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ARTIFICIAL INTELLIGENCE IN PRINTING

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Abstract: *Artificial intelligence has entered into many aspects of our lives – from virtual assistants and Netflix's recommendations, to fraud prevention and autonomous vehicles. In this paper we present an overview of the current use of artificial intelligence in printing industry. We discuss what does it imply for printers and clients, and how it might be used in the future. Since the main idea behind creating artificial intelligence is to mimic the capabilities of human mind, it does not surprise the fact that in printing it is mostly use for monitoring and decision making. Smart algorithms for choosing different layouts in order to minimize print waste, automated process control, creating targeted catalogues, are just a few examples. Even though the printing industry is one of the few not so disrupted by AI, it seems that the things are changing, and we might expect to see more of AI in printing in the near future.*

Key words: artificial intelligence, printing, automated process control, inspection systems

1. ARTIFICIAL INTELLIGENCE AND ITS BRANCHES

Artificial intelligence (AI) is usually defined as a branch of computer science whose goal is to build smart systems, those that can perform tasks in the same manner as humans. From the psychological point of view human intelligence is not a single characteristic, but a combination of different abilities: learning, reasoning, problem solving, perception, and using language (Colom et al., 2010). Hence, the goals of artificial intelligence are to simulate those traits to higher or lesser extent, depending on the application. AI can be divided into many branches such as machine learning, natural language processing, expert systems, robotics, speech and vision processing (Chopra, 2012; Ip, 2017). Of interest for this work are machine learning and vision applications (image processing and machine vision).
Machine learning main focus is to use the data and algorithm in order to imitate the way humans are learning (IBM Cloud Education, 2020). To be regarded as intelligent, a system should be able to adapt to the environment, to learn from the example data or past experience (Alpaydin, 2020). Machine learning relies on the statistics in building mathematical models, so the goal is first to train the model and later to make it efficient on the new set of data. Many times, this term is used interchangeably with deep learning, while in fact deep learning is a subfield of machine learning (IBM Cloud Education, 2020; Alpaydin, 2020). The main difference between the two is that in deep learning the system does not depend so much on human intervention to learn, meaning that most of the feature extraction and processing is automated (IBM Cloud Education, 2020).
Machine vision is another interesting branch of AI where the goal is to make a system able to detect and understand the scene. Machine vision systems use camera to detect the scene and computer vision algorithms to process images and make conclusions and decisions based on the results. Industrial application of machine vision includes: positioning, identification, verification, measurement, flaw detection etc. (Teledyne, 2022). Object recognition is not only important in industrial application, but also in everyday lives (face recognition for example) and the whole process usually employs some deep learning model.

2. AI IN PRINTING

2.1 Checking files for printing

Before printing starts, it is essential to check files for any potential errors. Evaluation can include both visual and automated inspection, where latter is usually done by the preflight option/software, which can detect and correct the most common errors (RGB objects, missing bleed, ink coverage, transparency, spot colors etc.) (Enfocus, 2022).
Some issues, however, were not so easy to correct. One of the examples are files with low resolution images, or small images that should be printed in large formats. If the original was not available in higher resolution, and there was not enough information to resize the image properly, the only solution used to be image replacement.

Today we can rely on AI to solve this problem. The algorithm behind Gigapixel AI (Topaz Labs, 2022a) is able to upscale and enhance low resolution image by up to 600%. It is based on machine learning where algorithm was trained with millions of photographs, in order to reconstruct instead of interpolate information (Topaz Labs, 2022a). This makes it a perfect choice for preparing small images for printing. Figure 1a shows the result of resolution improvement in case when extreme pixelation is caused by compression, while Figure 1b demonstrates recovering details of a very blurred face.

(a) 

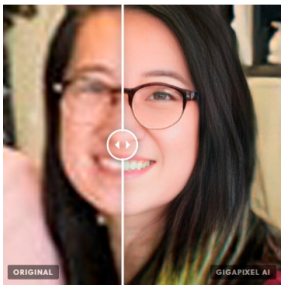
(b) 

Figure 1: Improving image resolution with Gigapixel AI – (a) correcting extreme pixelation, (b) recovering details and textures in low-resolution image (source: Topaz Labs, 2022a)

