Automatic identification – applications and technologies

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Abstract

Automatic identification technologies are used in a wide range of applications. The applications vary from process automation to security control. The publications written on the use of automatic identification have been very practice oriented, and usually written by systems providers inclined to marketing their solutions. Until now, few efforts have been made to classify the various automatic identification applications. Furthermore, the suitability of different identification technologies to different kinds of logistics applications has been scarcely studied by neutral parties.

First, this article builds four categories of automatic identification applications: Authentication, tracking, process effectiveness, and information management applications. Then, the article reviews different identification technologies on their technological basis, and functionality. Finally, criteria for evaluating the functionality of different technologies in the application areas are proposed. The criteria are then applied to compare bar coding and radio frequency identification (RFID) technologies in the different types of applications.

Key words: Automatic identification, bar code, radio frequency identification (RFID), logistics

Applications of identification technology

This paper consists of three parts, presentation of the application classes we have formed, review of different identification technologies, and a comparison of bar code and RFID technologies in the different application areas. In this section typical applications of identification technology are reviewed. The applications are classified to: Authentication, tracking, process effectiveness, and information management applications. The technologies typically used with the applications are also discussed.

Authentication of animate or inanimate objects

Authentication applications are used in situations, in which exact identification of an object is needed. The identification can be done either automatically or by humans. Most common authentication applications are access control applications for human beings and linking physical objects equipped with identifiers to databases.

In access control applications, people are given an identifier, which is used to verify their personality. Identifiers used in access rights applications are usually magnetic stripe cards, contact memory cards or Radio frequency identification (RFID) cards. These applications are often used also in personnel tracing and work hour control. Another approach for access control is to use biometric identification, which relies on unmistakable individual physical characteristics, such as finger and hand prints, voice identification, and iris identification (Finkenzeller, 1999).

Authentication of inanimate objects is needed, when there is a need to verify that an object is really what it claims to be. Authentication of inanimate objects is often needed for example in the communication between RFID transponders (or tags) and reader device, and in fraud prevention. If classified information is exchanged, there is a need to know that the recipients of that information are what they claim to be. Identifiers can have a fixed or changing security key to access the information located at reading station or further in databases. Often the reading devices also need to provide certain security codes in order to access the information on the tag, or to change or append the information. In fraud prevention, identifiers are used to ensure that the product is not a counterfeit. Traditionally labels that are human read (e.g. hologram labels) have been used in fraud prevention, but nowadays RFID technologies are increasingly used.

Item tracking applications

All applications that gather knowledge about the location and route of items, or the state of the object are classified under the category of item tracking applications. Item tracking applications have
significant impact on many business processes, most significant in logistics. In logistics, they are used from express parcel carriers and heavy industry project enterprises (which is one of the most demanding business environments for building an extensive tracking system), to the defence forces of many countries. Although most tracking applications are used with inanimate objects, access control applications of human beings often have tracking features also.

Tracking applications are most often based on a reader network. Whenever a tracked object passes a reader belonging to the network, the pass is recorded, and the information is sent to a central database either instantly or in batches. As a single database gathers information from all the reading points, each object can be located with the accuracy of the reader last visited and the time of visit. The identification technologies that are most often used in tracking applications are bar codes and Radio Frequency Identification (RFID). These traditional checkpoint based tracking approaches do not suit multi-company environments well as they work only when the goods are within one company’s tracking system. The integration of the systems of different companies is time consuming and cumbersome, and the companies usually utilise different identifiers also. Therefore, many companies are still seeking solutions for global tracking of their goods. Utilising only one logistics service provider to co-ordinate deliveries does not eradicate the problem because the handling facilities, in which the checkpoints for the tracking are located are controlled by several companies all operating with their own coding.

Technologies used specifically for tracking include the Global Positioning System (GPS) and GSM cell tracking. GPS is a satellite navigation system, which is funded and controlled by the U. S. Department of Defence (Dana, 2000). The location of objects equipped with GPS modules can be triangulated through a satellite network. GPS does not need a specific reader network in order to track the items, which is a major strength for example in sea transportation. However, GPS is inoperable in sheltered locations (Jones, 1999) and a separate communication means is required to make the location information available. GSM cell tracking is based on GSM cell locations. When in GSM coverage area, the mobile GSM device has one ground station that is communicates with it. The station used for communication is the one that has the strongest signal of all stations within operable range to the mobile device. Thus, the location of the mobile device can be calculated from the known locations of each ground station that is within the communication range. (Varteva, 2001).

