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PACKAGING DESIGN USING AI-GENERATED GRAPHICS AND INFRAREDESIGN® PROTECTION, EXECUTED BY DIGITAL PRINTING

DIZAJN AMBALAŽE S GRAFIKOM GENERIRANOM UMJETNOM INTELIGENCIJOM I INFRAREDESIGN® ZAŠTITOM, OTISNUT DIGITALNIM TISKOM

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SAŽETAK

U ovom radu istražena je mogućnost tiska ambalaže koja sadrži dvije slike od kojih je jedna generirana AI grafikom te sjedinjena s drugom slikom Infraredizajn metodom, a otisnute su na digitalnom tiskarskom stroju proizvođača Minolta tipa AccurioPrint C4065.

Praktični dio rada sastoji se od dizajna grafike pomoću umjetne inteligencije, grafičke pripreme tako generirane slike, ugradnje Infraredesign® zaštite te realizacije ambalaže digitalnim tiskarskim strojem Minolta tipa AccurioPrint C4065. Detaljno se prikazuje priprema i realizacija ambalaže s vizualnom AI-generiranom te infracrvenom slikom, zajedno otisnutima digitalnim tiskom. Time se daje dodana vrijednost suvremenim metodama dizajna i grafičke pripreme za manje serije luksuznih ambalažnih proizvoda. Atraktivnost, a ujedno sigurnost ovako koncipirane ambalaže koja je visoko zaštićena od mogućeg falsificiranja, ima primjenu u području farmaceutskih ambalažnih proizvoda kao i svih ekskluzivnih ambalažnih proizvoda koji se rade u manjim nakladama.

Ključne riječi: *dizajn, umjetna inteligencija (AI), Infraredesign®, grafička zaštita, digitalni tisak*

ABSTRACT

This paper examines the feasibility of printing packaging that incorporates two images: one generated by AI graphics and integrated with another image using the Infraredesign® method, produced on a Minolta AccurioPrint C4065 digital printing press.

The practical component of this work involves graphic design using artificial intelligence, graphic preparation of the generated image, integration of Infraredesign® protection, and the production of packaging on the Minolta AccurioPrint C4065 digital printing press. The process details the preparation and production of packaging featuring a visible AI-generated image and an infrared image printed simultaneously via digital printing. This approach adds value to contemporary design and graphic preparation methods for small runs of luxury packaging products. The attractiveness and security of such packaging, which is highly protected against potential counterfeiting, make it suitable for pharmaceutical packaging and all exclusive packaging products produced in limited editions.

Keywords: *design, Artificial Intelligence (AI), Infraredesign®, graphic protection, digital printing*

1. UVOD
1. INTRODUCTION

Recently, much has been discussed about the possibilities of design with the assistance of artificial intelligence (AI). Once a design concept clearly contains an idea [1], artificial intelligence can serve as one of the tools for creating an attractive graphic solution. This paper presents packaging designed in two spectral areas: visible and infrared. The image created for the visible spectrum offers a surreal graphic experience and was generated according to the designer's AI instructions, combined with the logo as a unique integrated image printed in a single pass on the Minolta AccurioPrint C4065 digital printing machine. The purpose of these tests is to demonstrate that a double image can be printed in one pass on a standard Minolta AccurioPrint C4065 device with minimal preparation and testing from the initial prints. When designing visually perceptible graphics, we used new AI capabilities to create surreal illustrations. The presented graphic was designed for the Printing and Design conference held in March 2025 in Zagreb. The conference symbol is embedded in two illustrations using the Infraredesign® (IRD) method [2], an original Croatian patent. This new and innovative method for packaging product protection is implemented in the graphic as an image invisible to the naked eye but visible with infrared cameras at 1000 nanometres [3]. The paper also presents and describes packaging printed on the Minolta AccurioPrint C4065 digital printing machine [4] that features Infraredesign® protection, i.e., a double image. Printing was carried out by the same process as if it contained only one visual image, meaning that the printing and finishing costs remain unchanged, and the infrared protection is maintained as if there were no such protections [5]. By combining two images – one generated by artificial intelligence according to the designer's instructions, and the other being the conference symbol visible in the infrared spectrum – an expanded communicative and protective graphic was achieved. The images are applied to a popcorn packaging sleeve and, after being digitally printed in a single pass, are cut on a Minolta cutter.

