pd.tvz.hr

POLYTECHNIC & DESIGN Vol. 5, No. 2, 2017.

Pregledni članak DOI: 10.19279/TVZ.PD.2017-5-2-05

HIDDEN NIR DUAL IMAGE TECHNOLOGY PRINTED ON THE FABRIC

TEHNOLOGIJA SAKRIVENE DVOJNE SLIKA OTISNUTE NA TKANINI

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Sažetak

Primjenom principa Infraredesigna® te osnova dvojnih boja na tkanini su otisnute dvostruke slike. Praktični dio razrađen je na pamučnom tkanju uz principe CMYKIR tehnologije, separacije kao i slaganja boja. Pri stvaranju testnog modela provelo se je usavršeno spektralno barijerno skeniranje za područje ultraljubičastog, vidljivog i bliskog infracrvenog dijela spektra.

Tako postavljena metoda vodi pomicanju djelokruga sigurnosnog otiskivanja kao i dvojnih informacija na niz mogućih tiskovnih podloga, kao i zaštićenih informacija na svili, pamuku, koži, poliesteru i srodnim materijalima primjenom dvojnih boja i dvostrukih informacija. Ta raznolikost mogućih korištenih podloga, varijacije kod kombinacija boja, te pokrivenosti površine omogućuju tehnolozima i dizajnerima široke mogućnosti različitih koncepta, kombinacija te primjene dostignutih saznanja. Tehnologija IRD se bazira na razvoju kao i stvaranju "dvojnih boja" čije su spektralne značajke za ovdje navedenu primjenu ovdje prikazane. Također su prikazani i neki dodatni alati za bolju vizualizaciju i slaganje dvojnih boja. Sve promatrane dvojne boje postižu iste spektralne značajke, prikazane kao Z domena iznad 900 nm, uz ΔZ razliku za "vidljive kao i NIR" boje.

Ključne riječi: *NIR tehnologija, CMYKIR separacija, dvostruka slika, dvojne boje, sakrivena slika*

Abstract

Dual images printed on fabric are achieved due to INFRAREDESIGN®, through twin colors basic. Tentative part is performed on cotton fabric through CMYKIR technology principles of separation and matching of colors. Sophisticated barrier scanning while procreating testing model, is performed for ultraviolet, visible and near infrared part of the spectrum.

This method leads to moving boundary scope of security printing and dual information to a variety of possible printing substrates and sheltered information to materials like silk, cotton, leather, polyester and similar by appliance of twin colors and dual information. These diversity of possible substrates, variations in dyes mixture combinations and coverages allows technologist and designers wide field of concepts, projects and acquirements. IRD technology is based on developing and forming "twin dyes", whose spectral characteristics for this appliance, some here are presented. Also some additional tools for better visual twins matching are introduced. All observed twins render same spectral characteristics designated as Z domain, beneath 900 nm area with ΔZ difference for "visual and NIR" dyes.

Keywords: *NIR technology, CMYKIR separation, dual image, twin colors, hidden image*

1. Uvod
1. *Introduction*

The term hiding information, "steganographic" [1, 2] encloses variety of actions and approaches of hiding some text, images, miniatures, painted out pictures, symbols or any method that could some information make invisible or unreachable to undesirable observer. Up to date procedures are often bond to forensic methods, while they can preserve variety of data about substrates, inks, structure or some other criterion.

As an example for a image-picture interest [3] can be focused to its oldness, materials, forgery, mending, or similar. According to its properties, IRD technology ensures "hiding technology" meaning a secondary image placed in NIR domain. [4]. Such image is stable and can be visualized by means of Z camera. In such situation human "visual experience" is broadened to NIR domain

Within IRD procedure acronyms are inducted: CMYKIR [5][6], what designates process colors cyan, magenta, yellow, black and infrared; VZ separation is acronym for visual and Z domain. Z designates NIR (near infrared) wavelength at 1000 nm [7]. That tagging is introduced because our ZRGB cameras and forensic camera Projektina (4500 /Ultra Forensic Technology inc. www. projec tina.ch/) record at 1000 nm IRD nature condition, and in our IRD graphics, infrared painting [8] and other appliances.

