging print, which also shows a clear growth for flexography. In addition, electrophotography gained a significant share increase in commercial print and publishing markets. The investments are planned to return to greater growth after the current slowdown.

Findings from a survey among book readers and listeners

The survey was commissioned by Stora Enso, the company that develops products and technologies based on wood and biomass and contributes to a wide range of innovations towards greater sustainability. The goal was to gain insight into the current state and outlook of the book market. The results, collected this spring and published in summer, are based on the answers of 2 400 respondents from the UK, France, Germany and the USA. The key findings include the positive effect of the COVID-19 pandemic on reading, with 63 % of respondents stating they read more, the strong position of physical books, which are preferred by 65 % of respondents compared to 21 % preferring e-books and 14 % preferring audiobooks, and the concerns for carbon footprint as 61 % of all respondents and 70 % of youth would accept a higher price of carbon neutral books.

The transformation of the Ghent Workgroup specifications

The new version, GWG 2022, is available from this March. It remains based on PDF 1.6 format and PDF/X-4 standard because PDF 2.0 and PDF/X-6 are not yet sufficiently implemented and used in the industry. The major novelty is the possibility of reducing false positives in preflight results. Also, the packaging variants of the specification now permit PDF files to contain information on processing steps compliant with the corresponding standard (ISO 19593-1), defining the concept of a 'Product Type' and identifying the appropriate processing steps for different product types. The most apparent change from previous specifications, released in 2015 and later, consists in their transformation into one Google Sheet document to facilitate improving the structure and consistency in the use of terms and definitions, further development, and tracking of the changes.

ISO 12640-3:2022
Graphic technology – Prepress digital data exchange
Part 3: CIELAB standard colour image data (CIELAB/SCID)

This standard provides a set of test images with a large colour gamut related to illuminant D50 and data encoded as 16-bit CIELAB, which can be used for evaluating changes in image quality during coding, processing, displaying and printing. In August 2022, the original version from 2007 was replaced by this second edition; it reflects minor changes in the related CIE publications, such as the International Lighting Vocabulary; see also JPMTR Vol. 9, No. 4 (2020).

ISO/TS 18621-11:2022
Graphic technology – Image quality evaluation methods for printed matter
Part 11: Colour gamut analysis

The first version from 2019, see JPMTR Vol. 9, No. 3 (2020), was replaced by this technically revised edition published this April. The changes include the correction of the equation for volume computation, the clarification of conformance requirements, and the selection of example gamut volumes.

ISO 19445:2022
Graphic technology – Metadata for graphic arts workflow – XMP metadata for image and document proofing

This version from June 2022 constitutes a minor revision of the first edition from 2016, see JPMTR Vol. 5, No. 3 (2016), with updated references.

ISO/TS 21328:2022
Graphic technology — Guidelines and recommendations for multicolour (CMYKOGV) print characterization

This new standard, available from August 2022, provides guidelines and specifies requirements for colour definition, data reporting and printing for the development of characterisation data for the multicolour process using CMYK + orange, green and violet, or CMYK plus any subset of the three added colours. Also, it recommends the ink pigment selections to produce an optimum colour gamut for specific printing processes or use cases.

ISO 24487-1:2021
Graphic technology — Processless lithographic plates
Part 1: Evaluation methods for characteristics and performance

This new standard defines test procedures and assessment methods for characteristics, on-press development performance, usability and print image quality of processless lithographic plates; plates for waterless lithography are out of scope. The standard was published in November 2021; since this September, its new version has been under development.

ISO 28178:2022
Graphic technology — Exchange format for colour and process control data using XML or ASCII text

This standard is focused primarily on the exchange of spectral, densitometric and colorimetric data. The second edition released this September replaced the version from 2009; it improves the specification of printing sequence, the use of delimiters and the plausibility of the sample ID usage.

Bookshelf

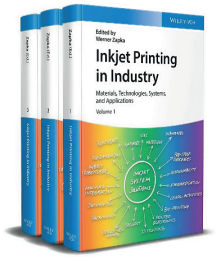
Inkjet Printing in Industry
Materials, Technologies, Systems, and Applications
3 Volumes

Gathering the knowledge and experience of many experts from different fields, three volumes of this new, extensive handbook cover a wide range of topics relevant to various applications of inkjet printing in the industry, from the basic considerations of the technology and materials to advanced processes and formulations, up to standardisation, legislation and licensing.