2. EKSPERIMENTALNI DIO
2. EXPERIMENTAL PART

In the research presented in this paper, a box was developed and tested containing a dual image: one visible to the naked eye and the other hidden. The visible image shows the motif of Gutenberg, while the dragon is revealed only by an infrared camera. This demonstrates how theoretical concepts can be transformed into concrete, functional, and commercial products. The task is to conceive, design, and produce packaging with a dual image using digital printing on a Minolta AccurioPrint C4065.

IR-active packaging enables camouflage in the infrared spectrum while remaining neutral in the visible spectrum. This represents a new application of Infraredesign® protection, implemented in the dragon graphic using AI, for the first time on the Minolta AccurioPrint C4065 printing machine – a high-production colour digital system that combines fast, high-quality printing with versatile media capabilities (up to 360 g/m², banner formats, covers, embossing) and professional finishing options. It is ideal for medium and smaller print centres, in-house reprographics, and corporate users. This next-generation printing machine was exhibited at the Minolta representation in Zagreb, where tests were conducted for this final work and for the Printing and Design 2025 conference, with the aim of achieving a double image – Infraredesign® – on this machine. The goal is to test the machine and contribute to research on the possibility of creating a packaging product in a real printing process without increasing production costs, while enabling the creation of a double image. This research can enhance the value of printing capabilities on the Minolta AccurioPrint C4065 device.

Infraredesign® is a modern design approach that enables the simultaneous display of two different images in the same physical location: one visible to the human eye (400–700 nm) and the other revealed exclusively in the infrared spectrum (700–1000 nm) using specialised infrared cameras and filters. Infraredesign®, which creates a double image on packaging, allows the integration of a hidden mark as information invisible to the naked eye but detectable only with an IR camera or filters. This provides an additional security layer

that complicates product counterfeiting [6] and is generally applicable to packaging for products sensitive to authenticity, such as pharmaceuticals [7], luxury cosmetics, and electronics. This approach maintains the existing brand identity and product aesthetics while simultaneously embedding sophisticated security elements. This method enables quick product authenticity verification at retail without requiring additional labels or electronic codes. In this way, a security layer is introduced that cannot be imitated by the end user, effectively preventing the distribution of counterfeit products.

The main objective of this paper is to examine the potential of packaging design that incorporates AI and a traditional symbol integrated by Infraredesign® and produced on the Minolta AccurioPrint C4065 digital printing machine. This paper presents tests carried out on the Minolta, described in detail from preparation through realisation and subsequent application of the packaging product. The tests and initial products were produced in the Minolta Centre test office in Zagreb on 28 February 2025, for popcorn packaging presented at the Printing and Design 2025 conference. The aim was to investigate the successful implementation of Infraredesign® on the digital printing system of this model. The test packaging was popcorn packaging distributed to students and conference participants at Printing and Design 2025, held at the Borongaj educational campus. The design contributes to packaging security for small series primarily used for high-value products in limited quantities, which are susceptible to counterfeiting.

Creating packaging with a double image, one visible only in the infrared (IR) spectrum, is an innovative process combining design and printing technology, resulting from scientific analysis of the dyes [8-13]. Such packaging has two functional levels: visible (V), perceived by the end user, and hidden (Z), revealed only through an infrared camera or specialised filters.

2.1. STEPS FOR CREATING THE INFRAREDESIGN® MODEL FOR POPCORN PACKAGING

1. Defining visual and infrared content

Visible image (V): Identify the main packaging design – logo, popcorn illustrations, brand colours, and nutritional information created with the assistance of artificial intelligence.