Topaz Photo AI, a new solution from the same company (Topaz Labs, 2022b), address not only the resolution problem but also noise, sharpness and focus. It assesses the image and automatically chose the right correction by first solving noise and sharpness, then performing face detection and enhancement in case there are faces in image and, at the end, increase the sharpness of the subjects in an image in order to create better visual focus (Topaz Labs, 2022b).
In addition to the abovementioned, AI can increase the list of things that can be evaluated in a print ready file. One of the most popular solutions are artwork proofing and proofreading. Artwork proofing uses so-called *visual inspection AI* where comparison between two documents is made. Either the print-ready or the step-and-repeat-file can be compared with the customer proof file (EyeC, 2022d; Vijau, 2021). Any difference is marked, alerting the operator. Similarly, proofreading systems that compares print ready document with various text sources are good solution for checking for any errors regarding text.
The biggest disadvantage of these systems is the necessity for the reference. In order to detect the flaw, system has to have an "ideal file" - approved artwork or the source text, which is not always the case. If the pre-press operator is preparing material for printing, the AI based solutions can be used to validate raw text data and correct any spelling or typographical errors. Some of these solutions can even correct the style and grammar, if that is what a customer would allow, of course. However, for artwork evaluation, if referent file is missing, still there is a need to rely on visual inspection done by a human operator, or some other software solution.

2.2. Process setup and quality control

Maintaining high print quality and consistency while increasing production speed and print runs is by no means an easy task for operators, and leaves no room for errors. It is essential to choose correct parameters for each printing process in order to ensure the best reproduction for chosen substrate-ink combination, as well as the fastest possible press setup. During the printing process, the errors should be spotted on time and the correction should be done as fast as possible. This is precisely why in print quality control there is a need for limiting human involvement, replacing the operator with a system that can detect errors and correct them on the fly.
If there are many parameters that had to be chosen before the print start, and that should be changed during the process, it is not easy for an operator to determine how each one of them influences the final result. Computers have no limit in that sense. AI algorithm can be fed with the huge number of parameters and the corresponding results, and can detect patterns that might not be obvious to a human.
Preset 2.0 implemented in Heidelberg Speedmaster presses is one of such examples (Heidelberg, 2022). Data from 600000 print jobs was used to train the algorithm which detect patterns, identify potential and generate basic settings for the press, autonomously and without human intervention (Heidelberg, 2022). Besides choosing the starting parameters, thanks to another AI solutions (namely Intellistart 3, Wash Assistant, Powder Assistant, and Color Assistant), the process is also controlled automatically (Heidelberg,

2022). During printing, the chosen initial setups and quality parameters are collected and evaluated, the patterns are found and learnt, and the results are used to optimize the production. Intelligent job changes are also possible, leading to the higher efficiency.
So-called *self-monitoring presses* enable adequate print setup entirely without human intervention. For example, Xerox iGen 5 is a press equipped with many sensors that send information to AI algorithm in order to automatically adjust the press (paper alignment, image quality and so on) for the best possible output (Pavlovic, 2018). Data about the press are sent back to manufacturer and analyzed in order to provide better performance, and to determine the necessity for software update or a service (Pavlovic, 2018). This personalized assessment provides longer lifespan of a press and more efficient production.
Besides color control, and other options mentioned previously, the quality control can be extended to many other parameters. It can be realized in the form of the inspection system, that can perform two tasks: identifying the error and changing printing parameters or compensating the defect when possible (CVisionLab, 2022; EyeC, 2022a). These systems can be incorporated offline and inline, where latter provide more efficiency. The system comprises of a camera and image analysis software that compares the original (digital master image) with the image of a printed page. Margins of errors are defined for every part of interest, following the preestablished tolerances for each printing process. The machine vision system can inspect the whole sheet or only the control stripe, make the adjustments where possible (ink setup for example) or informing the operator in case action is needed (EyeC, 2022a).
Inline systems can be implemented both of sheetfed and web presses and can detect color variations, missing inks, registration problems, streaks, misprint spots, hazing, doubling, hickeys, scratches and other errors that commonly occur in the process (EyeC, 2022a; EyeC, 2022b; IVS, 2022). Reproduction of text and artwork can also be assessed. Some systems can check the readability of printed text, verify pharmaceutical traceable text (EyeC, 2022a; IVS, 2022), assess content conformity with approved artwork and provide bar codes verification by evaluating contrast, defects, decodability, edges, reflectance etc. (CVisionLab, 2022).
Registration errors, as well as color variations, can be corrected automatically in case the manufacturer provide closed loop register control (Heidelberg, 2022; Pavlovic, 2018). The outcome is a waste reduction, faster setting up and running the press, as well as minimal involvement of press operator. As concluded by Heidelberg: "*When it comes to configuring intelligent job changes, ink profiles, washup programs, or other complex, dynamic parameters, an intelligent algorithm will always be more effective, more efficient, and faster than a human*." (Heidelberg, 2022)
Apart from the abovementioned, machine vision systems can also be employed to keep track of production aspects not directly related to printing. Cameras in conjunction to AI can monitor the environment and alert in case of safety rules violations, thus preventing the accidents. Under-utilized resources, uncontrolled access violation and other aspects related both to productivity and safety can also be controlled (Vijau, 2021).