Implementation of secondary image in NIR domain, CMYKIR principles and separation, development and application lasts more than ten years [9] [10]. Symposium Printing and design that is under auspices on Center of graphic engineering at Croatian Academy of Engineering presents examination, prototypes and usage of IRD technology. Producing of "twin dyes" as a basic postulate for IRD technology is broadened with spectral analysis of ΔE and very important ΔZ criteria, that is helpful at critical situations quality determination of twin dyes.

2. Graphic reproduction in correlation to near infrared spectrum
2. *Grafička reprodukcija i korelacija sa bliskim infracrvenim spektrom*

Most of standard visualization systems and models cover "human visual area" covering approximately range from 380 to 760 nm. Graphic arts reproduction, separation and printing ability is also covering that area. According to nowadays opportunities, broadening the visualization area to NIR in not a complex task. CMYKIR technology covers domain up to 1000 nm. It ensures two images, one in visual (V) space and another Z image hidden and secured at 1000 nm in NIR domain (11). It must be stated that fulfilling knowledge for substrates, inks and other materials provides NIR technology of dual image implementation to a variety of fields and potentiate new projects.

3. Spectral absorption of observed dyes in visual and Z domain
3. *Spektralna absorpcija promatranih boja u vidljivom i Z području*

For IRD technology basic point of view is response of dyes and substrates in visual and Z domain. Physical and chemical properties of all applied materials and media are examined. Absorption/reflection properties of materials used make possible specificity of fulfilled visual experience. Various models for describing colors are used [12] . Standard methods are spectrophotometric/optical determinations from 250 nm (for UV control) to 1000nm. Most graphic arts (visual) reproduction procedures dyes and materials are defined and described by world wide accepted specifications [13]. There is already a variety of other (not in specifications or classifications) dyes, spot colors, pigments or other media, that can be used by various artists.

Aggravating occurrence exists in discrepancies in achieving surrounding of adjusting twin colors. It is considered that human vision with a low yield reaches till 760 nm, whereas separation filters (red) transparency overcomes 700 nm also. This points out that cyan color (red filter separation) protracts towards NIR domain.

Standard optical instruments often measure until 700 or 720 nm, what implies that ΔE does not fit entirely, what is crucial for visual estimation of twins. Standard instruments do not provide information of disjoining domain of twins spectral curves also, what is important for separation process.

4. Carbon black

4. *Karbon crna*

Standard graphic arts separation mixture procedure connotes situation of modulation some color intensity. Applying black according to achromatic principles subtractive process C M Y colors (dyes) could be reduced. Supplemental situation in graphic arts reproduction is when subtractive process dyes is added black, whereat reproduction is improved. Black ink [14][15] usually designated as "carbon black", that has high absorbance through entire visual, but also in NIR domain. Such black effects is neutral, "achromatic" from lowest to highest intensities[16]. This behavior is similar as complementary color acting for hues lightness adjusting at reproduction.

5. Chromatic process colors interchange on achromatic manner

5. *Izmjena kromatskih procesnih boja na akromatski način*

Graphic arts reproduction utilizes autotypic principles for color experience creating. This model involves basic subtractive dyes and a screening system. Color gamut is in correlation with printing media and materials used. Correspondence with graphic arts reproduction principles is further accomplished with three primary process inks/dyes C M Y channels, and additional black in adequate channel, while screening elements, angles and other parameters are according graphic arts rules adjusted. Achromatic principles are in most graphic image tuning applications incorporated [16] .

Such approach enables situation that a variety of color experiences can be achieved by mixing process primaries and black coverages, and further a possibility to get variety of mixture combinations for the same visual experience. This situation represents one of the postulates for twin colors (twins) creation, and that is necessity for dual images producing. Image correction applications often offer achromatic reduction option, but it is found out that for dual images this rate has to be defined in a dedicated way. Broadening knowledge about CMYKIR way of reproduction it is found that a fixed reduction rate for the whole image area is a more appropriate way of operating, and that principle is incorporated in basic CMYKIR separation module [17] [18]. That modification becalmed some visual deviations, whereat visibility and recognizing described in Z state (in NIR domain) is improved, as well programmed/reproduction properties of the applied printing technology [19] [20].