Hidden IR image (Z): Create an additional layer, which may include a logo, promotional message, symbol, or design element.

2. Preparation of colour twins

Use pairs of dyes (so-called twins) that appear identical in the visible spectrum (400–700 nm) but display different responses in the infrared spectrum (700–1000 nm). This allows two images (V and Z) to be printed in the same location without visible difference, while the infrared image is revealed only when viewed with an IR camera.

3. Digital processing and design separation – Infrared design

Use specialised colour separation software (CMYKIR) that enables two images to be printed in the same position. Implement the infrared layer as an additional channel (Z channel), often printed using black toner (K), with careful programming of the coverage percentage (e.g., 40% for optimal IR reflection). [12]

4. Integration with popcorn packaging design

Combine both layers (visible and infrared) within the same graphic layout. Ensure the infrared component does not interfere with the package's visible aesthetics; hidden elements should not be detectable to the naked eye. Adjust typography, illustrations, and background textures to support the concealed layer.

5. Implementation in the production process

After design approval, integrate it into the digital printing workflow (e.g., for popcorn series of different flavours or promotional packaging). Enable variable data in the IR layer, such as unique codes, messages, or slogans that can change for each packaging unit.

6. Final inspection and quality control

Ensure consistency in infrared image representation throughout the print run. Conduct both visual and IR inspections of packaging before shipment, ideally with automated cameras within the packaging line.

2.2. DESIGN OF THE VISUAL ASPECT OF THE PACKAGING USING AI.

The visual design features an image generated by artificial intelligence according to a specified brief. Themes include the printing press, Gutenberg, and the dragon as a symbol of power. The packaging design is a key element in communication between the product and the consumer. It serves not only as a means of brand recognition but also as a functional channel for information transfer and the creation of emotional impact.

Integration with infrared design:
If infrared design implementation is planned, the visual design must allow for spatial and tonal compatibility with the IR layer. Neutral areas must be provided where hidden content will be added without causing visual saturation. Tones and ink coverage (especially black pigment – K channel) must be precisely defined to enable correct image separation for the CMYKIR system.

The Z-image (hidden) must be aesthetically and thematically aligned with the visible part, although it should not be recognisable without instruments.

2.3. ADVANTAGES OF THE MINOLTA ACCURIOPRINT C4065 DIGITAL PRINTING PRESS FOR PACKAGING PRODUCTION

Digital printing presses allow package printing in very small series without the need for plate production. This makes them ideal for personalised products, promotional campaigns, and test runs. Brands can easily adapt packaging to specific markets, languages, or even individual consumers. Digital printing eliminates the setup time typical of conventional printing, significantly reducing the time from design to finished product. This enables a rapid response to market demand and changing trends.

The Minolta AccurioPrint C4065 digital press uses only as much toner as required, avoiding material residues and waste common in traditional methods. It is also widely used for on-demand production, reducing storage needs and minimising the disposal of obsolete packaging. Many models also use environmentally friendly toners.

2.4. INTEGRATION OF SECURITY AND INTELLIGENT ELEMENTS

As demonstrated in packaging applications, the Minolta AccurioPrint C4065 supports the implementation of hidden markings. An advantage of the digital press is its high level of automation, typically requiring only one operator. Software control solutions simplify colour management, registration, and quality assurance without the need for extensive staff training.

2.5. REDUCED COSTS FOR MULTIPLE DESIGNS

When multiple versions of the same package are required (different languages, images, flavours, etc.), digital printing allows easy file changes without extra costs, unlike analogue methods that require new plates for each version.

Packaging produced this way avoids high warehousing costs and reduces the risk of stock obsolescence, a common issue in industries with frequent design updates. Because it is digital, data can easily integrate smart tags, app links, augmented reality features, or user-interaction-based campaigns.

