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The development of novel smart packaging labels and mobile application for protection, information and identification of product shelf life

Authors

Stefan Đurđević, Dragoljub Novaković, Gojko Vladić, Nemanja Kašiković, Darko Avramović,

University of Novi Sad, Faculty of Technical Sciences, Graphic Engineering and Design, Novi Sad
e-mail: djurdjevic@uns.ac.rs

Abstract:

Use of mobile devices for the purpose of reading information from the packaging has already been present for some time. Today present applications that replace bar or QR code readers with a mobile camera interact with the database server successfully and transmit information about the product. This paper shows the conceptual solution for reading not only product information but also the condition of the product in terms of freshness, shelf-life and protection. The paper gives an overview of existing solutions of special inks that could be used in order to create smart labels, the algorithm for data reading through the camera of the mobile devices and mobile application. The aim is to set up a concept for the development of smart labels, from the standpoint of the materials and existing QR codes, but also to define the basis for the development of mobile application that can provide information on the state of the product in interaction with special inks.

Keywords:

smart packaging, intelligent packaging, special inks, application development

1. Introduction

The society has become increasingly complex today and the traditional packaging is no longer sufficient. Although it has contributed to the early development of the food and pharmaceutical distribution systems (Otles and Yalcin, 2008).

A modern quality and safety assurance system should prevent contamination through the monitoring, recording, and controlling of critical parameters during a product's entire life cycle, which includes the post-processing phase and extends over the time of use by the final consumer (Koutsoumanis, et al., 2005).

Intelligent packaging is packaging that in some way senses some of the properties of the product it encloses or the environment in which it is kept and can inform the manufacturer, retailer, and consumer of the state of these properties. Yam et al. (Yam, Takhistov and Miltz, 2005) describe a package is "intelligent" if it can track the product, sense the environment inside or outside the package, and communicate with the consumer. Such packaging systems contain devices that are capable of sensing and providing information about the functions and properties of the packaged products (Han, Ho and Rogrigue, 2005), and/or contain an external or internal indicator for the active product history and quality determination (Ohlsson and Bengtsson, 2002). These types of devices can be attached outside the package, and include time-temperature indicators and physical shock indicators or placed inside the package - placed in the headspace of the package or attached to the lid – for example, oxygen leak indicators, microbial indicators (Ahvenainen, 2003). The indicators also can increase the efficiency of information flow and effective communication between the product and the consumer. For example, special bar codes that store food product information such as use, and consumption date expiration. Product traceability, anti-theft, anti-counterfeiting, and tamperproof devices are also included in this category of packaging (Coles, McDowell and Kirwan, 2003). Today's intelligent packaging solutions for primary packaging are based on applying of small self-adhesive labels with irreversible changes of ink colour tone or shape, which reacts when the indicator suffers unfavourable changes in properties of the packaged products. Also, today many special codes with food product information are implemented (barcode, QR code, etc.). This paper presents a conceptual solution that combines: an informative function which contain QR or Barcodes, status control of product analysing parameters that affect the shelf life of products and protective function with using a mobile application.

2. Special Inks for Smart Label Printing

Different types of special inks that are already produced and whose implementation is most often associated with the processing of graphic products through special effects were considered during the development of smart labels (LCR Hallcrest, 2015). During the control of products quality and shelf life different parameters can be taken into consideration: time elapsed before using the product, temperature changes during storage, light exposure of the product, exposed to water, etc. The remainder of this section are examples of special colours that are beneficial for the development of novel smart packaging labels for protection, information and identification of product shelf life.

2.1. Fadable Inks

Fadable ink is able to disappear in a defined time period. The fading time is determined by the oxygen diffusion rate through the polyacrylate protective layer of ink and temperature. Different polyacrylates have different rate of air diffusion coefficient that is correlated with the glass transition temperature of polyacrylates. This time–temperature indicator can be easily fabricated for monitoring elapsed time and temperature.

Y. Galagan and W.-F. Su (Galagan and Su, 2008) developed a new fadable ink for novel new colorimetric time –temperature indicator. Reduced anthraquinone derivative was mixed with the polymer binder to obtain the ink. The binder is water soluble or water dispersible polymer. Water is a necessary component of the reduction process. They have used hydroxypropylcellulose as a binder that dissolves in water–alcohol mixture. The fadable ink should be kept in an oxygen-free environment. The fabrication of the device including printing and protective layer coating needs to be operated in the oxygen-free environment.