**Process effectiveness applications**

In process effectiveness solutions, automatic identification is used to automate processes or to automate the data input to save time and reduce errors. The most common applications of automatic identification have been in industrial applications, especially in warehousing and manufacturing, and in retail applications, such as sales-point scanning and inventory management.

In applications, where the whole process is automated, identification technology is used as a means to communicate the identity of certain items to the process infrastructure. As machines can identify the processed object, and receive instructions concerning the handling of it, the whole process can be automated and significant gains in efficiency and error reduction are obtained. Examples of completely automated systems are the sorting systems of express parcel carriers or airport luggage sorting systems. Also, car manufacturers use identification technology as an enabler for automated production lines. The most common technologies for automating processes are bar coding and RFID. Bar coding is used in a variety of applications, whereas RFID technology is usually only applied when the identifiers can be recycled (often attached to recyclable pieces of logistics infrastructure).

In applications where data collection is automated, automatic identification is used to obtain data from objects and to feed data to databases. Automatic data handling applications are common especially in warehouses and retail outlets. In warehouses, the applications usually aim at easing inventory bookkeeping. Picking lists, storing places, and often also item containers are equipped with identifiers. Warehouse employees use these identifiers to update the information in a database concerning the warehousing processes (e.g. what items have been shelved and where, and what have been picked). In automatic data collection applications bar code technology is the most commonly used identification technology. However, RFID based application are beginning to emerge, as they offer greater flexibility and effectiveness with less need for human intervention. Although they currently cost significantly more than bar codes (especially with applications, in which the volume of items is large), the improvements in operational efficiency may justify the costs of implementation.
Optical Character Recognition (OCR) is also used in automating data collection and input in office environments. For example, in banks the registration of cheques is often done using OCR systems.

**Information management applications**

In information management applications, identifiers are used to access information concerning the objects the identifiers are attached to. The information concerning the items can be stored either in the identifier or in a database. When the information is stored in a database, the identifier is used as a reference to access the information. There are several levels on which the item information can be managed. The most generic level is the product functional level, which is used for design and usage purposes. In logistics applications the common alternatives for information management are at the product type level, production batch level, and product individual level.

Product type level information management is used for example with consumer goods. Individual products of same type contain basically the same product characteristics, and are interchangeable. Production batch level information management is usual for example in perishable retail products and pharmaceuticals, as they have to be managed according to their batch dependent use-by date. Information management on product individual level is necessary, when the attributes of individual products are of importance, for example with unique products. Factors influencing the need for product individual level information management are: The value of the item, the criticality of the item, length of the item's lifetime, complexity of the system the item is attached to, and external requirements. Complex machines (e.g. aeroplanes) are good examples of items that demand product individual level information management. The components of complex machines also frequently demand product individual level information management to ease maintenance.

The most commonly used technology for item information management is bar coding. It is used on all levels of information management. One-dimensional bar codes are most commonly used, and two-dimensional codes are used in applications, where it is difficult to apply the one-dimensional code due to the size and place of the marking. RFID based applications are emerging, but still unusual due to the high cost of technology.

In managing and communicating information concerning objects handled, identification technology can have a dual role: it can either be a media for communicating and storing the information, or it can be a key to information located in a database. Further, the role of the identifier as an information storage and media can be divided into two separate classes: identifiers contain read-only information, and identifiers contain read/write information. Thus, three different classes of information management applications can be identified: 1) license plate applications (the identifier connects the object to information stored elsewhere); 2) read only information stored in the identifier (the information that is stored can only be read, not changed or amended); 3) read/write information stored in the identifier (the information stored in the identifier can be read, changed and amended).

**Identification technologies**

In this section, identification technologies most commonly used in logistics are briefly reviewed. The section covers the basics of bar coding, Radio Frequency Identification (RFID), Optical Character Recognition (OCR), vision recognition, smart cards, contact memory technology, and Bluetooth technology. More detailed descriptions of the technologies can be found for example in (Kärkkäinen et al., 2001).