The first volume is organised into five parts and begins with the part introducing the content of individual chapters. Part II discusses wood-graining effects and reliable jetting performance, and the next one reviews the advantages and limitations of inkjet printing in comparison with other printing processes, especially screen printing. Part IV is dedicated to inks. It provides the fundamental background on inkjet ink formulations and details the monomers, oligomers, photoinitiators and formulations of UV-curable inkjet inks, including the inks for food packaging and label printing, as well as the inks and coatings cured by electron beam; further, it presents the dye-sublimation inks, ceramic inks, inks for security printing, conductive inks for digital-printed electronics, advanced formulations for optoelectronics and related applications, formulation of inks for regulated markets, the approaches to deinking and factors influencing deinkability. Part V brings an overview of printhead technologies from HP, Konica Minolta, Dimatix, Xaar, Seiko, Toshiba Tec, and Memjet.

The second volume also contains five parts. Part VI describes glass as well as paper and paper-based substrates for industrial inkjet applications together with their appropriate coating. Part VII deals with metrology, discussing the measurement of complex rheology and jettability of inkjet inks, inkjet droplet size, velocity, and angle of trajectory, the drop watcher technology and print quality analysis, measurement automation, print quality control, considerations for UV radiation measurement, and testing of printheads. Part VIII reviews different pre- and post-processes, including UV curing, priming for inkjet printing on textiles, UV lamps and UV-LED technology, the UV Direct Cure technology, electron-beam curing and processing, IR drying and processing, and photonic curing. Part IX describes software options for colour management and data handling, including the specifics of security printing. Part X presents several examples of machine integration.

In the third volume, four parts focus on printed electronics, the use of robotics, 3D printing and bioprinting, two parts describe selected case studies or examples and printing strategies, and the remaining four parts deal with the inkjet-related standards, regulatory requirements, ecological aspects and patents.



Editor: Werner Zapka

Publisher: Wiley-VCH
1st ed., August 2022
ISBN: 978-3-527-34780-3
1872 pages
Hardcover
Available also as an eBook

3D Imaging Technologies
Multidimensional Signal Processing and Deep Learning
Volume 1: Mathematical Approaches and Applications

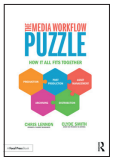
Editors: Lakhmi C. Jain, Roumen Kountchev, Junsheng Shi

Publisher: Springer
1st ed., October 2021
ISBN: 978-9811633904
360 pages, 165 images
Hardcover
Also as an eBook

This collection of selected papers presented at the 2nd International Conference on 3D Imaging Technologies – Multidimensional Signal Processing and Deep Learning (11–13 December 2020, Kunming, China) deals, for example, with digital camera spectral reconstruction, image recognition based on super-resolution nets, low-resolution image matching and recognition, digital watermarking, and 6D controller for mobile augmented reality. In addition, Volume 2: Methods, Algorithms and Applications is available and includes, among others, studies on spectral reflectance reconstruction and digital 3D representation of printing gamuts.

The Media Workflow Puzzle
How It All Fits Together

Editors: Clyde Smith, Chris Lennon

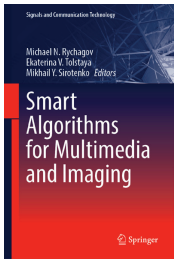


Publisher: Routledge
1st ed., March 2021
ISBN: 978-0815392897
272 pages
Hardcover
Also as an eBook

This book provides a comprehensive insight into evolving tools, processes and approaches used in electronic audiovisual media workflow, combining the technical information on resources and systems with practical advice, discussion of creative and quality aspects, future outlook, and also management and business context. It covers production, post-production, media assets and workflows management, distribution, archiving and preservation.