2.2. Termochromic Inks

Thermochromic inks or dyes are temperature sensitive compounds, developed in the 1970s, that temporarily change color with exposure to heat. These type of inks change colour gradually in response to fluctuations in temperatures. There are both irreversible and reversible types (LCR Hallcrest, 2015).

Reversible Inks can be heat or cold activated. Heat activated inks change from a coloured state at room temperature to a translucent colourless state when heated and can reveal messages or pictures beneath often used for „Touch & Reveal" or „Rub & Reveal" interactions. They revert to their coloured state on cooling (Figure 1).

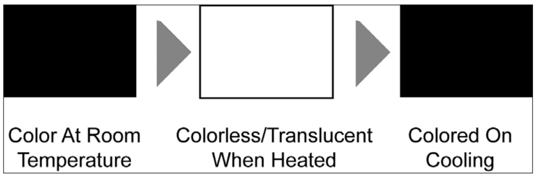

Figure 1 Heat activated reversible inks

Reversible cold activated inks (Figure 2) are colourless at room temperature and become coloured or reveal a message when chilled, becoming colourless again when warmed (LCR Hallcrest, 2015).

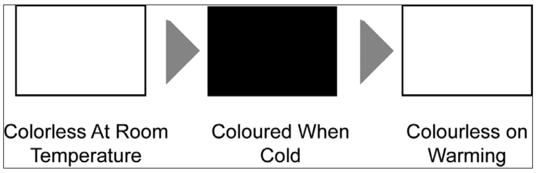

Figure 2 Cold activated reversible inks

Reversible inks are available in many colours such as Black, Red, Blue, Green, Orange and Magenta and in varying temperatures between -10 and 65°C. Producers of these inks hold a few standards. However, most products can be developed to customers' needs.

Uses of these products fall into three areas: cold, body and hot and are used to enhance labels, give warnings, the advice of correct consumption temperature, show proof of authenticity or simply act as an interactive game mechanism on cards and coasters. Figure 3 shows the example of thermochromic packaging. The red dot changed colour to show that the pizza was hot within the box. The idea was that on delivery the red dot would be showing (LCR Hallcrest, 2015).

Figure 3 Example of thermochromic packaging

Thermochromic Irreversibles are inks that change colour permanently when activated by increases in temperature from a colourless to a coloured state. The reaction is irreversible. These inks are often used to show permanent proof. They can be produced as screen or flexo printing inks (Figure 4) (LCR Hallcrest, 2015).

Figure 4 Thermochromic packaging which changes colour to show whether instore part baked bread has been baked

2.3. Photochromic Inks

Photochromic inks change colour when exposed to ultraviolet light usually from the sun or a black light. The inks are effectively colourless indoors and turn into vibrant colour outdoors (LCR Hallcrest, 2015).

When brought back inside, the inks become clear again. The inks become intensely colored after only 15 seconds in direct sunshine and return to clear after about 5 minutes indoors (Figure 5).

Figure 5 Photo chromatic colour tone change, after UV light exposure and moving away from the source of UV light

Photochromic inks have many features. When they are not exposed to UV Light, they are near invisible. These inks have fast reversible transition - Intense colour in 15 seconds returns to clear after 5 minutes indoors. Sixteen standard colours including process colours are available. They are washable without chlorine. These inks can be printed on paper substrates, textiles, glassware, ceramics, plastics, etc (LCR Hallcrest, 2015).

2.4. Hydrochromic Inks

Hydrochromic inks react to the presence of water. There are reversible and irreversible types of hydrochromic inks on the market. Irreversible can be produced in two types of ink. The first changes from a colour to white when exposed to water and remains so when dry again. The second dissolves and washes off the surface revealing a message below. These irreversible inks are usually available in Blue and Black (Figure 6) (LCR Hallcrest, 2015).

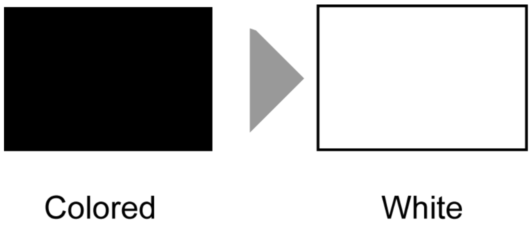

Figure 6 Colour tone change of Irreversible hydrochromic ink

Reversible ink is white in appearance but become translucent when exposed to water and then reverts to a white state when dry. This reversible ink is available only in white colour (Figure 7) (LCR Hallcrest, 2015).