**Bar codes** are identifiers, in which the information is encoded in a series of printed areas (bars) and spaces. Bar code technology encompasses these printed symbologies that encode data to be optically read, the printing technologies that produce machine-readable symbols, the scanners and decoders that capture visual images of the symbologies and convert them to computer-compatible digital data, and the verifiers that validate symbol quality (AIM, 2001). At the moment, bar codes are the most commonly used automatic identification technology (Forger, 2000).

There are more than two hundred different bar code symbologies, but only a handful of these are widely used. The bar coding symbologies can be roughly divided into three different classes, one-dimensional (linear), two-dimensional, and composite bar codes. One-dimensional symbologies have
a low data capacity (typically 15-to-50 characters), but fast line-of-sight machine-readability and a wealth of reading technologies at reasonable prices. Two-dimensional bar codes have a higher data density, and they often include error detection and correction capabilities. Composite codes contain both one- and two-dimensional codes. (AIM, 2001; AIM buyers guide, 2000). However, the latter two codes need to be carefully aligned when read, and the readers required are more expensive.

The strength of bar coding is that it enables automated data entry with relatively low costs and can be successfully utilised to expedite processes and cut error rates (Fraza, 2000). Also the standardisation status of bar codes is quite good, as it is a mature technology. The main weakness of bar coding relates to the optical reading mechanism: A line of sight has to be obtained with the code to read it. Bar codes have to be oriented towards the reader and multiple codes can not be read at the same time, causing extra handling in many applications (Jones, 1999; Boxall, 2000). The line-of-sight requirement also means that the codes have to be located at the surface of the packaging, which leads to serious readability problems due to dirt and bending in difficult environments or repetitive handling (Moore, 1999; Ollivier, 1995). Another weakness is that the information is always in a read-only format.

Radio Frequency Identification (RFID) is a method for identifying objects and transferring data without line-of-sight requirements. RFID systems consist of electronic devices called transponders (or briefly tags) that are attached to the items to be identified and readers that communicate with the tags. This equipment communicates via radio signals that carry data either uni-directionally or bi-directionally. When a transponder enters a read zone, the reader captures its data that can then be transferred to a host computer. RFID tags provide from few bits to several kilobytes of read only or read/write memory, which is very fast to read (Finkenzeller, 1999; Gould, 2000). RFID systems perform well in security critical applications, because RFID tags are difficult to copy and advanced encryption techniques can be incorporated in the systems (Finkenzeller, 1999).

There are different kinds of RFID systems. In some systems the transponders contain an own power source to operate the memory- or microchip on the tag (active tags), while in others all the energy required is obtained through the magnetic field of the reader by inductive coupling (passive tags). (d'Hont and Frieden, 2000). Furthermore, some tags contain a transmitter from which the data is sent to the reader, and some only reflect the radio waves of the reader (backscatter tags). The most decisive element of the RFID system is the frequency it operates on. Generally, the higher the frequency, the more data transfer capacity it offers, and the lower the frequency, the more power there is available for the transponder on inductive systems. At microwave frequencies the power to the transponder cannot be provided by inductive coupling, so transponders always need an internal power source to operate a microprocessor or memory chip. (Finkenzeller, 1999). The four main frequencies that are globally available for RFID systems are 135 kHz and below, 13,56 MHz, UHF frequencies ranging from 869 MHz to 928 MHz, and microwave band 2,45 GHz (see e.g. Finkenzeller, 1999 or Jabri, 2000). Some systems use the frequency range of 6,78 MHz, but they are not very common.

The most important strength of RFID technology is that when using RFID tags, no line of sight is needed with the identifier in order to identify the object. Products can be identified effortlessly, during processing and without additional handling. Tags can be read through non-metallic materials, and about 60 tags can be read simultaneously (Jones, 1999; Boxall, 2000). Also, most RFID tags are durable and resistant to temperature and other environmental factors (DeJong, 1998).

A drawback of RFID technology is that although tens of tags can be read simultaneously, one can not know which tag is being read (Ackley, 2000). And it is also impossible to write information on only one of many tags in the reading area. The cost of RFID technology is also notably higher than with bar code technology.