Smart Algorithms for Multimedia and Imaging

This book presents an overview of solutions developed by the contributors as a part of their industrial research in the field of multimedia processing, especially for imaging technology. Among five chapters dealing with image and video conversion, two explain different approaches for super-resolution, one based on multi-frames and the other on machine learning. Next two focus on 3D signal processing, namely the algorithms for estimating and controlling depth and semi-automatic 2D to 3D video conversion. The fifth chapter is dedicated to visually lossless colour compression technology. Three chapters on TV and display applications present the solutions for automatic video editing, real-time detection of sports broadcasts using video content analysis, and the generation and reproduction of natural effects. The following four chapters describe the use of machine learning and artificial intelligence in image classification provided as a service, mobile user profiling and two methods employed in magnetic resonance imaging – automatic view planning and dictionary-based compressed sensing. The last four chapters deal with algorithms for mobile devices, including a depth camera based on colour-coded aperture, an animated graphical abstract for an image, real-time video frame-rate conversion and iris recognition.



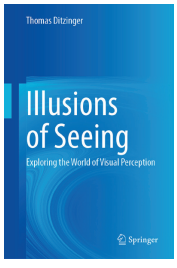
Editors: Michael N. Rychagov, Ekaterina V. Tolstaya, Mikhail Y. Sirotenko

Publisher: Springer
1st ed., May 2021
ISBN: 978-3-030-66740-5
447 pages, 278 images
Hardcover
Available also as an eBook

Illusions of Seeing
Exploring the World of Visual Perception

In this book, the author shares with readers his fascination with the human system of perception, in particular, colour vision. The content is organised into eight chapters. The first one provides the background on light, perception and the laws of seeing. The following chapters are dedicated to geometrical-optical illusions, perception of forms and brightness, ambiguous perception, colour vision, spatial perception, and perception of motion with illusions of movement. The eighth chapter illustrates the described phenomena with various examples from everyday life. The book demonstrates, among other things, many aspects worth considering or exploiting in graphic design and media production, such as why lighting conditions are essential for legibility and why the choice of colours is important for conveying the basic picture in the case of insufficient illumination.

Author: Thomas Ditzinger



Publisher: Springer
1st ed., July 2021
ISBN: 978-3-030-63634-0
291 pages, 243 images
Hardcover
Available also as an eBook

Prints as Agents of Global Exchange: 1500–1800

This collection of essays is part of the established scholarly series on Visual and Material Culture, 1300–1700. It explores the significance of printmaking in the early modern period in terms of the dissemination of prints beyond the borders of Europe shortly after the invention of the letterpress and considers the impact of spreading written and visual knowledge to the rest of the world mostly for conversion and didactic purposes with frequent modifications and meaning shifting in local conditions. The authors studied the influence on depicting the female body in Mughal paintings in India and the Ottoman sultan portraiture, the collection of Persianate calligraphies, drawings and paintings also containing two German engravings, the dissemination of Christian iconography to Armenia, the use and adaptations of the Jesuit printed materials in Japan, the evolution of the iconography of the Virgin of Guadalupe in Mexico City, the engravings of Indigenous culture adapted to Catholic education in New Spain, the use of auxiliary plastic models and prints in Italy, Spain and Peru, and the role of prints in the crafting of Mexican featherwork. While focused on specific cases, the contributions to this book also reveal broader trends.

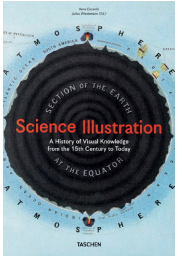
Editor: Heather Madar

Publisher: Amsterdam University Press
1st ed., November 2021
ISBN: 978-94-6298-790-6
322 pages
Hardcover
Available also as an eBook

Science Illustration
A History of Visual Knowledge from the 15th Century to Today

In large format, this book showcases illustrations of significant scientific discoveries from the early modern period to the present day, accompanied by textual information. The selection of about 300 discoveries presents the work of more than 700 scientists in various fields, which include geography, astronomy, physics, chemistry, and biology. In addition to graphics explaining new theories and inventions or detailing the subjects explored, from living matter to the universe, the illustrations in the book encompass statistical graphics visualising quantitative information and other graphical approaches to communicating information. The collection is organised chronologically into chapters from Copernicus's heliocentrism to Newton's law of gravitation, from Watt's steam engine to Lavoisier's synthesis of water, from Darwin's theory of evolution to Edison's light bulbs, and from Einstein's relativity theory to CERN's Large Hadron Collider.

