The Utilization of Camera Phone Technology in Publication and Packaging Applications

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Abstract: It has been predicted that about one billion mobile phones will be sold in the world in 2009 – and that 90% of these phones will be equipped with a digital camera. So the emerging camera phone technology will be in everyday use for most people in the near future and this development will offer great prospects for the services based on this technology. Two of the most potential application areas of this multi-billion dollar industry of the future are publication and packaging products, because these items are extensively used in everybody's everyday life.

There has been an increasing amount of projects both in publication and packaging at VTT, in which mobile phones with digital cameras have played a crucial role. In the publication area we have conducted several projects, in which we have for example developed and tested "print-to-internet" demonstrations enabling links from printed media to updated information.

The largest packaging area project is called SustainPack, which is "Innovation and Sustainable Development in the Fibre Based Packaging Value Chain". It has been said that SustainPack is the biggest and the most important packaging research project ever undertaken, with a budget of €36 m. The purpose of SustainPack is to establish fiber based packaging as the dominant player in the packaging area within a decade.

In this paper we describe the technologies and the operational environment, in which the new camera phone based applications are developed. We have for example built demonstrators where 2D bar codes can be utilized in information transfer, entertainment, anti-counterfeiting and logistics for printed products. We have also developed special inkjet printed quality indicators, which can be used for example in checking the freshness of food supplies.

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VTT's digital printing research

VTT has worked with digital printing technologies for a relatively long time. The first material test series were made in the end the 80s, and we have focused on various development projects in co-operation with material manufacturers and printer developers since the mid-90s. Our main focus in the digital printing area has been the inkjet, because we have always believed that it will be the dominant printing technology and an extremely important manufacturing technology in the future. The latest developments in the area and the rapid expansion of our research activities have proven that that our vision has been right.

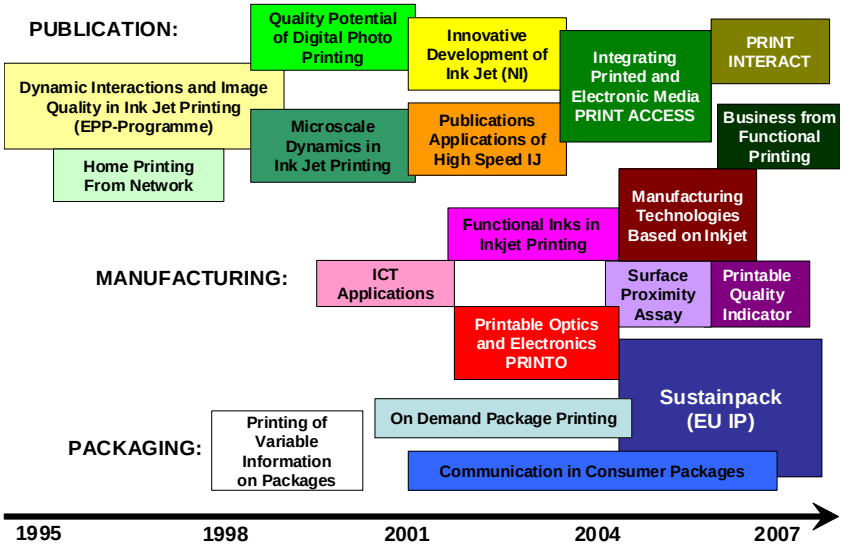

Figure 1. The short history of VTT's digital printing projects.

The short history of our digital printing research can be seen in Figure 1. Our first research focus in the area was to develop suitable publication paper grades for digital printing processes in co-operation with the Finnish paper industry. In order to do that, we developed new research methods based on high-speed camera technology, because we wanted to clarify dynamic interaction mechanisms between inkjet droplets and the printing surface. These are valid tools - in addition to our other state-of-the-art, industrial scale inkjet equipment - for the research, for example, of printed electronics and other digital manufacturing applications. Several test drives were also made in the high-speed inkjet printer manufacturer's plants in the USA as there were no printers available closer to Finland, because the high-speed color inkjet printing

technology was only under development at that time. Soon after this we became interested in network printing, the potential of digital photography and the publication applications of high-speed inkjet. More recently we have developed hybrid media solutions for publications, where the goal has been to find easy ways to gain access from printed products to electronic information – or even build interaction between a printed product and electronic systems.

