

Development and Application of Multifunctional Three-Dimensional Printed Products (Postprint)

Authors: Machine learning is one of the core research areas of artificial intelligence. Traditional machine learning methods rely on manually designed feature extractors, which require substantial domain expertise. However, deep learning automatically learns hierarchical feature representations through end-to-end training, significantly reducing the complexity of feature engineering.

Specifically, deep neural networks consist of multiple layers of nonlinear transformations. For classification tasks, the final layer of the network typically employs a softmax function to output probability distributions:

$$p(y = j|\mathbf{x}) = \frac{\exp(\mathbf{w}_j^\top \mathbf{x})}{\sum_{k=1}^K \exp(\mathbf{w}_k^\top \mathbf{x})} \quad (1)$$

where K denotes the total number of classes. This formula is discussed in detail in the literature [?].

Despite the tremendous success of deep learning, its interpretability remains an open problem. As described in Section ??, existing methods can be mainly divided into two categories: post-hoc explanation methods and self-explanatory models. The former analyzes after model training is completed, while the latter incorporates interpretability constraints during the model design phase.

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Abstract

This study involves improvements in printing technology, specifically a novel printing process method that employs dampening solution to retain special substances—including plants, pharmaceuticals, luminescent agents, and color-changing agents—on printed materials, as exemplified by offset and flatbed printing machines. Through technological innovation, two-dimensional printed products are transformed into three-dimensional multifunctional printed products, conforming to contemporary trends and accommodating public aesthetic preferences. Individuals not only obtain visual sensory experiences but also gain additional olfactory enjoyment. Furthermore, the functionalities of mood regulation, physiological state modulation, and immune enhancement are strengthened, thereby elevating the cultural sophistication and economic value of printed

products and demonstrating significant potential for practical application and development. On June 29, 2016, a key achievement of this project, “A Printed Product with Special Functional Characteristics,” was awarded an invention patent certificate by the State Intellectual Property Office.

Full Text

Multifunctional Three-Dimensional Printed Products: Development and Application

Abstract: This paper addresses improvements in printing processes, specifically a novel method that uses dampening solution to retain special substances such as botanicals, medicinal agents, luminescent materials, and color-changing agents on printed products, exemplified by offset and flatbed printing. Through technological innovation, two-dimensional printed materials are transformed into three-dimensional multifunctional printed products, aligning with contemporary trends and catering to popular aesthetic preferences. While obtaining visual sensory experiences, people additionally gain olfactory enjoyment. Simultaneously, functions for regulating emotions, physiological states, and immunity are enhanced, elevating the cultural quality and economic value of printed products, which demonstrates substantial potential for practical application and development. On June 29, 2016, a key achievement of this research, “A Printed Product with Special Functional Characteristics,” was granted an invention patent certificate by the State Intellectual Property Office.

Keywords: dampening solution; special substances; printing process; health-care function

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2. Specific Implementation Plan

Printing is defined as the technological process of transferring graphic information from an original to a substrate using printing plates or other methods. Newspapers, magazines, books, and other printed products are the most common reading materials in people’s daily lives, and their quality directly affects physical and mental health. In recent years, to enhance readability and interest, new functional printed products have gradually emerged. According to public reports, media outlets such as *Nanjing Morning News* and *Luoyang Daily* have used fragrance inks to print scented newspapers in single issues, resulting in significant increases in circulation and advertising revenue, demonstrating that readers have a distinct preference for newspapers with special functions. However, due to the high cost of fragrance inks, no print media has yet implemented

continuous long-term publication.

Compared with existing conventional methods, the special substances are not mixed into the ink or sprayed onto the paper surface, but are instead added directly into the dampening solution. Water and ink are incompatible on the same plane, and the calligraphic principle of “preserving white while knowing black” provided the inventive inspiration.