Author: Anna Escardó
Editor: Julius Wiedemann



Publisher: Taschen
September 2021
Multilingual Edition: English, French, German
ISBN: 978-3-8365-7332-0
436 pages
Hardcover

The Contemporary Small Press
Making Publishing Visible

Editors: Georgina Colby, Kaja Marczewska, Leigh Wilson

Publisher:
Palgrave Macmillan
1st ed., January 2021
ISBN: 978-3030487836
298 pages, Hardcover
Also as an eBook

In this title, published in the New Directions in Book History series, the authors explore the effects of publishing on literary writing with the rise of small literary presses in the Anglo-American publishing industry since the economic crash 15 years ago, two historical small presses that influenced modernist aesthetics, differences in poetry collections design across three different publishers, material forms of the small press, its gentrification, the ethical and financial implications of its professionalisation, the praxis of self-publishing, reader communities, the role of women-led small presses in the inclusive youth literature movement, editorial choice-making, the importance of evaluative judgement, and the small press as a space for radical politics.

Visible Signs
An Introduction to Semiotics in the Visual Arts

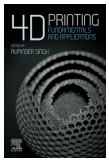
Author: David Crow

Publisher:
Bloomsbury Visual Arts
4th ed., August 2022
ISBN: 978-1350164932
192 pages, Softcover
Also as an eBook

The intention of this book is to help understand key concepts of semiotic theory, thus increasing the ability to analyse how visual communication works or why the message is biased. The fourth edition includes new illustrations, extended captions and updated exercises. In addition, it covers propaganda, emojis and other 'neutral' communication, as well as social media representation specifics.

4D Printing
Fundamentals and Applications

Editor: Rupinder Singh



Publisher: Elsevier
1st ed., January 2022
ISBN: 978-0128237250
194 pages
Softcover
Also as an eBook

Contributed solely by authors affiliated with universities and institutes in India, this book presents a selection of materials for 4D applications. These include different multi-material and hybrid-blended polylactic acid (PLA) composites, graphene-reinforced acrylonitrile butadiene styrene (ABS) and polyvinylidene fluoride (PVDF) composites, composite matrices combining ABS/PLA and high-impact polystyrene, PVDF with graphene and $BaTiO_3$, and PLA with ZnO. It also describes two-way programming of secondary recycled PLA composite matrix using a magnetic field, hydrothermal stimulus for 4D capabilities of composite based on PA6 polyamide with Al and Al_2O_3, and characterisation of rechargeable, flexible electrochemical energy storage device.

Recent Advances and Applications of Thermoset Resins

Author: Debdatta Ratna

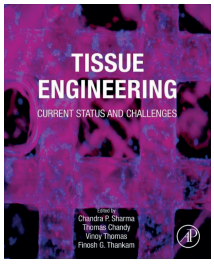
Publisher: Elsevier
2nd ed., February 2022
ISBN: 978-0323856645
612 pages
Softcover
Also as an eBook

This book is an extensive revision of the original edition, Handbook of Thermoset Resins. It covers the chemistry and applications of thermoset resins, their properties and processing, including 3D printing, toughened resins, composites and nanocomposites. Also, it deals with characterisation, performance evaluation and lifetime analysis of thermoset resins.

Tissue Engineering
Current Status and Challenges

This volume is contributed by almost 90 experts with different backgrounds to cover diverse aspects of tissue engineering and offer a global perspective on the developments in the field. The book intends to provide a reference from the fundamentals to the latest research advances and applications of tissue-engineered devices for clinical purposes. After introducing the basic concepts and historical evolution of tissue engineering and regenerative medicine, the editors organised the remaining 26 chapters of the content into six parts dealing with regenerative technologies, relevant aspects of stem cell research and technologies for nanomedicine, soft and hard tissue engineering, and also with regulatory guidelines, modelling and ethical issues in translational tissue engineering. Among others, the book reviews various applications of 3D scaffolding and printing, for example, to cell spheroids, bone and dental pulp tissue regeneration and engineering, muscle regeneration and skin tissue engineering, myocardial tissue engineering and heart valves, nerve tissue engineering and brain organoids, stem cell therapy, and organ printing, such as artificial liver and lung construct. Also, it presents suitable printing methods and materials, including innovations related to 4D printing, in-situ bioprinting, and more.