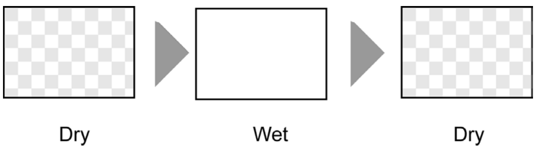

Figure 7 Prints made with Texilon ink on ORACAL 640 (77, 120 and 140 threads/cm)

These products can be used in applications revealing that a product has been exposed to water, such as a mobile phone, through to interactive game cards that reveal images or messages either reversible or permanently (Figure 8) (LCR Hallcrest, 2015).

Figure 8 Hydrochromic inks were used on an area of the packaging which when washed off revealed a win message to the consumer

3. Software for digital image processing of smart labels - MATLAB

Programming code on which will the mobile application for protection, information and identification of product shelf life will be based is Matlab. MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language.

Digital image processing is the use of computer algorithms to create, process, communicate, and display digital images. Digital image processing algorithms can be used to convert signals from an image sensor into digital images, improve clarity, and remove noise and other artefacts, extract the size, scale, or a number of objects in a scene, prepare images for display or printing, compress images for communication across a network.

Image analysis is the process of extracting meaningful information from images such as finding shapes, counting objects, identifying colors, or measuring object properties.

Image Processing Toolbox provides a comprehensive suite of reference-standard algorithms and visualization functions for image analysis tasks such as statistical analysis, feature extraction, and property measurement (The MathWorks, 2015).

One of the most powerful features of the Image Processing Toolbox is its transparent access to the MATLAB programming environment.

M-files in MATLAB can be scripts that simply execute a series of MATLAB statements, or they can be functions that can accept arguments and can produce one or more outputs. The focus of this section in on M-file functions. These functions extend the capabilities of both MATLAB and IPT to address specific, user-defined applications (Rafael, 2012).

4. Results

Based on the analysis of existing types of special inks and the possibilities of Matlab application, concept for novel smart packaging labels and mobile application for protection, information and identification of product shelf life have been formed.

Different products have different tolerance to temperature, weather or other conditions.

A new kind of smart labels are specialized for the certain product type. In the case of frozen products important parameters are critical temperature and elapsed storage time, while in the case of other example pharmaceutical products important parameter can be information about product contact with water. Part of the novel smart label is QR or other code systems for product identification, while the rest is a matrix with fields that are printed with different type of special inks (Figure 9).

4.1. Smart label Matrix

The smart label contains QR code used as the carrier of information about the product and matrix of special inks. The matrix of special inks is filled with referent and control fields depending on the product type (Figure 9). Different inks with different special effect, changeable with time and temperature, are used in the matrix. Mobile device camera records matrix and sends photography for analysing, as shown in the algorithm (Figure 10).

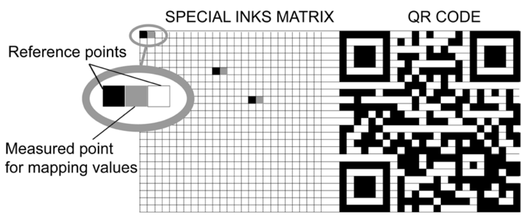

Figure 9 Elements layout of smart label for protection, information and identification of product shelf life

4.2. The measurement algorithm

The measurement algorithm begins with photographing of the label using a mobile device. Before making a photo, it is necessary to control focus and position of a camera during shooting. If the photo quality satisfies application requirements, the label is scanned, and position of QR code and matrix of special inks are determined. The information about the product contained in QR code is obtained. The corresponding function for analysis of the special inks matrix is applied. If the function coincides with the matrix of special inks, calibration via reference fields can be started. Otherwise, it is necessary to repeat the photographing the label. After calibration photo is recorded, digital image analysis and the program code for a previously defined type of product is applied. The code creates gradient scale between reference values for each special ink and its characteristics. Then the mapping is based on the critical values for the product type. The position of each referent field is projected on the scale. The values are translated based on the product type. Processed results are presented to the application user as the information about product usability and the remaining days until the expiration date (Figure 10).