Optical character recognition (OCR) is based on reading human readable characters with machines. The most important advantage of OCR systems is the high density of information and the possibility of reading data visually in an emergency (or simply checking). The weakness of OCR systems is that they have failed to become universally applicable because of their high price and the complicated readers they require in comparison with other ID procedures. (Finkenzeller, 1999).

In Vision recognition systems the objects that are identified do not need to posses any specific identifier, but are identified from their physical dimensions. With vision recognition systems, an image of the object under study is automatically captured and analysed. The systems are used in automating
assembly plants and also in surveillance and quality control. The strength of a vision recognition system is that the strict location of the object is also attained from the system. Good illuminative conditions are critical for errorless functioning of a vision recognition system. (Suomi, 1999)

**Magnetic ink** recognition is a mature technology, which was developed in the 1950s. Magnetic ink is used to read plain text, when the authenticity of a document is to be ensured. The characters can be read by specialised magnetic readers even if they are covered with cancellation marks or smudges. The reader must have a contact with the text in order to read it, and the positioning of the text has to be precise. Magnetic ink has customarily been used mainly in the financial sector, but is growing more common in retail outlets as a means of ensuring the authenticity of cheques. (AIM, 2001)

**Smart cards** are a stable but developing identification technology. A smart card is an electronic data storage system, possibly with additional computing capacity (microprocessor card), which, just for convenience, is incorporated into a plastic card. Smart cards are placed in a reader that makes a galvanic connection to the contact surfaces of the smart card. The smart card is supplied with energy and a clock pulse from the reader via the contact surfaces. Smart cards are used for providing services that relate to secure information or financial transactions, e.g. as telephone booth cards (Finkenzeller, 1999). A disadvantage of contact based smart cards is the vulnerability of the contacts to wear, corrosion, and dirt. Readers that are used frequently are expensive to maintain due to their tendency to malfunction.

**Contact memory technology** is a similar technology than that is used in smart cards. The data in the memory is read by establishing a contact of conductive surfaces with the memory device. However, contact memories only contain memory, and do not possess any computing capability. The contact memory devices can be embedded in plastic cards, or made to look like small electronic batteries. Strengths of the technology are that it contains from reasonable to large amounts (from 1-4 k bits to megabytes) of read/write memory and can cope in quite harsh environments. It can be used in applications where its weakness, the necessity of contact to interrogate the device, is endured; for example in tagging containers and component carts. (AIM, 2001; AIM, 2000.)

**Magnetic stripe** is a low cost identification technology used for example in bank cards and credit cards. The security characteristics of magnetic stripe cards are lower than in smart cards and RFID cards. The magnetic stripe is read by passing the stripe manually or mechanically past (in contact with) a reading head. In a standard magnetic stripe card, the data storage capacity is approximately 240 alphanumeric characters. (AIM, 2001)

**Bluetooth** is the codename for a technology specification for a low-cost, short-range radio links between mobile PCs, mobile phones and other portable devices. Bluetooth chips can also be used as an item identification technology, as all Bluetooth chips have a unique identification number. Parts of the Bluetooth standard are still under development, and Bluetooth chips are just advancing to mass production stage.

The strength of Bluetooth is that it does not need a conventional reader, as it is capable of sending the information proactively itself to other Bluetooth chips. Therefore Bluetooth can be applicable in situations where its ability to proactively transport information can effectively be used, e.g. in preventive maintenance of mobile assets. The biggest obstacles in its use are the need for an energy supply and the current prices of Bluetooth chips. The total costs of identifications systems based on Bluetooth can thus get considerably high, even if considered the significant savings generated by the absence of reader investments. (Deckmyn, 2000; Stirpe, 1999)

Figure 1 summarises the application areas of different identification technologies.
Conclusions: comparing Bar code and RFID technology

In this final section we discuss the considerations needed when choosing identification technologies for the presented application areas. As bar coding is the most established automatic identification technology and RFID can be considered the most promising, we evaluate their suitability in the different application types.