6. Managing colors and NIR domain specificities

6. *Upravljanje bojama i specifičnosti NIR područja*

Specifications of color managing are incorporated in most graphic arts image adjusting applications, with intention of improving reproduction of colors and images. Modules and procedures for image enhancing are common in graphic arts practice and assist for optimal reproduction conditions for selected reproduction process and materials used [21]. Definitions activate application tools for concerned situation of media, inks, and other relevant data for the printer that will be used. But this option covers only visual part. Applied CMYKIR module besides visual has to cover secondary image properties in NIR domain, depending to ink properties, which have to be determined. In visual domain twin pairs ("twins") have to be reproduced as much as similar, and produce the same visual output. Controlling and manipulation of entire twin environment through visual management appeared unacceptable, neither visual nor disjointing area and Z domain, what is very important.

Wavelength domain from 750 to 1000 nm can be split to extended (750-800 nm) and expanded area (800-1000 nm).

For better understanding discussion on NIR designing initial area is distinguishing one, important for differentiation in expanded area. Establishing and mixing inks combinations, in the first area spectral curves have no need to be very close. If that condition is fulfilled, area 900-1000 nm designated as Z domain identification and differentiation between two images is considered to be acceptable. This is important for secondary hidden image visibility. Differentiating ratio and visibility with Z camera [22] within presumed and/or fulfilled Z parameter. This is important for secondary image quality [23]. Such approach broadens cognition about usage and implementation of new materials and dyes [24] [25] and expands technologies, design and information sciences [26] [27]. All mentioned are new, undiscovered visualization fields [28] in fabric and other colorations [29][30].

7. Duality of reproduced colors and Z domain importance

7. *Dvojnost reproduciranih boja i značaj Z područja*

Duality in meaning of reproduced colors is crucial for acquiring dual images surrounding. CMYKIR separation in relation to "standard" graphic arts CMY+K separation in visual domain, has to make possible instrumental determination and visualization within NIR domain without influencing on visual primary image [30]. Standard graphic arts, irrespective of applying achromatic principles, provides materialization of colors in printing meaning, where the same color visual output can be achieved on various ways.

Colors achieved on such way by changing some printing parameters, e.g. coverage, are twin dyes. Technically, difference between such pairs, in visual, should be as small as possible, visually and instrumentally. Fig. 1 shows spectral curves for blue (1, V and Z), red (2, V and Z) and grey (3, V and Z), and yellowish substrate (4). Measurements are made by forensic instrument. All Z inks obtained the same absorption values of NIR light at 900 nm. V inks obtained also the same value at 900 nm, irrespective to their absorption in visual domain. Difference between V and Z inks is annotated as ΔZ value.

Blue pair renders spectral curves overlapping till 650 nm, and a meaningful absorption at about 700 nm. This is followed by curves disjointing, so after 800 nm difference between V and Z curves is distinct, and in Z domain defines absorption difference, expressed as ΔZ. This difference is responsible for quality separating of Z graphic. Red pair (2) has a absorption till 600 nm, with close curves overlapping. Differentiation also starts after 700 nm. Gray pair (3) displays a unifying flow with overlapping, with some more absorption in red area, due to yellowish absorption property of substrate. Substrate (yellowish canvas) shows some dominant absorption in blue (0,06), and unifying absorption (0,3) in other visual and Z domain.

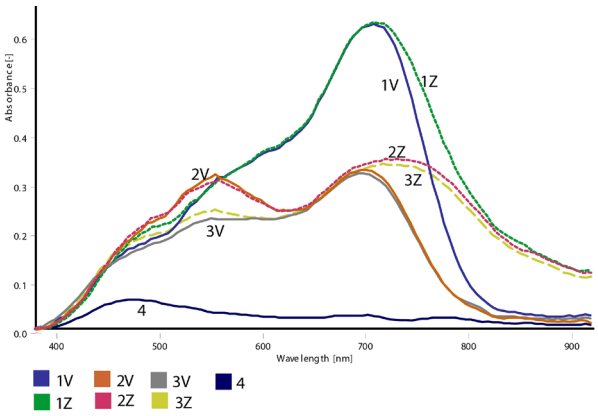

Figure 1 *Spectral curves of twin dyes*

Slika 1 *Spektralne krivulje dvojnih boja*

Coverage of (carbon) black is chosen to be K=40, as optimal value for the Z (NIR) part of twin pair, expressing equable absorption in visual and NIR domain. Transient area (700-800 nm) is significant, that leads to acceptable, and guides to acceptable ΔZ differentiation, so diversity of ΔZ readings

Basic combination twin pairs in this examination includes three color twin V and Z pairs: blue (1), red (2) gray (3). In visual there should not any difference between twins occur. In Z domain difference is determined with Z camera. ΔZ is expressed numerically as value of dual NIR image separation efficacy.