Editors: Chandra Sharma, Thomas Chandy, Vinoy Thomas, Finosh Thankam

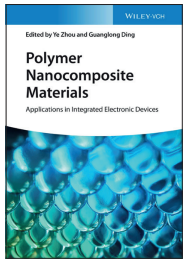


Publisher: Academic Press
1st ed., January 2022
ISBN: 978-0-12-824064-9
724 pages
Softcover
Available also as an eBook

Polymer Nanocomposite Materials
Applications in Integrated Electronic Devices

The first chapter of this concise book, reviewing the recent research on polymer nanocomposites, introduces the advantages of this rapidly developing group of materials, basic types of nanoscale fillers and properties of polymer nanocomposites, and methods for their synthesis. The following nine chapters focus on the fabrication of conductive polymer composites and their applications in various sensors, biodegradable polymer nanocomposites used in electronics, and polymer nanocomposites for specific types of devices and applications – namely photodetectors, pressure sensors, energy storage devices, triboelectric nanogenerators, resistive switching memory, temperature sensing and self-regulating heating devices, and electromagnetic interference shielding.

Editors: Ye Zhou, Guanglong Ding



Publisher: Wiley-VCH
1st ed., June 2021
ISBN: 978-3-527-34744-5
304 pages
Hardcover
Available also as an eBook

Bookshelf

Academic dissertations

Vat 3D Printable Materials and Post-3D Printing Procedures for the Development of Engineered Devices for the Biomedical Field

Doctoral thesis – Summary

Author:
Gustavo Adolfo Gonzalez Flores

Speciality field:
Material Science and Technology

Supervisors:
Fabrizio C. Pirri
Annalisa Chiappone
Ignazio Roppolo

Defended:
30 March 2021,
Politecnico di Torino, Department of Applied Science and Technology
Turin, Italy

Contact:
gustavo.gonzalez@polito.it

The concern of this thesis was to extend the range of biocompatible materials available for light-based 3D printing by developing custom-made photosensitive polymers and post-printing procedures modifying the surface of the 3D-printed parts to better meet the biomedical requirements and thus expand their applicability, especially in point-of-care testing. The approach facilitates the fabrication of more complex 3D microdevices with specific surface or bulk features.

Two chapters of the dissertation bring an overview of 3D printing fundamentals with a focus on photopolymerisation in general and biomedical vat 3D printing, especially towards the 3D-printed polymeric microfluidic devices, in particular. The experimental work is presented in three chapters. The first of them deals with the 3D printing of fluidic devices from custom-made, acrylate-based photocurable formulations and their appropriate post-printing treatment with the main objective to study and increase the cytocompatibility of 3D-printed transparent parts. The findings helped fabricate the bi-material fluidic chip by digital light processing in a single 3D printing step from two different photopolymers, one of them being acrylate–polydimethylsiloxane resin. The next chapter presents two methods for further enhancing surface properties through post-printing treatments. One makes use of the UV-induced bio-activation with selected functional groups linked by grafting polymerisation to the acrylate groups unreacted in the printing step, while the other one is based on the surface modification by microwave radiation, where both acrylate and epoxy moieties were exploited to link different amines to improve the antibacterial properties. The last experimental chapter is dedicated to tailoring optical features by adding the fluorescent dye commonly used for labelling biological units into the 3D-printable resins to increase the printing resolution and produce photoluminescent waveguides and light splitters, also applicable as solvent polarity sensors.

Further reading:
http://hdl.handle.net/11583/2897002
https://orcid.org/0000-0002-0501-9494

Ukrainian Ex-libris of the Late 1980s – 2010s: Traditions, Transformation, Latest Achievements

Doctoral thesis – Summary

Author:
Yuliya Vyacheslavivna Kamenetska

Speciality field:
Art History – Ukrainian Graphic Art of the XX and XXI Centuries

Supervisor:
Petro Volodymyrovych Nesterenko

Defended:
26 May 2021, National Academy of Fine Arts and Architecture
Kyiv, Ukraine

This thesis focused on a specific area of Ukrainian graphic art in the last three decades – the bookplates. The study systematically investigated different kinds of available sources, from the art and bibliophilic literature to private collections and exhibition catalogues, and considered various aspects, such as the incorporation of new graphic technologies, the influence of topical exhibitions as well as international contacts, and the representation of Ukrainian works in major foreign ex-libris collections. The resulting work brings a comprehensive account of the topic.