Authentication applications

Authentication applications are usually applied in security critical situations, i.e. granting access rights to restricted locations or providing possibilities for accessing privileged information. Therefore security aspects are highly relevant when considering the best possible technology for authentication applications. The easiness and speed of using the technology in the application should of course also be taken into account, as well as the applicability of the technology for other supporting purposes.

RFID technology is far more suitable than bar coding for authentication type applications due to the relative ease of copying and forging bar codes. In contrast, RFID technology is considered to be almost impossible to counterfeit or copy, which makes it a valid technology for authentication purposes.

Tracking applications

Tracking applications are built when it is necessary to track the progress of a product or a consignment in the delivery network, therefore the accuracy of identification is an important criteria. As the applications are most often utilised in situations where great numbers of parcels are handled, the disruptions to material flow caused by reading (read speed/distance), and level of automation (how much manual work needed for identification) are important. Finally, as checkpoints are often spread in geographically distant locations and varying conditions, the global availability of reader technology as well as the resistance to different environmental factors (dirt, damp, bending) should also be considered.

In most tracking applications, bar codes will currently provide the best payback for investment. It helps to alleviate the problems of manual data handling with relatively low costs (Fraza, 2000). The installed base of bar code readers is extensive, as it is by far the most popular automatic identification technology (Forger, 2000). Therefore, many checkpoints can be created with minimum investment when using bar codes. However, if the deliveries are likely to require excessive handling and poor environmental conditions, radio frequency identification (RFID) is a viable option as the identification technology (Boxall, 2000; Jones, 1999; Moore, 1999). Of course, the use of RFID greatly increases the needed investments, and thus easily reduces the number of tracking points in the system, as even the cheapest RFID readers with limited functionality cost around one thousand Euro (Tossavainen, 2003).
Process effectiveness applications

The functionality to be considered here include the ones presented with tracking applications, but also the information capacity and memory type (read-only/ read and write) of the identifiers should be considered. This is because a large and flexible memory space enables utilising the identifiers themselves as information carriers.

At the moment bar code based applications are widely used in the short shelf life supply chain. Various types of scanning equipment, ranging from fixed readers to finger scanners, are used in many phases of the distribution network (Banks, 2001a). Bar code scanning reduces errors associated with manual data handling, and produces visibility to aid supply chain management (Fraza, 2000). Also, the introduction of new bar coding standards that enable adding the sell-by dates to the codes have helped in retaining the integrity of stock rotation and hence help solve the spoilage problem (Shulman, 2001; Anon., 2001).

However, there are problems associated with bar code data collection. The reading of bar codes invariably requires manual handling in the supply chain. Either the packages with bar codes or the reading devices are handled manually in order to read the codes (Boxall, 2000; Bylinsky, 2000; Jones, 1999; Moore, 1999). This makes data capture difficult, especially in the retail store environment where large amounts of goods are handled in facilities not designed for effective logistics (Fidler, 2001). Readability of bar codes is, occasionally, problematic due to dirt and bending; resulting in reduced accuracy of reading rates, particularly in successive handling situations and in difficult environments (Ollivier, 1995; Moore, 1999).

With the current cost of RFID technology, investment in tagging for consumer packaging are not likely to be profitable. However, if tagging is applied at the transport-unit level, i.e. transport cartons, and not for individual consumer packages, then many of the potential benefits can be achieved with a considerable reduction in capital investment. The greatest cost efficiency can be achieved with recyclable transport containers, as the same investments in transponders can be continuously utilised (Albright, 2002).

Information management applications

The functionality requirements for identification technologies in information management applications depend on the type of the application (the application types are discussed in the first section of the paper).

Read accuracy and speed, and the environmental resistance of the identifiers are important for licence plate applications. When storing read-only information on the identifier, the information capacity of the identifier is also important, and when building applications where read/write information is stored in the identifier the memory type of the identifier is also of great significance.

In licence plate applications bar coding is the most cost efficient technology. Currently, RFID technology should be utilised only when its easier readability provides sufficient benefits in handling or when the difficulty of copying can be utilised for counterfeit prevention. When storing read-only information directly on the identifiers, two-dimensional bar codes are often the best alternative due to the amount of information that can be incorporated and the relatively low price. In applications with requirements for read-write capabilities RFID is, of course, preferable.

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