Table1: *colorimetric values and coverages of twins combinations*
Tablica 1: *kolorimetrijske vrijednosti i pokrivenosti kombinacija dvojnih boja*

ΔE76 (X0 / X40)	L*a*b (V)	Visual X0 C-M-Y %	NIR - Z -X40 experimental	NIR Z X40 regression.
Blue; 5,22	54, -18, -10	90, 48, 51	77, 2, 2, 40	77, 0, 0, 40
Red; 7,60	52, 18, -8	40, 86, 36	0, 68, 15, 40	7, 68, 16, 40
Gray; 1,52	64 4 7	43, 43, 46	12, 10, 10, 40	14, 7, 9, 40
substrate	89 0 8	Canvas, light yellowish		

8. Barrier scanning
8. *Skeniranje sa barijerama*

Images 2 and 3 are showing " input images" that will be applied in dual secured NIR technology. Detail of security clothes (masked-camouflage design) will be visual, fig 2, and graphic, fig. 3, will be Z secured dual image to be recognized/ scanned in NIR domain.

Masked design is scanned in scanned in 12 barriers from 245 nm to 1000nm, some presented on fig. 4-10. Video demonstration on www jana. ziljak.hr/anayat.swf

Pictures (fig. 2 and fig. 3 present prof. dr. R. Anayat handwriting) are initial stages that will be applied for this CMYKIR technology separation process. This dual pair is incorporated in color scheme of canvas.

According to used colors/dyes properties and its (eventual) non-foreseeable reflection/absorption behavior, barrier scanning from UV to NIR domain with a forensic scanner Projectina 45OO is performed.

Aim of all experimental X40 for proposed X0 involves equivalence of all spectrograms after 850 nm, fig.1. The major differences between V and Z inks (ΔZ) are at 850 nm. There are attempts to build a NIR filter for standard cameras just for this wavelength. This extreme difference can be observed by scanning with forensic scanner-instrument Projectina.

Another example is shown on fig. 10, "Two blouses". They have the same Z images, authors of design portraits: Ula, Jana, Lidija, Ana. Visually that are two different designs: vertical lines and monochrome green.

Figure 2 *Input visual image on fabric*
Slika 2 *Vizuelna slika tkanine*

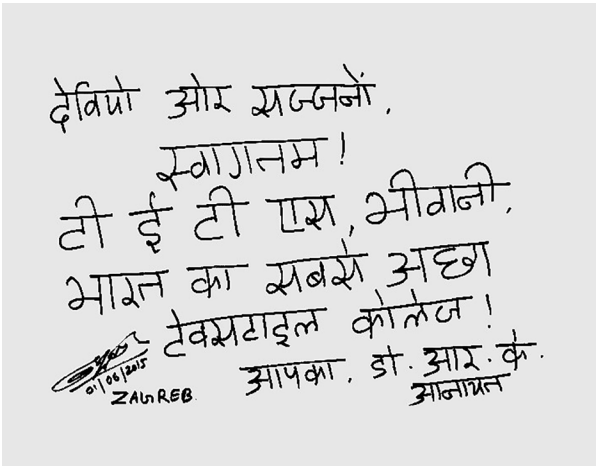

Figure 3 *Input Z graphic that will be hidden*
Slika 3 *Z grafike koja će biti sakrivena*