The first chapter presents the bookplate art as a subject of scientific study and documents the development and growing popularity of the Ukrainian ex-libris in the studied period. Further, it introduces the organisations of book lovers in Ukraine – from the Soviet era to the new stage after the Declaration of State Sovereignty of Ukraine – and their role in popularising

Language:
Ukrainian

Original title:
Український екслібрис кінця 1980-х – 2010-х: традиції, трансформація, новітні здобутки

Contact:
kamenecka.yliya@ukr.net

Further reading:
https://orcid.org/0000-0002-9172-8923

the bookplate, including the exhibition "Ex-libris – winners" that presented the achievements of Ukrainian bookplate artists of the 1980s to early 1990s. The chapter also discusses the source base of the era of independent Ukraine with its role in the study of modern ex-libris. The second chapter details the activities of the Ukrainian ex-libris club and the relevant publications and exhibitions, increasing the international awareness of Ukrainian bookplate art as well as creating opportunities for graphic art students. Its other sections bring the analysis of thematic facets and stylistic features of the modern bookplate, document the evolution of graphic concepts, various techniques and genres, and review the accomplishments of Ukrainian artists in the field of ex-libris, including the contributions of artistic families. The third chapter focuses on the materials demonstrating the international recognition of Ukrainian ex-libris, which is reflected in the successful participation of Ukrainian artists at dedicated international congresses, exhibitions and competitions, as well as in the representation of their works in collections of many museums in the world, including the largest and oldest one, the Frederikshavn Art Museum Exlibris Collection. Overall, the analysis of the works of the last 30 years reveals specific features of Ukrainian ex-libris and a growing expression of the national spirit.

Doctoral thesis – Summary

Author:
Mohammad Usman Waheed

Speciality field:
Design Engineering

Supervisors:
Connor Myant
Peter Childs

Degree conferral:
1 January 2022, Imperial College London, Dyson School of Design Engineering
London, United Kingdom

Contact:
u.waheed@imperial.ac.uk

Functional Mechanical Metamaterials: Development of Programmable Mechanical Structures

This thesis contributed to the research into engineering the materials that can form devices with desired functionality thanks to their appropriate, programmable mechanical behaviour. The work aimed to investigate the possibility of designing mechanical metamaterials computing Boolean logic, developing a mechanical metamaterial control system, integrating the mechanical metamaterial device into a larger morphological system, and achieving a multi-plane programmable behaviour. Such metamaterials could be beneficial in all industrial applications where electronic solutions can fail.

The dissertation provides the background on different types of mechanical metamaterials, namely the auxetic, origami and kirigami, multistable, topological, and combinatorial ones. For functional metamaterials, it discusses non-mechanical stimuli, mechanical metamaterials exhibiting Boolean logic, and selected industrial applications. Also, it presents the chosen manufacturing options, which included material jetting, stereolithography, and fused deposition modelling. The main part documents a step-by-step approach to accomplishing the objectives. It begins with the chapter describing the development of mechanical metamaterial logic. In particular, it discusses the concepts of mechanical Boolean logic gates, the theory of suitable bistable systems and their design, fabrication and applications in mechanical AND/OR and NOT logic gates, as well as the connected AND gates. The next chapter deals with the tunable bistable mechanical metamaterial control system, presenting its function and design with the corresponding analytical model and experimental setups for testing. The results were utilised in the successful development of combinatorial functional mechanisms. The corresponding chapter describes 3D mechanical metamaterials, a multi-plane bistable system, rod-logic mechanical metamaterial, and a mechanical metamaterial safety system. Finally, the work presents a case study comprising the design of a nuclear safety mechanism. The text explains the nuclear safety principles (isolation, incompatibility, inoperability, and independence) and the concept of unique signals. Then it compares the so-called pin-in-maze and counter meshing gears discriminating mechanisms, discusses their recent developments and presents the novel design using mechanical metamaterial.