Another crucial area since the late 90's has been the packaging applications. In the beginning we wanted to know how to add variable information on packages, but during the first project we understood the whole potential of the digital package production and we started to intensively lecture about on demand package printing or even package communication. At the current time our intelligent package contest continues in the SustainPack project, which is a huge European Union sponsored research project on "Innovation and Sustainable Development in the Fibre Based Packaging Value Chain".

The third important area of our inkjet work is the manufacturing applications of inkjet printing, what we nowadays call functional printing. This work started with printable electronics, but we have expanded it into other areas of manufacturing technologies. An intensive co-operation with the developers of new printers and materials is crucial in the area, so we have close relations with the industry. It also has to be envisioned that inkjet could be the first self-reproductive technology. This means that in the distant future inkjet printers could produce more inkjet printers.

Benefits of digital printing

So why use digital printing? We believe and have even proven in many cases that it is the key technology for flexible production and it also provides a strong tool for the value addition for publications and packages. Digital printing can also produce small and nowadays even larger quantities of printed products cheaper and faster than any other printing method. Different work phases can also be integrated, and the transportation and storage of semi-finished products can be avoided. Printing can also be decentralized and carried out in the locations where it is logistically most economical - and new operational and business models can thus be developed. In short, the main benefit of digital printing is that it opens up possibilities for new ways of marketing and creates logistical savings. VTT Information technology has carried out several multidisciplinary projects to screen the possibilities and technical solutions of new digital publication and package production chains.

Optical codes and RFID

The most commonly used linear bar code system is the Universal Product Code (UPC) which is one of the most successful standards ever developed. Originally

this code was meant to benefit the retail trade, but over the years its use has also become common among raw material producers, manufacturers, wholesalers, distribution companies and consumers. This code makes it possible to control many activities of product supply chains and to track and identify products all over the world. The downside of the UPC bar code is that it carries only a limited amount of information, usually only twelve characters. For this reason, the normal bar code cannot include real information. But it also has a link to a database where the information is stored.

A two-dimensional bar code can act as an independent database. In this case, information can be read wherever a suitable scanning device for the code can be found. The other benefits of two-dimensional bar codes are small physical size, scalability, large capacity of data storage and high data density, good correctness of information and high durability. Two-dimensional bar codes can be attached to packages by using stickers or printing them straight onto the packages by means of an ink jet printer.

Two-dimensional bar codes are usually used in the manufacturing sector, because more information, even over one thousand alphanumerical characters, can be included in the code. Every 2D code includes an independent database with total freedom of transportation. This is a great benefit compared to a landline network, because the information can be downloaded wherever the product is. Moreover, special encryption technologies can be used if the information is confidential. Multi-level confirmation technologies can also be added to the 2D bar codes to ensure that the code will be read right. We believe that, in the future, consumer-level electronic devices such as mobile camera phones will be used for scanning and converting 2D bar code data into readable format. In this way, a huge amount of information can be added to each printed product.

Another developing coding system is Radio Frequency Identification (RFID). This technology allows information loaded onto a tag to be transferred wirelessly and without optical contact between a tagged product and an electronic reader. RFID tags use radio antennas, which transmit information over a short range. Active tags include batteries so that they can actively send data over longer distances. Passive tags need power from the reader to be activated and to transmit data. The biggest benefit of electronic tags is that they make continuous identification, tracking and communication of products possible, when they are connected to a reader network. Compared to optical bar codes, RFID tags can carry much more information. The downside is that their price is much higher than the price of printed tags, so they can’t yet be used in applications, where price of the coding must be low, as is usually the case with publications and consumer packages.

Utilization of camera phone technology with 2D codes

Two-dimensional bar codes can be decoded by a reading device that has a two-dimensional CCD cell such as CCD scanners or cameras. The reading device interprets the coded information into text, sound or video – i.e. to the sensible format for humans. A mobile phone with an integrated digital camera can be used as a reading device for two-dimensional bar codes. The basic idea is to take a picture of the two dimensional bar code. The decoding software installed into the camera phone decodes the information in the bar code and returns to the user the stored information. Two-dimensional bar codes can also be printed with an invisible ink. These invisible codes can be decoded with the mobile phone when using IR or UV light source for making the code visible during imaging. The advantage of invisible two dimensional bar codes is that they can be printed on some graphics depending on the ink used since the bar codes only become visible when needed.