Figure 4 *Barrier at 254 nm (UV)*
Slika 4 *Barijera kod 254 nm(UV)*

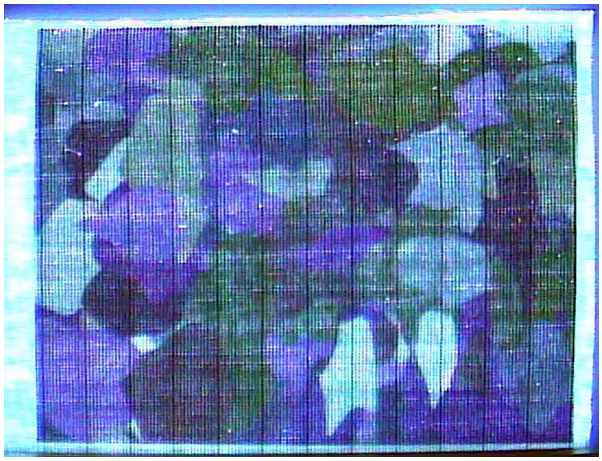

Figure 5 *Barrier at 365 nm (UV)*
Slika 5 *Barijera kod 365 nm (UV)*

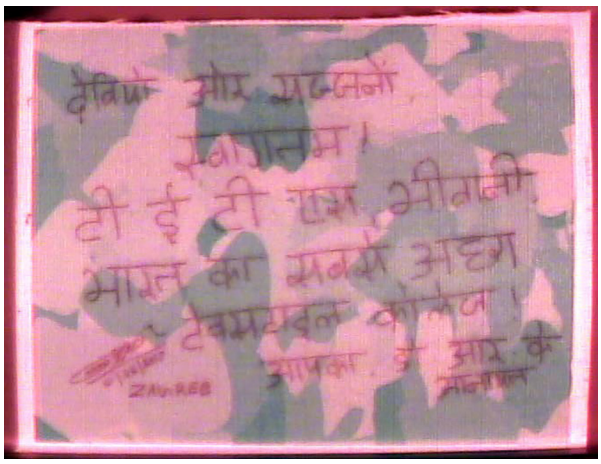

Figure 6 *Barrier at 570 nm*
Slika 6 *Barijera kod 570 nm*

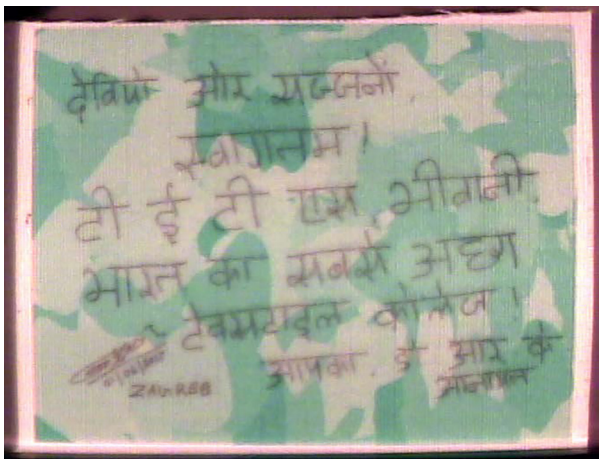

Figure 7 *Barrier at 645 nm*
Slika 7 *Barijera kod 645 nm*

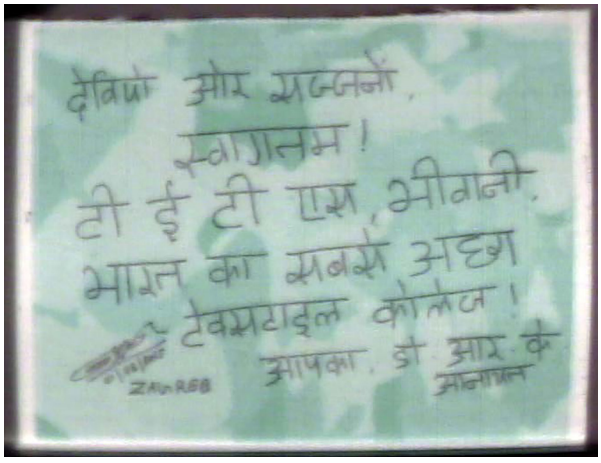

Figure 8 *Barrier at 715 nm*
Slika 8 *Barijera kod 715 nm*

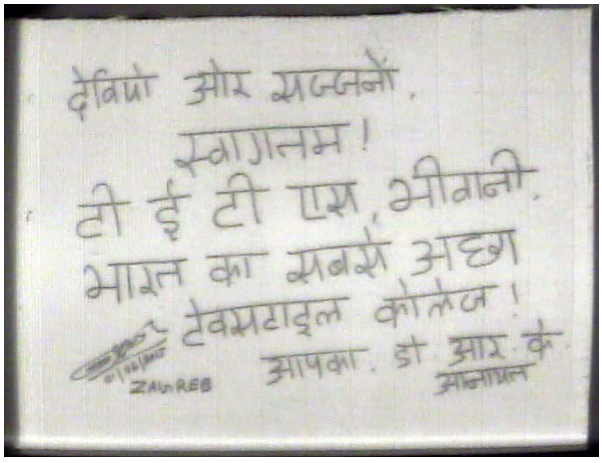

Figure 9 *Barrier at 1000 nm*
Slika 9 *Barijera kod 1000 nm*

9. Model of color matching through "cotton regression"

9. *Model usklađivanja boja uz "regresiju za pamuk"*

Regression model X40 (C40, M40, Y40, K=40) as dependence on X0 (C, M, Y, K=0) is derived for twin dyes calculated for real cotton fabric. All experimental data for deriving twin pairs are performed on yellowish fabric substrate. (fig 1) For real matters and appropriate dyes new dependence models X40 about X0 have to be performed. Proposition of autonomous variables is dependence of all process C40 M40 Y40 dyes on each C0 M0 Y0 on process dyes/inks at various positions of "zero separation". Fabric is printed on HP500 plotter, with its standard inks. Regression analysis relies on sixty experimental results of color twins. Four twins pairs (table 1) as input data for regression are displayed on fig 1. Continuous color tones on carbon black coverage 40% are presented as a model:40% are presented as a model:

C_{40} = - 0.176 * Y - 0.133*M + 1.380* C - 31.501
M_{40} = 0.0015* Y + 1.388 *M - 0.337* C - 37.650
Y_{40} = 1.060 * Y + 0.385*M - 0.351* C - 41.309

Coloration of fabrics is rendered according to regression values, while initial image (fig 2 and fig 10) X0 is set task as a large number of colors. All neutral tones for NIR view are rendered by linear extrapolation between range zero according to 40% coverage carbon black dye/ink. Till now about ten regression models for various printing procedures and materials are published with belonging parameters [31] [32] [33] [36]. Models include mutual conditions of process dyes, respecting their transparency, halvtoning elements shape, penetration on materials where visible and invisible image will be printed. Slightest mistake produces unpleasant result, as secondary image could "rise" to bear eye, while the only bounty criterion is hiding the secondary image.
