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Low cost augmented reality and RFID application for logistics items visualization

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Abstract

One important component of the gross domestic product (GDP) is logistics services the quality and added value of which is growing due to the application of modern information and communication technologies and electronics. RFID use increases the performance of logistics items identification, however some errors, which could cause substantial damage and losses, remain. The amount of potential errors could be diminished by the additional checking of items using 3D visualisation. The authors researched the use of augmented reality for item visualisation in a warehouse combining AR and RFID solutions.

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Keywords: Virtual and augmented reality (VR/AR); Augmented reality platforms; Radio frequency identification (RFID); Logistics; Identification.

1. Logistics and identification

The Council of Supply-Chain Management Professionals estimated that in 2009 the amount of logistics services in the gross domestic product (GDP) of USA reached 7.7%, but 7.15% in Europe[1]. European Commission structures believe that about 10-15% of all product expenses can be attributed to logistics services[2].

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Various definitions for logistics correspond to the current state of economic and technological development. For example, logistics can be considered a cost-effective planning, realization and management process of moving raw materials, stocks, products (and information associated with them) from their point of origin to the place of consumption. The aim of this process is to fulfil clients' needs.

Logistical tasks are related to customer service, demand planning, organization of supplies, inventory management, freight and order processing, manufacturing and warehouse facility placement, procurement, product packaging, organization of the reverse flow of goods and packaging, transportation, storage and other auxiliary activities.

One of the most important processes is the identification of an object (goods, cargo). Various identification methods are available. The most widely used is bar-coding. A barcode is a combination of black and white lines that allow encoding, reading and decryption information about goods using optical scanning. Barcodes have a wide range of applications: shops use them to tag goods; medical professionals mark medication; airlines use them to identify tickets and luggage claim tags; institutions, banks, post offices and libraries mark documents, parcels, books and magazines; manufacturing facilities tag raw materials, semi-finished and finished products, instruments etc. A barcode is easily readable and decrypt-able, however, for it to be recognized correctly, direct visual contact is necessary. This determines the exact orientation in space for the object and greatly increases the operator's workload, and identification of heavier and larger goods is complicated. There are more than 50 different coding standards. The most popular standards in the world are UPC (Universal Product Code) created in USA and EAN (European Article Numbering). American and European codes are partially compatible; however, both tags are attached to shipments most of the time. The EAN-13 code has the capacity for 13 numbers. Several two-dimensional barcodes, for example, PDF417, Datamatrix, Aztec and others allow up to 2000 graphical symbols to be used in the construction of codes. However, by increasing the number of symbols, scanning precision is reduced and more errors occur. One of the main disadvantages of using barcodes is that previously written information cannot be altered and/or rewritten. The route and description cannot be added to the product code so that it could later be automatically changed at various logistics points and hubs[3].

2. RFID – next step to avoid misunderstanding and mistakes

One of benefits of IT technology, which is currently mainly used in logistics and the transportation sector, but actually has unlimited application possibilities in every sector of the economy, is RFID. The main task of RFID is to provide an easy to use, unambiguous and non-contact way to identify an object (goods, living beings etc.). This is achieved by allowing an RFID scanner (scanner, reader) to read the ID code and other information of an object from a passive/active RFID tag (transponder, tag, label etc.) from a distance. This information has usually been written using a RFID writer (writer, printer). A multi-frequency radio signal is used as the carrier frequency. Since this technology provides the simultaneous non-contact identification of multiple objects, information-processing performance is increased which in turn reduces the number of staff required. RFID tags are rewritable and can contain much more information than a barcode. An RFID tag does not require direct visual contact with the scanner. This means that the object RFID tag does not have to be in the same orientation in space as the scanner.

RFID technology is nothing new. Separate applications were used in the 1980-ies. By reducing the manufacturing costs of electronic elements and the size of RFID tags, as well as the power output required, an opportunity emerged to significantly reduce the costs of RFID tags. This facilitated a rapid growth in the use of RFID in several economic sectors – logistics and transportation, trade, healthcare, tourism, security etc.[4].

The most significant problems that affect the choice of RFID technology are the selection of a frequency bandwidth as well as the determination of a transmission protocol, data format and the amount of stored information on the RFID tag. The choice of the above-mentioned parameters is further encumbered by fuzzy standards. Another concern is security, because RFID is a contactless technology.

The basic components of an RFID system are:

- Tag (transponder, tag, label, responder);
- Scanner (scanner, reader);
- Antenna (internal, external) (antenna, gate);

- Writer (writer, printer);
- Control equipment and software (middleware).

Tag – a device (passive, semi-passive or active) used to identify a marked object. It consists of an internal antenna and a microchip (memory or microprocessor). Its function is based on Faraday's law. The electronic devices are fed current that inducts in the antenna when it resonates with the corresponding variable electromagnetic field carrier frequency which is emitted by the scanner. Information exchange with the scanner and data formats are determined by protocols. The induced current not only feeds the integrated microchip but also, by flowing through the oscillation circuit, which is created by an integrated antenna, causes a radio wave transmission that corresponds with the carrier frequency. These radio waves transmit the encoded information to the scanner.