The utilization of 2D codes in publications

VTT has carried out several projects where we have built smart 2D applications for publication products. For example a Finnish company started to use 2D codes in February 2005. A 2D code, a so-called “smart box” was printed on different magazines. A camera phone with VTT’s decoding software was used

Figure 2. A smart magazine. A 2D code can be read by a mobile phone and additional information is automatically downloaded from the Internet.

to read the code. The code provides many services, like more information about a product in an advertisement or an article in its original language. Readers of a magazine can download the code reader software with their mobile phone's browser. An example of a smart magazine can be seen in Figure 2.

The significance of printing methods, paper grades and mobile phones in 2D code technology

Several printing trials with different conventional and digital printing methods have been made in our 2D research projects. The objective has been to investigate what are the limitations that printing processes, printing materials and camera phones give to code size and quality. The objective has also been to investigate how much information can be stored into publications.

The effect of printing methods

Differences between different printing methods in printing 2D codes can be seen in Figure 3. The print quality with offset and electrophotography is quite similar, but with inkjet printing the ink spreading degraded the code quality especially with small cell sizes. In this case, the inkjet printer, integrated into a magazine production line, had a very low resolution (240 dpi), which inevitably affected the final print quality. But the surprising result was that the ink spreading didn't affect code decoding even in this case. The cells also curved into the print direction, but even this had no effect on code decoding.

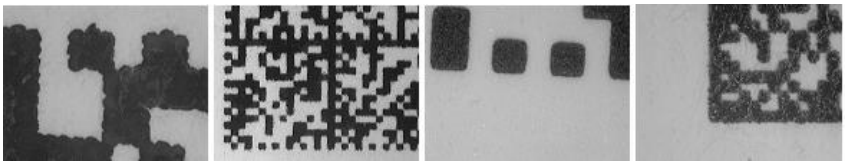

Figure 3. Two dimensional bar codes printed with different methods. From left: continuous inkjet, dry toner electrophotography, liquid toner electrophotography and offset.

All in all, it was concluded that digital printing methods are suitable for printing two-dimensional bar codes especially when variable data is needed. Inkjet printing can be used for online printing and electrophotography for offline printing.

The effect of paper grades

2D bar codes on different papers are presented in Figure 4. On all papers the cells were square-like even at cell sizes as small as 200 µm. On the coated LWC

and SC papers the cells with the size as small as 100 µm were square-like, but on the newsprint and uncoated paper cells this small were indefinite due to ink spreading. Ink spreading was also seen from cell area measurements since areas on newsprint and uncoated paper were larger than on other papers.

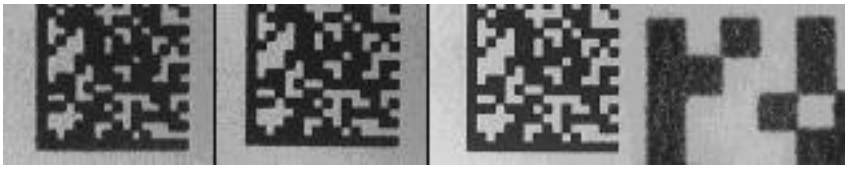

Figure 4. Two dimensional bar codes on different papers. From left: newsprint, SC paper, LWC paper and coated paper. Cell size is 250 µm.

The effect of camera phones

The objective of code detection tests was to investigate what size codes and how much information can be detected with camera phones. The smallest cell size decoded with the current camera phones is 200 µm depending on the paper grade used. Since at least offset printing is capable of producing smaller cells than 200 µm on certain papers, it is expected that smaller cells could also be decoded. The cameras and lenses on the camera phones improve constantly so the opportunities to achieve this improve all the time. But even with the current camera phones, as much as 172 ASCII characters or 348 numbers can be stored in an area of 9.6 mm × 9.6 mm and this code can still be decoded with a camera phone. If an UV or IR light source would be integrated into the camera phone, this code could be invisible.