Most IRD regression models consist of six autonomous variables with different mutual relations of X0 values [34] [35]. Reason is in dyes/inks with expressed saturation. That are colors consisting minor amount of at least one of three process dyes. Such extreme situation is sensitive in IRD technology, what claims GCR principles subtracting CMY dyes/inks with proposed intensity. Algorithms that raise CMY dyes with goal minimization of approaching to uniform gray are developed.

Figure 10 *Blouse design with infrared hidden graphic, visual left, Z image right*

Slika 10 *Dizajn bluze za infracrvenom skrivenom grafikom, vizuelna slika lijevo, Z grafika desno*

CMYKIR separation and natural saturation ensures liveliness of initial design of colors composition. This work also emphasizes controlled algorithm design, as a solution of ΔZ maximizing, respectively contrast differentiation of Z-NIR image.

10. Conclusions

10. *Zaključak*

Near INFRAREDESIGN® means two images, first in visual and second as a Z-NIR one. First image is visible at standard (human) viewing conditions, and second, hidden, is recognized and visualized instrumentally, by means of Z camera. Such hiding way enables creation of image, graphic, text hiding and securing information, creating Z graphic on canvas by means of digital or silk screen printing. That procedure is adaptable, and can be provided in various fields, enabling designers and technological applications including on camouflage clothing. Ink jet or silk screen printing uses inks/dyes very different in composition, chemical and physical properties, where dispersion, absorption, soaking and binding to substrate can depend on various mechanisms. Stabilization of dyes/inks on substrate may influence the entire printing process. For each printing procedure combination additional investigations are needed. Reproduction parameters from one surrounding cannot be directly applied to another printing environment

Two differentiated stages are possible, one for visual and another for near infrared domain. Independence of stages is ruled by CMYKIR separation module with process dyes. First image, visual, shows oneself as standard one, but secondary image as monochromatic is displayed in near infrared domain by means of Z camera. NIR information started as printed offset techniques, but they can be applied on various media such as leather, silk, canvas and similar.

Acknowledgement:
On respect that original work is issued in Croatian language,this work is broadened and translated to English native from the work Blisko infracrvena spektroskopija blizanaca bojila na tkanini, issued in the Annual 2016 of Croatian Academy of Engineering, Zagreb

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