4.3. Calibration

Calibration is performed by the reference field contained in the matrix. First, it is necessary to determine reference points (start and end) to define the exact gradient scale. This reduces the impacts of the environment and photo quality on the

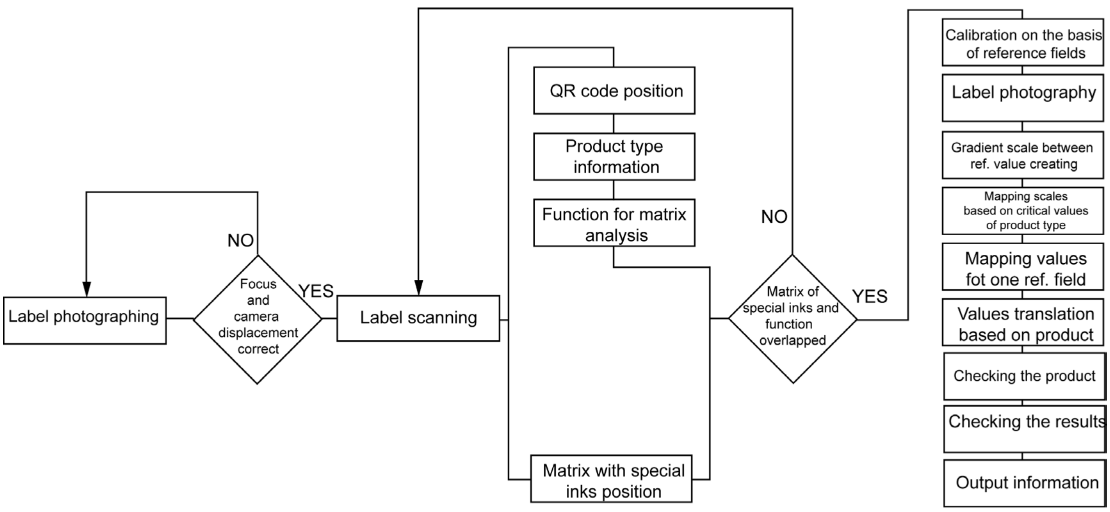

Figure 10 The algorithm for product state measurement using mobile application

measurement. Possible influences are:

- exterior lighting of the labels,
- additional lighting device (camera flash),
- print quality of indicators,
- the characteristics of the substrate on which labels are printed,
- the characteristics of the ink used as the indicator.

4.4. Gradient Scale

The gradient scale is based on the values of referent fields within the matrix of special inks. This ensures that general scale used for later mapping is dependent on the ink specification.

Considering that application uses the colour measurement of special inks that change from a transparent state to the opaque black, it is necessary to create a gradient scale with the transition between the substrate colour of label (white) and opaque black. (Figure 11)

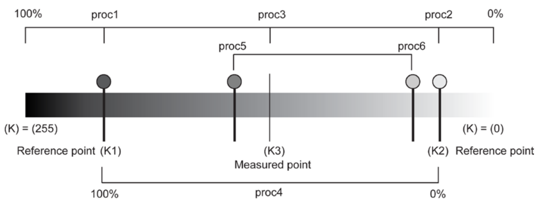

Figure 11 Gradient scale created with transition between substrate color of label (white) and full tone black

The scale is created between two reference points K1 and K2, whose values are obtained by image analysis. In the case of temperature changes control colour marked as proc1 may represent the highest temperature up to which the colour changes its characteristics. Proc2 is the substrate colour as measured and it represents initial temperature from which special ink starts to change its colour.

Product type obtained from QR code determines critical values (highest storing temperature), based on manufacturer's specifications. Based on the product, specific values proc5 and proc6 are defined and mapped on existing scale (proc1-proc2), as shown in Figure 11.

Proc3 value, representing the current color of the special ink field, is positioned between product defined acceptable values proc5 and proc6 (Figure 11). In case of time-sensitive inks this information can be further converted to the number of days remaining until the expiration date of the product. Temperature sensitive inks can provide "do not use the product" alarm, due to the non-permitted temperature changes.

After the analysis of each special ink field information about time, temperature or other conditions during storage can be obtained and presented as the meaningful instruction to the consumer increasing quality and shelf life of the product.

On the basis of the application the output information can be:

- The product is unusable
- Product expires in X days (X represents the number of days remaining)

5. Conclusion

Product freshness identification solutions with time-temperature indicator label significantly increase the price of the product. On the other hand application of special inks in smart packaging labels slightly increases the cost of producing packaging and they do not require contact with the product as TTI indicator do. To achieve interest and confidence of consumers, the concept of application for additional user interactivity with novel smart packaging labels have been proposed.

Special inks open up the exciting new research field and the possibility for novel ideas. The paper presents the basis for the development of mobile applications for about shelf life and condition of the product. This paper is the basis for the further development of the application. Further research will explore possibilities of linking QR code information and information about product condition using database system.

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