Results

All the printing methods and papers were found to be suitable for the printing of two-dimensional bar codes. On high quality papers such as coated and LWC papers, even two-dimensional bar code cell size 100 µm was square-like. Newsprint and uncoated paper are also suitable for printing two-dimensional bar codes, but they are more suitable for larger cell sizes due to ink spreading and absorption that degrades print quality with small cell sizes.

When decoding two-dimensional bar codes with camera phones, it is important that the black cells do not spread too much onto the white cells. Spreading with very small cells can cause white cells to appear blackish thus hindering decoding. It is also important to keep satellite drops to a minimum as these can also make white cells appear black.

Digital printing methods are suitable for printing variable data either online with inkjet printing or offline with electrophotography. With online inkjet printing, as small a cell size as with offline electrophotography printing cannot be used. However, even a cell size of 350 µm with online inkjet printing, with a resolution of 240 dpi, was found to be occasionally good enough for decoding. If an inkjet printer with a higher resolution would be used, especially with UV curable colors, much smaller inkjet printed cell sizes could inevitably be detected.

Package applications of camera phone technology

Functions of packaging

The original function of packaging was to protect the product. Today, however, packages have to meet increasingly rigorous requirements. This is especially true of consumer packaging, where one of the main purposes of the package is to market and sell the product. Because of this, packaging is nowadays an integral part of the trademark. Moreover, due to the requirements of the authorities and consumers, packaging needs to contain precise product and safety information. In the future, packaging will become an increasingly important medium of communication. Manufacturers will also want to trace their products more accurately and pack shorter series or smaller quantities for different user groups, language areas, etc. There is also a very tempting possibility to use consumer packaging as a medium for advertisements. The number of packages will increase in information societies. Future packaging will thus be much more multifunctional, informative and demand-driven than at present. This is why packaging industry companies are interested in all R&D activities that pave the way for future ways of doing business.

VTT Information Technology has launched several projects to develop comprehensive systems for new kinds of package production chains. The systems pay attention to the special needs of consumer packages with regard to product information, identification and appearance. For example, intelligent coding, RFID and data networks are the technologies applied.

SustainPack

SustainPack is an EU sponsored research project on "Innovation and Sustainable Development in the Fibre Based Packaging Value Chain", which started in 2004. SustainPack is a pull-driven project, focusing on customer and downstream supply chain needs in order to identify and prioritize research requirements and to integrate other key themes such as sustainability, European competitiveness, legislation and policy. A European consortium of 14 research institutes, 11 universities and 8 industrial companies has been formed to undertake the research project.

Cardboard is a versatile packaging material because of its strength, printability and sustainability. However, the requirements imposed on packaging nowadays go beyond its physical ability to protect the product. Qualities such as barrier against gases, fastening by seals, excellent print results and information provision are now almost common practice for conventional plastics. The next step is to develop new innovative solutions to incorporate this range of qualities into renewable raw materials.

The work program for SustainPack is structured around a series of six sub-projects. VTT is actively involved in two sub-projects. In the first sub-project we will determine the market needs and therefore provide direction for the applied research projects. The success of SustainPack will be confirmed through a series of demonstration projects with industry partners delivering commercially and technically viable packaging solutions. In the second sub-project we will develop one- and two-way communicative packaging.

Package applications of camera phone technology with 2D codes

Based on our research results, several applications for the printed codes on the packages integrated with camera phone detection have been identified. These applications for two-dimensional bar codes include identification, logistics, additional information, information transfer, fitting information in small areas and integration of printed and electronic media.