2.3. Finishing inspection systems

Machine vision systems find their place in finishing inspection systems as well. They can be used to verify folding cartons, labels, leaflets, flexible packaging, multiple-page samples, or cylindrical packaging (EyeC, 2022c). The same errors as in printing can be assessed, as well as cracking, presence of saddle stiches, glue integrity on perfect bound products, coatings uniformity etc. (FSI, 2022).
Another interesting application is Braille inspection system (EyeC, 2022e) that assess the quality of embossing, content, layout and placement of Braille in accordance to relevant standard.

2.4. Workflow solutions

As computers can process huge amount of information, it is no wonder that AI solutions are also found in print production and workflow solutions. Hence, apart from software for quality control and process setup, there are more complex solutions integrating and automating each step of the printing process, from job submission, management, imposition, preflight, to printing, finishing, job accounting etc. (Xerox, 2022; Vijau, 2021).
In job submission, for example, smart software can monitor machine load and detect which press would be the best option for a current job (Xerox, 2022; Vijau, 2021). AI is also successfully used to quickly analyze different document layouts and determine the best option which would minimize the paper waste (Xerox, 2022). The automation provided by AI increase productivity and minimize errors, leading to the more efficient production.

2.5. AI in 3D Printing

Even though 3D printing is an additive manufacturing, and not printing in a classical sense, we will just briefly comment the application of AI in this important domain.
In 3D printing AI can be used for remote defect detection (Paraskevoudis, Karayannis & Koumoulos, 2020), to control the material flow (Brion & Pattinson, 2022), as well as for automating the workflow (AMFG, 2022). Software packages based on AI are also able to evaluate and optimize design files by implementing machine learning in generative design approach (Vasilev, 2022). 3D models are created and optimized based on user requirements, ending up with the most efficient solution for a given application. In this way, significant reduction both in design complexity and material usage can be achieved.
A neural network tool was also successfully used to propose entirely new material for 3D printing, such that satisfies requirements related to application, production and estimated costs (Conduit et al., 2019). By learning the properties of many different materials and the effect they have on the final product, the algorithm proposed new nickel-based alloy that is more suitable for a given application than any commercially available material.

2.6. Relationship with clients

Processing vast amount of information is also useful for personalizing printed products, as well as for direct mail and catalogues (Pavlovic, 2018). Adequate analysis of customer data allows creating mailings that better reflect customers' interests and needs, increasing the sense of connection with the company.
Better mutual connection can also be established through good communication. Failure to understand what customer wants can be costly to the company. Clearly determining the customer expectations is especially important today, when most of the "talking" is done via messengers.
Apart from chat bots, that are widely integrated in websites and mobile apps (Vijau, 2021), pre- and post-sales communication in printing sector can also be done via print bots. Pioneered by HP, print bots are essentially improved versions of chat bots offering the guidance through the whole process of print ordering. While chatbots assist customer by replying the questions, print bots are doing much more – they allow customer to upload photos, preview the chosen products (by creating a realistic mockup), make changes and ultimately send the file to the chosen printer or a printshop (Vijau, 2021; Zebra Instant, 2018). And all that without leaving the messaging app (Figure 2). Most of print bots are connected with print-on-demand companies that take care of order fulfilment (Zebra Instant, 2018).

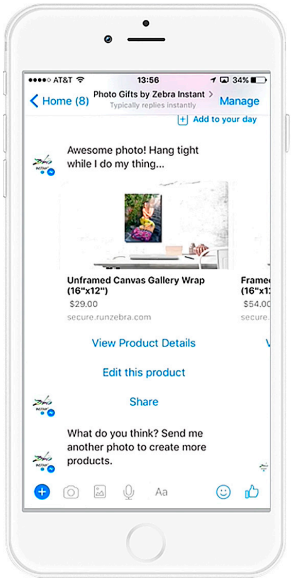


Figure 2: Zebra Instant print bot interface (source: Zebra Instant, 2018)

The potential of print bots in its early days was acknowledged by Facebook, that partnered with HP and included its print bot in beta version of Messenger in 2016. Even though this collaboration is now over, the potential of such solutions for quick ordering of printed products is undisputed.

3. CONCLUSION

Unlike other industries, up to now printing has been rather slow in adopting AI. However, things are changing, and we are seeing more of automatization, personalization and problem solving done by AI in this sector. From the inspection systems to print bots, AI solutions are gaining more importance, mostly due to their unpreceded speed and accuracy. With the burst of AI in all sectors, the prices are going down, so even the small print shops can benefit from it.
It is clear that the printing devices are evolving to leverage AI, IoT (internet of things) and cloud solutions. This will most certainly benefit users, but only if security and privacy issues are considered and addressed properly. Looking of the trajectory of a change, it is reasonable to assume that all the operations that can be, will be automated in the future. Increasing print speed and quality, while reducing waste and costs will still be a priority, as well as improving user experience.

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