Further reading:
DOI: 10.25560/95429

Events

ICPFE 2022
12th International Conference on Flexible and Printed Electronics

Seogwipo, South Korea
11–14 October 2022

This year's edition of this established international event, taking place in Eastern Asia, is jointly organised by the Korea Flexible & Printed Electronics Association and the Korea Flexible & Printed Electronics Society. On the first day, it offers tutorials in the areas of artificial intelligence, micro-rheology, organic transistors, printing and coating processes, display technology, and bioelectronics. For the next three days, the schedule combines plenary lectures and technical sessions in four parallel tracks. The former includes six presentations: 'Printed wearable electronics for human and robots' by Unyong Jeong, 'Skin-inspired organic electronics' by Zhenan Bao, 'Inkjet printing based technologies for displays' by Yeogeon Yoon, 'Printed electronics for advanced displays' by Kwon-Shik Park, 'The productization of IJP-OLED technology for large size display' by Xin Zhang, and 'Future display technologies with perovskite emitters' by Tae-Woo Lee. The contributions accepted for the latter cover the printed and molecular electronics, biosensors and bioelectronics, printing process and equipment, new technologies and applications, smart packaging, flexible electronics for soft bodies and robots, display technology, flexible electronic materials, 3D/4D printed electronics, energy storage devices and materials, and artificial intelligence for printing. In addition, the programme includes a poster session and an industrial session.

American Printing History Association's 47th Annual Conference

Los Angeles, California, USA
13–15 October 2022

The theme of the 2022 volume of this event is 'Making Artistic Noise: Printing and Social Activism from the 1960s to the Present'. The aim is to explore the printing and printmaking revolution in this period in different areas and from a variety of perspectives, which include printing history, alternative publishing, do-it-yourself printing techniques, graphic design, book arts education, community engagement, labour organising, feminism, Black studies, Chicano and Latino history, as well as sexual and gender minorities' activism. The invited speakers are Lincoln Cushing, sharing the findings from his research on the so-called 'Long 1960s', Marshall Weber surveying current progressive activist printmaking, and Staci Steinberger presenting activist graphics from the Los Angeles County Museum of Art and exploring how their authors employed the available means of production from newspaper broadsheets and screenprints to risographs and social media, with the corresponding exhibition being on view during the conference. The focus of panel discussions is on the legacy of self-help graphics, the role of booksellers in preserving the history of social movements, and engaging students in social activism through the social justice poster project. In addition, conference attendees can visit Rare Books LAX, an antiquarian book, ephemera, fine press, and map fair.

Smithers Events for Printing and Packaging

The events scheduled for the last months of this year are all planned to take place in person, in some cases with an option of virtual participation, and include the 2022 editions of Specialty Papers US in Milwaukee, Wisconsin (4–6 October), Pigment and Colour Science Forum co-located with TiO_2 World Summit in Amsterdam, Netherlands (5–6 October), SmartPack US in Chicago, Illinois (17–18 October), and Sustainability in Packaging Europe in Barcelona, Spain (1–4 November).

FTA's Fall Conference 2022

Covington, Kentucky, USA
11–13 October 2022

Like each year, the Flexographic Technical Association designed the programme of this event to share the best practices in the flexographic industry and introduce essential innovations, including the exhibition of solutions available in the market. The 2022 edition highlights the novel print calibration technique using tone curves to match an ICC profile, the need for new human capital strategies, and more.

NAPIM 2022
Fall Technical Conference

Oak Brook, Illinois, USA
18–20 October 2022

In 2022, this event held by the National Association of Printing Ink Manufacturers focuses, among others, on new growth opportunities, patents and trade secrets, new energy-curable digital ink raw materials, and new legislation and compliance standards.

PRINTING United Expo 2022

Las Vegas, Nevada, USA
19–21 October 2022

For this year's edition of this large event with hundreds of exhibitors, the PRINTING United Alliance announced a new feature – the Keynote Theater with a panel discussion of how to grow profitably in the present conditions and six speakers sharing their expertise in finding new opportunities in the commercial print sector, software-driven manufacturing of printed products, transforming the postal service, using sustainability as a competitive advantage, building workforce and a loyal customer base.