3. REZULTATI I DISKUSIJA
3. RESULTS AND DISCUSSION

3.1. SPECIFICS AND DETAILS IN TEST PACKAGING PRODUCTION

1. Precise separation of visual and infrared content

It is necessary to define in advance which design elements will be visible in the 400–700 nm spectrum and which will appear exclusively in the infrared range (700–1000 nm). During the software preparation stage, special CMYKIR channel separation is used. The infrared content is assigned to the Z channel, which is commonly

printed with black toner (K) due to its high absorbance in the NIR region [3].

2. Use of colour twins

Colour twins are pairs of inks that appear identical in the visible spectrum but exhibit completely different behaviour in the IR spectrum. Careful selection of colour components (especially C, M, Y) is required so that, in combination with K toner, they can either conceal or reveal parts of the image in the IR spectrum. The twins must satisfy $\Delta E < 3$ in the visible spectrum (imperceptible to the human eye) but show strong absorbance contrast at 1000 nm.

3. Optimisation of K toner

Hidden information is often produced exclusively with black pigment (K) and partial substitution of CMY components (the so-called GCR – Grey Component Replacement). For optimal IR response, K toner coverage should range between 20–60%, depending on the material and design. Excess coverage may expose the hidden elements in the visible spectrum.

The substrate should have low IR absorption to ensure the hidden image is clearly visible under IR cameras. The infrared image is designed with higher contrast and simpler forms, as IR cameras have lower sharpness and contrast compared to visible light perception, requiring precise raster control in the IR layer. Hidden messages are carefully aligned in size and position with the visual image to ensure accurate detection under IR sensors.

After completing the Infraredesign® graphic preparation, the print was tested using an IR camera and a professional forensic device (Projectina). Testing was performed at wavelengths between 850–1000 nm, with best visibility achieved above 900 nm.

The originality of this study lies in the successful implementation of test packaging designed with the assistance of artificial intelligence and integrated Infraredesign® protection, printed on the Minolta AccurioPrint C4065 digital press. The packaging contains a specially conceived infrared message, visible only at 1000 nm through an IR camera and embedded within an AI-generated visible image.

Both images must be carefully designed so that they do not visually interfere with each other, while maintaining full functionality within their respective spectral ranges. The key to achieving the dual-image effect is the so-called CMYKIR separation – a digital file preparation process for printing in which the roles of inks are defined. CMY inks form the primary visible image, while the K channel (black pigment) is used for the controlled addition of IR-active areas. Using a mathematical model, the Z value of each pixel is determined – a measure of infrared absorption at 1000 nm – defining where and how the Z image will appear in the infrared spectrum.

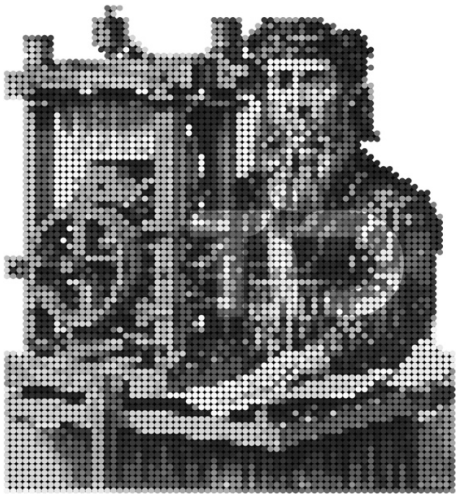
The adapted graphic file is then sent through the standard digital printing workflow. The only requirements are the use of precisely defined ink formulations and consistent control of toner density, especially in the K channel.

3.2. PRINT TESTING AND VERIFICATION

After printing, testing is carried out using an infrared camera – a "money detector" – to confirm that the hidden image is clearly visible in the IR spectrum. This phase validates the overall design and security effect.