Dampening solution is an indispensable chemical additive in the color printing process, forming a uniform water film on the non-image areas of the printing plate to resist ink infiltration from the image areas, maintaining good hydrophilicity in the blank portions of the paper, and ensuring ideal water-ink balance for optimal print quality. It typically consists of water, buffering agents, drying agents, fungicides, and other components at a concentration of 1% to 5% in water, generally not exceeding 10%, thereby regulating plate temperature, preventing machine overheating, and avoiding drastic changes in ink viscosity and tack that would affect printing.

1. Functions of New Functional Printed Products

Currently, new functional printed products are limited to fragrance printing. Common fragrance printing methods in the market include microcapsule ink printing, UV-curable fragrance agent printing, perfume spraying, and adding essences to ink and paper raw materials. These processes are prone to printing failures, affecting printing adaptability, or suffer from rapid perfume evaporation and high costs, failing to meet new social consumption demands for niche, diversified, and rapid production. It is imperative that printed products adapt to contemporary trends and innovate toward multifunctional aspects such as aesthetics and healthcare.

Fragrance printing is achieved through special scents, which are a type of odor. As an external characteristic of substances, odor is transmitted through molecular diffusion, with concentration inversely proportional to distance. Printed products such as newspapers, magazines, and books are in close proximity to people and used frequently. If special odors from plants and medicines can be retained on printed materials, they can exert subtle, gradual influences, allowing people to regulate emotions and health while enjoying spiritual culture, thereby improving physiological states and immune function—a win-win outcome.

Since 2010, the author has conducted years of repeated experiments at a printing company in Zhejiang, successfully developing “A Printed Product with Special Functional Characteristics,” which has received positive feedback. This functional printed product can adsorb special odors from plants and medicines onto printed materials for sustained volatilization, achieving healthcare effects.

The special substances added to the dampening solution include soluble medicinal components, fragrances, fluorescent powders, or color-changing agents, with medicinal and fragrance components having the highest practical application

value. These substances are compatible with dampening solution and can maximally retain special effects such as botanicals, medicines, luminescent agents, and color-changing agents on the final printed product for extended periods, with uniform printing density, minimal paper deformation, and improved appearance, quality, and reading effectiveness. While reading, these products can provide healthcare benefits or special effects—for example, fluorescent powder can assist reading in dark environments.

According to different needs and efficacy requirements, medicinal formulations are divided into several categories, including traditional Chinese medicine formulations primarily for improving vision, skin quality, and insomnia. The optimal mass ratio selected under the lowest cost conditions results in a neutral pH when Chinese medicine components are mixed, which does not affect printing with dampening solution and does not produce irritating odors at concentrations that could affect humans. The scent is released gently and can be maintained for approximately 30 days.

Natural fragrances can also be added to dampening solution without affecting the uniformity of printed products. Natural fragrances or synthetic fragrances with molecular weights of 50–200 are preferred; larger molecular weights result in lower volatility. Natural fragrances refer to aromatic materials derived from animal or plant sources, such as rose essential oil, jasmine concrete, civet, castoreum, and ambergris; synthetic fragrances include coumarin, nitrobenzene, and ionone. Preferred fragrance components include lemon essential oil and cinnamon essential oil. These components can be individually selected or mixed before addition to the dampening solution. Under minimal cost conditions, mixing several essential oils does not affect individual efficacy and can simultaneously exert multiple effects. The resulting printed product has a non-pungent odor within an acceptable concentration range for humans, with scent retention lasting 15–35 days.

Similarly, special substances added to dampening solution can also be water-soluble fluorescent powders or water-based reversible temperature-sensitive coatings. These materials do not affect pH changes, maintain neutral conditions, and reversible temperature-sensitive coatings return to normal color after temperature decreases, providing color-changing functionality under normal conditions and presenting special colors for identification when environmental changes occur.