GRID 2022
11th International Symposium on Graphic Engineering and Design

Novi Sad, Serbia
3–5 November 2022

In 2022, this established bi-annual professional and scientific symposium, which covers a wide range of topics from content creation and design for a variety of applications to production, quality control and environmental considerations, keeps a hybrid format.

33rd International Publishers Congress

Jakarta, Indonesia
10–12 November 2022

The current volume of this event for the publishing industry is entitled 'Reading Matters – Embracing The Future' and held in a newly appointed UNESCO City of Literature. Its programme includes panel discussions on whether social media promote or suppress freedom of expression, what are the impacts of artificial intelligence on book piracy, what challenges arise when addressing climate change, and other essential topics.

IS&T Events

Advances in Printing Technology

https://www.imaging.org
11–12 & 25–26 October 2022

This year, instead of the Printing for Fabrication conference, the Society for Imaging Science and Technology organises this series of topical meetings in a virtual format. Students can attend for free and all participants can access the recordings until 28 February 2023. The first session is dedicated to innovative technology for digital printing, in particular, for inkjet, as highlighted in the keynote 'Inkjet technology innovation: optimization versus diversification' by Adam Strevens. Other topics include multi-material printing, electrohydrodynamic printing, the use of big data for inkjet printing optimisation, and the benefits of nozzle sensing. The two sessions at the end of October deal with the sustainability of essential printing, from photographs to advanced printed electronics, and life cycle assessment, featuring the keynotes 'Eliminate the idea of waste' by Eric Kawabata and 'Ecological challenges of décor printing' by Robert David.

CIC30 – 30th Color and Imaging Conference

Scottsdale, Arizona, USA
13–17 November 2022

For its anniversary edition, this event returns to an in-person format. The offer of the short courses and workshops includes three new options focused on quality and comfort assessment for immersive technologies, physics of organic light-emitting diodes and quantum dots, as well as their application in display systems, and colour calibration and colour rendition challenges for virtual production stages. The announced keynote speakers are Roland Fleming, presenting recent advances in the understanding of material appearance and surface perception, Erik Reinhard, arguing that colour science can and should contribute to sustainability, and Vien Cheung, discussing the state-of-the-art of facial recognition and the concerns associated with applications of this technology. The topics of technical lectures cover the contrast matching between different luminance levels, the perceptibility of colour differences between thin lines, the perception of the appearance of metal-like package printing, and many more.

IGAS 2022
International Graphic Arts Show

Tokyo, Japan
24–28 November 2022

Held after four years, this international exhibition of printing technology and solutions for pre-press, pre-media, printing, binding, paper processing, labels, packaging, and cross-media publishing again offers special features, which include live TV streaming, panel discussion sessions, innovative business zone with the small start area and the industrial printing area, and JPEX, the Japan Printing Exhibition showcasing prize-winning pieces of work from calendars, catalogues and bookbinding to packages, stickers and labels.

Journal of Print and Media Technology Research
A PEER-REVIEWED QUARTERLY

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Call for papers

The Journal of Print and Media Technology Research is a peer-reviewed periodical, published quarterly by iarigai, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries.

JPMTR is listed in Emerging Sources Citation Index, Scopus, DOAJ – Directory of Open Access Journals, Index Copernicus International, NSD – Norwegian Register for Scientific Journals, Series and Publishers.

Authors are invited to prepare and submit complete, previously unpublished and original works, which are not under review in any other journals and/or conferences.

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Journal of Print and Media Technology Research
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Vol. 11, 2022
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Methods: Describe in detail how the research was carried out (e.g. study area, data collection, criteria, origin of analyzed material, sample size, number of measurements, equipment, data analysis, statistical methods and software used). All factors that could have affected the results need to be considered. Make sure that you comply with the ethical standards, with respect to the environmental protection, other authors and their published works, etc.

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Discussion: Answer your research questions (stated at the end of the introduction) and compare your new results with published data, as objectively as possible. Discuss their limitations and highlight your main findings. At the end of Discussion or in a separate section, emphasize your major conclusions, pointing out scientific contribution and the practical significance of your study.

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3-2022

Journal of Print and Media Technology Research

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- Printing technology and related processes
- Premedia technology and processes
- Emerging media and future trends
- Social impacts

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