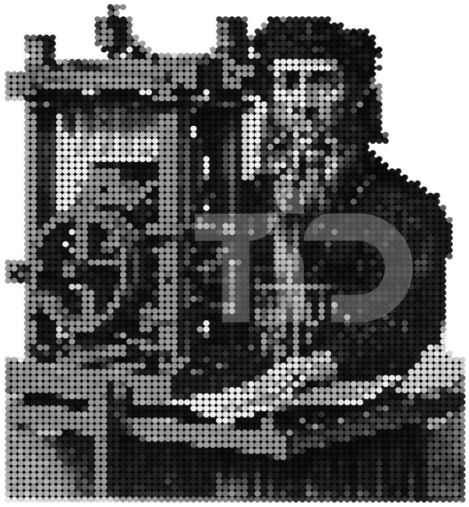
Slika 1 *Slika kutije ispisane na uređaju Minolta AccurioPrint C4065, koja prikazuje i vidljivu i infracrvenu sliku.*

Figure 1 *Image of a box printed on a Minolta AccurioPrint C4065, showing both a visible and an infrared image*



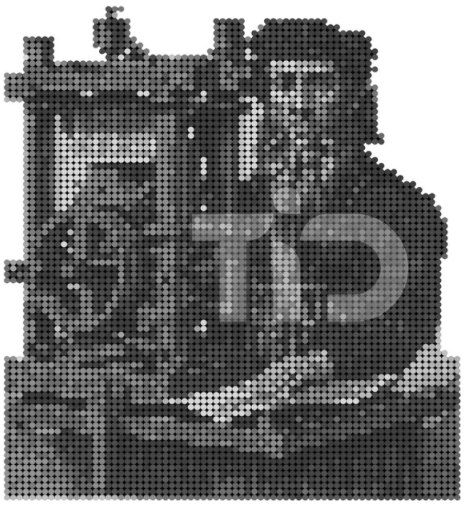
Slika 2 *Prikaz cyan separacije*

Figure 2 *Display of Cyan separation*



Slika 3 *Prikaz magenta separacije*

Figure 3 *Display of Magenta separation*



Slika 4 *Prikaz žute separacije*

Figure 4 *Display of Yellow separation*

Slika 5 *Prikaz crne separacije*

Figure 5 *Display of Black separation*

Slika 6 *Prikaz rezultata kutije za kokice u vizualnom i IR pogledu*

Figure 6 *Display of popcorn box, visual and IR view of the result*

4. ZAKLJUČAK
4. CONCLUSION

Graphics generated by artificial intelligence support Infraredesign® graphic protection and together represent a significant breakthrough in contemporary packaging design, combining aesthetic functionality and technological innovation in a unique, multilayered visual system. With this technology, packaging products gain added value– the possibility of hidden communication in the infrared spectrum, activated only with specialised devices. Thus, packaging becomes more than visual product protection; it

becomes an interactive medium, a security tool, and a platform for market differentiation.

By applying a double image– one generated by artificial intelligence and visible to the eye, the other hidden and containing a mark visible in the IR spectrum – this approach provides a new solution that enables product protection against counterfeiting, adds personalised information, with creates visual effects that surprise and engage the consumer. Infraredesign® technology is particularly effective in digital printing, allowing variability, flexibility, and rapid production without the need for additional material resources. The Minolta AccurioPrint C4065 digital printer supports precise colour control and enables accurate implementation of so-called colour twins– tones that appear identical to the eye but react differently to infrared light. All key aspects of Infraredesign® packaging production on the Minolta AccurioPrint C4065 have been analysed – from theoretical foundations and spectroscopy through design preparation and software separation to a concrete example of application on a popcorn packaging prototype. It is demonstrated how the infrared content can carry logos, messages, or security marks without compromising the core visual aesthetics. It is also emphasised that this technology is applicable to the Minolta AccurioPrint C4065 digital printing press, with the first Infraredesign® packaging produced in Zagreb in February 2025. The significance of this achievement is that, in a time of increasing need for authenticity, originality, and sustainability in products, Infraredesign® with AI-generated images offers a solution that meets functional, commercial, and aesthetic requirements and can be executed on new digital printers without special machine preparation or increased production costs. The overall contribution of combining AI-generated images and Infraredesign® is evident not only in counteracting forgery but also in developing interactive, intelligent packaging that communicates on multiple levels. The future of packaging design will undoubtedly include graphics produced by artificial intelligence – AI solutions that transcend visible boundaries, as Infraredesign® demonstrates.