3. Specific Operation Steps

The specific implementation method is as follows: First, plants and medicines are boiled into liquid form, then added to the dampening solution. To ensure uniform odor distribution and effective release on printed products, the following printing steps should be employed: (1) Prepare dampening solution in the water tank. (2) Supply water to the water fountain. (3) Transfer from water fountain to the fountain roller. (4) Transfer water from the fountain roller to

the rubber roller; simultaneously, ink is transferred from the ink roller to the rubber roller. (5) The rubber roller simultaneously transfers both water and ink to the printing plate. (6) The printing plate transfers to the blanket cylinder. (7) The blanket cylinder transfers to the paper. (8) Water and ink are printed simultaneously. The operation is simple, without needing to consider coating amount or powder spray coverage, can withstand greater printing pressure, has no special requirements for image tone or printing area size, does not affect printing adaptability, and is not prone to printing failures.

4. Principles to Master

Two principles should be mastered when preparing multifunctional dampening solution: First, the pH value cannot be too high. With weak acidity, the hydrophilic colloid layer is not easily formed, the surface tension of the dampening solution drops sharply, ink water content increases, leading to ink emulsification and severe dot gain, while the cleaning ability of the dampening solution also decreases. Second, the pH value cannot be too low, otherwise it affects the oxidation drying speed of the ink itself and exacerbates damage to the printing plate, corroding the grain structure of non-image areas and photosensitive materials of image areas, reducing plate durability and potentially destroying the coating on alkaline paper surfaces.

After adding special substances, a neutral pH is ideal for dampening solution, but in practice, different substances have varying acidity or alkalinity. Adjustments should be made according to actual conditions. Practice has demonstrated that for PS plates, the pH range of 4.5–5.8 for prepared dampening solution meets printing technical requirements. When special functional substances are added at the aforementioned quality levels, the resulting dampening solution provides stable printing, long plate life, excellent print quality, and easy water-ink balance control.

5. Beneficial Effects Produced

- (1) Transforms existing fragmented, irregular, and low-utilization fragrance printing into three-dimensional printed products, enhancing cultural quality and economic value. Particularly for cultural products such as newspapers and magazines with continuous publication, the cultural and economic value becomes exceptionally prominent, benefiting advertising rates, product pricing, and readership expansion.
- (2) Simple operation, economical and practical, with low production costs. Does not affect printing adaptability or cause printing failures, maximally retaining special effects of botanicals, medicines, luminescent agents, and color-changing agents on paper for extended periods, with uniform printing density, minimal paper deformation, and improved appearance, quality, and reading effectiveness.

- (3) Aligns with contemporary trends and popular aesthetic preferences, meeting new social consumption demands for diversification and rapid production. Expands printing process scope from single fragrance printing to multiple special domains including medicines, luminescent agents, and color-changing agents. While obtaining visual sensory experiences, people additionally gain olfactory enjoyment with appropriate scent intensity and longer retention, providing stronger functions for regulating emotions, physiological states, and immunity. Particularly when healthcare medicine-printed environmentally friendly, non-polluting newspapers are accidentally used for food packaging, they reduce the health safety risks commonly associated with ordinary newspapers.
- (4) Enhances local characteristics and printed product individuality, enabling rapid product transformation and upgrading with rich varieties adaptable to various printing press productions. Formulations can be adjusted and printed as needed, allowing short-term printing of new cultural products with special effects such as botanical and medicinal scents or luminescent and color-changing properties according to different regional characteristics and customer requirements (e.g., mosquito prevention in summer, flu prevention in winter, differences between healthcare publications and student reading materials).

6. Conclusion

In summary, although printing processes remain in traditional form, with era development and technological advancement, traditional process technologies used in production are subsequently being replaced, and production efficiency has significantly improved. Therefore, behind traditional printing with seemingly unchanged appearance lies concealed substantial technological innovation and complex process flows. The invention and application of new technologies inevitably create new demands for operation and control.

References [1] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China. *Printing Technology Terminology Part 1: Basic Terms* GB/T 9851.1-2008. China Standard Press, 2008.5.

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Note: Figure translations are in progress. See original paper for figures.

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