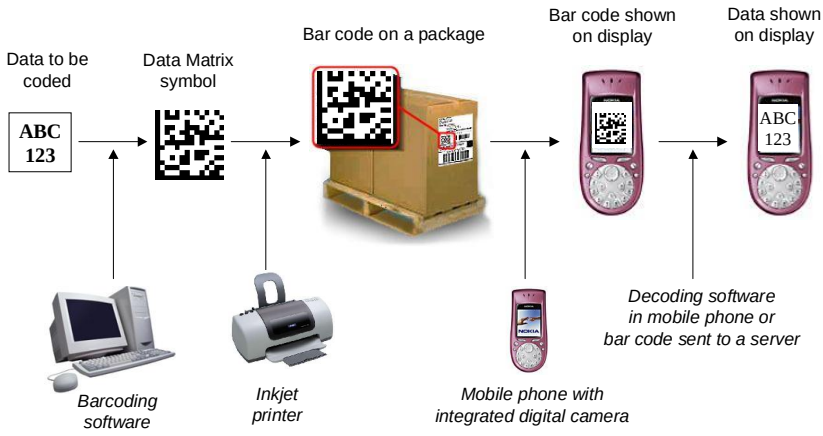

Figure 5. The utilization of 2D codes in information transfer. A 2D code can be printed with an inkjet printer and read by a camera phone when needed.

In identification and logistics, two-dimensional bar codes can individualize the product or transport package because with digital printing methods every printed code can be different. At any one time during the logistics cycle the code can be decoded with a regular camera phone and the individualizing information in the code can be read. The information in the code can be product or batch numbers, manufacturing and shipping dates, country of origin, etc. With two-dimensional bar codes even consumers can obtain information on the precise product. An example of this can be seen in Figure 5.

In addition to legal markings, additional information on packages is useful, because nowadays there are a lot of people with allergies or special diets. These people could check from the information in the two-dimensional bar code if the packed product is suitable for them. Product information can also be encoded into the symbol and saved into the phone or, for example, elderly people can magnify the text into the mobile phone screen. Figure 6 shows how a 2D code can include a recipe, which a consumer can read with their mobile phone from the package.

Figure 6. A recipe detected by a camera phone.

When coding the information less space is needed than when writing actual letters and numbers. Because the codes don't need as much space as written text, many special groups can be served in a small area. This idea also serves package designers that have to take into account all the markings required by legislation. The product manufacturers want to have additional information in the packages and two-dimensional bar codes are one way to fit a lot of information into the packages thereby leaving more space for marketing texts and impressive designs that promote the product.

Package applications of camera phone technology with indicators

When decoding the information held in a two-dimensional bar code, the color of the symbol can also be detected. One application for color detection is printed food quality indicators thereby enabling a combination of freshness information and other useful information in one symbol. Detection of color change in the food quality indicator is based on detecting the color coordinates i.e. RGB values of a printed area that changes its color based on the state of the packed product. The color detection device can tell if the product is fresh based on information given by the two-dimensional bar code. The bar code can, for example, contain the reference values for the RGB values and the detection software compares these values to the detected ones. If the reference values have too big a difference from the detected values, the software tells the user not to use the product.

Figure 7. VTT's internationally patented inkjet printed food quality indicator system. A consumer can check the freshness of a food product by taking a picture of an inkjet printed food quality indicator. After the frame is taken, the mobile phone software automatically interprets the color information and informs the user of the status of the product.

Applications for color codes read by a camera phone include reliable detection of color changes on quality indicators as well as ensuring that spoiled groceries are not sold or consumed. Because the human eye isn't always reliable, small color changes on quality indicators can go unnoticed. If the consumer hasn't noticed that the grocery is spoiled, he can get sick. Retail stores also need

quality control for making sure that they don't sell spoiled products that could harm the consumer. With camera phones the product freshness can be easily checked even when the products are already on shelves or at the cash desk. VTT has an international patent for the inkjet printed quality indicator system. An example of the utilization of a food quality indicator can be seen in Figure 7.

Conclusions

In this article, some areas of VTT's code and mobile phone research were covered. But the applications of coding and camera phone technologies are practically unlimited. Even today codes are used for example in a competition in the USA, where codes, which include hints for the competition, are printed on street banners in different cities. The more banners you scan with your mobile phone, the more hints you will get and the more likely you will be to win the competition. In Japan a 2D code is printed on a piece of white chocolate in a chocolate box and when you take a frame of your chocolate, your mobile phone connects you to the web site of the chocolate manufacturer. Or, again in Japan, you can take a frame of a 2D code on a music CD in a store, and you will immediately get a better offer from an Internet shop and you can even order that CD at the same time. So the applications of coding technologies are expanding rapidly and when individual people and smaller companies start to build their own appliances, the amount of potential uses and users will explode. So at the moment we are only at the beginning.

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