Slika 7 *Usporedba i prikaz dviju proizvedenih ambalaža za kokice kamerom; ambalaža za Printing and Design Conference sadrži skrivenu infracrvenu sliku s natpisom „TID“, dok ambalaža za Student Cuts ne sadrži skrivenu sliku.*

Figure 7 *Comparison and camera viewing of two produced popcorn packages; the packaging for the Printing and Design Conference contains a hidden infrared image “TID”, while the packaging for Student Cuts does not contain a hidden image*

5. REFERENCE

5. REFERENCES

[1.] Gršić, J. Ž., Jurečić, D., Tepeš Golubić, L., & Žiljak, V. (2022). Hidden information in uniform design for visual and near-infrared spectrum and for inkjet printing of clothing on canvas to enhance urban security. Applied Sciences (Basel, Switzerland), 12(4), 2152. doi:10.3390/app12042152

[2.] Žiljak Stanimirović, I., Pap, K., Gršić, J. Ž. (2008). Infraredesign (p. 103). Zagreb, Fotosoft. ISBN 9789537064099

[3.] Jurečić, D., Žiljak Gršić, J., Bratić, D., & Plehati, S. (2022). Separating information on transparent polypropylene labels on packaging with dual properties for the visible spectrum and instrumental infrared observation. Polymers, 14(24), 5341. doi:10.3390/polym14245341

[4.] Konica Minolta. AccurioPrint C4065 – Brošura proizvoda. Available at: https://www.konicaminolta.eu (pristupljeno 1.7.2025.)

[5.] Denis Jurečić, Vilko Žiljak, Jana Žiljak Gršić, Ivan Rajković: Bliska infracrvena spektrografija bojila za ofsetni tisak s individualiziranim rasterima na ambalaži lijekova, Acta Graphica, 29 (4), 2020., 7–12.

[6.] Hrvatska pošta (2020). Filatelistička izdanja – Serija „Minerali". Zagreb: Hrvatska pošta, 2020.

[7.] Denis Jurečić, Diana Bratić, Suzana Pasanec Preprotić, Ana Marošević Dolovski, Krunoslav Hajdek: Infrared na ambalaži: element zaštite ili promocije proizvoda, Međunarodni znanstveni skup Tiskarstvo & dizajn 2021, 2021., 1–1.

[8.] Žiljak Stanimirović, I., Pap K., Žiljak Vujić J. (2009). Infrared Security Graphics, Zagreb, Fotosoft. ISBN 9789537064112

[9.] Žiljak Vujić J. (2010). Prednosti infraredesigna u grafičkom dizajnu i dizajnu vizualnog komuniciranja, Zbornik radova Tiskarstvo 2010, Žiljak V. (ur.) (pp 109 - 110), Stubičke toplice, veljača 2010., Zagreb. ISBN 978-953-7064-14-3

[10.] Žiljak Gršić, J., Žiljak Stanimirović, I., Međugorac, O. (2012). Hidden information in visual and infrared spectrum, Informatol. 45, 2012., 2, 96 - 102, ISSN 1330-0067

[11.] Žiljak Gršić, J. (2025). Infraredizajn kutije za kokice – studija primjene. Interna dokumentacija, Minolta Zagreb, 2025.

[12.] Plehati, S., Žiljak Gršić, J., Stanić Loknar, N. (2019). Rasprava i usporedba CMYKIR i stupnjevite GCR separacije boja i bojila. Polytechnic & Design, Vol. 7, No. 2, str. 132. DOI 10.19279/TVZ.PD.2019-7-2-06

[13.] EUIPO – European Union Intellectual Property Office (2019). Design and Security Printing Standards. Alicante: EUIPO, 2019.

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