Passive RFID tags do not have their own power source. They use a scanners radio signal and convert it to current to process a request. Passive tags are cheaper and more widely used. Passive tags only work within the exposure area of a scanner. The reading distance is limited because the scanner has to transmit a signal that is strong enough to activate a tags' microchip and provide enough current to generate a response signal. The current reading distance of a passive tag is a few meters but it increases as manufacturing technologies are improved.

Semi-passive RFID tags use a battery to provide additional current for the microchip. However, energy induced by the scanner is still used to accumulate enough current to send a response signal. Semi-passive tags can be read from a greater distance than passive tags but their life expectancy is lower due to battery life. Semi-passive tags are more fragile and a lot more expensive than passive tags.

Active RFID tags use a battery to power the microchip and generate a response signal. Therefore, active tags can be read from even a hundred meters away. Active tags can communicate with each other and they are often equipped with sensors to acquire environmental data, for example, how the temperature of a refrigeration container fluctuates over time. They can also be read faster – up to 1000 units per second. Unfortunately, these tags are expensive. Good one can cost some tens of Euros.

Scanner – creates an alternating electromagnetic field within a radio frequency range (RF) that corresponds with a carrier frequency. This causes electromagnetic induction (EMI) in the built-in oscillation circuit (antenna) of a tag. The scanner reads the response signal which contains information recorded in the tag. Simple scanners forward raw data to the control equipment but more sophisticated readers can clean up the data, for example, filter records that have been created by repeatedly scanning the same label. Scanners can have a write function that allows to change a tag's previously recorded information, but only if the tag is writable. Scanners can be portable or stationary.

Antenna – amplifies the signal corresponding to the carrier frequency or is used to power the tag with induced current. A tag has a built-in antenna. Scanners can have internal or external antennas which improve scanning range and can point scanning in the direction necessary for the user. The ability to concentrate the electromagnetic field radiation in a specific direction to create a sufficiently narrow beam is important. This is easy over small distances like a couple of centimetres but becomes increasingly difficult if the scanning range increases some meters.

RFID protocols establish requirements for information exchange algorithms between a RFID scanner and a tag. In some cases, they describe information storage formats. RFID is characterized by a wide range of recommendations (standards) [5]: ISO 11784 & 11785, ISO 10536, ISO 14443, ISO 15693, and ISO 18000 [6] etc.

Unfortunately, there are still no complete recommendations on the selection of tags, scanners and antennas from different manufacturers. Furthermore, there are no constructive solutions for the tagging of specific types of goods, scanning distance and speed. Adequate solutions must still be found through experimentation.

To choose a RFID technology, the following parameters should be determined:

- Carrier frequency – LF, HF, UHF or MW (region specific);
- Protocol – a set of protocols determining the exchange of algorithms and data storage formats;
- Tag type – active, semi-active or passive;
- Tag size and material – must correspond to the specifics of the identifiable object and operating environment;
- Data modification possibilities – repeatedly writable tags (Class 0) or WORM tags (Class 1);
- Data protection against unauthorized access - active tags have better information coding options;
- Amount of data – passive tags up to 64KB or more, active – 8MB or more;

- Scanning distance – some meters for passive tags. Active tags up to hundred meters or more, depending on the frequency range;
- Security of item identification – a barcode is often printed on RFID sticker type tags to ensure the compatibility of both identification systems and provide information processing reservation;
- Scanning sequence – sequential (tags are read from a queue) or simultaneous (multiple tags at the same time);
- Expenses – price per tag. Expenses for other equipment are commensurable;
- Immunity to interference – an active tag has a stronger signal so it is less prone to interference;
- Operating time – unlimited for passive tags. For active tags, this depends on battery life (about 3 – 5 years).

Based on the above-mentioned RFID protocol standards (recommendations), it is possible to devise the following carrier frequency table (see Table 1).

Table 1. RFID frequencies bandwidth[7].

Region	Frequencies			
	MW (GHz)	UHF (MHz)	HF (MHz)	LF (kHz)
		867.6 – 868.0 (0.5W)		
Europe	2.45	865.6 – 867.6 (2W)	13.56	125 – 134
	5.8	865.0 – 865.6 (1W)		
North America		902 – 928 (4W)	13.56	125 – 134
Japan		950 – 956	13.56	125 – 134
Australia		918 – 926 (1W)		

The main practical introduction problems of RFID are caused by the properties of radio waves:

- Signal reflections from metallic surfaces;
- Signal absorption by fluids;
- Ether pollution creating parasitic EMI in antennas where RFID is used.

The possible scanning distance of RFID tags depends on the environment. What obstacles exist between the scanner and the label? Are the chosen radio frequencies used by other equipment? How large is the antenna of the tag? For UHF and MW the main obstacle, except metallic surfaces, is water and other liquids because they absorb these signals and transform them into heat.

The above-mentioned data suggests (see Table 2):

- A greater diversity can be seen in the UHF (Ultra High Frequency) and MW (Microwaves) range. The use of UHF and MW frequencies for RFID technologies is mostly seen in transportation and logistics because they provide greater scanning distances from a few to several tens of meters. This is achieved using signal amplification devices (also external antennas. The lack of common agreements makes identification of the same object (container, luggage) in different ports (airports) and regions more complicated and expensive. This also makes the purchase of RFID equipment more difficult in different countries. Since the wavelength is small, the necessity for a direct field of vision arises to avoid possible signal reflections from obstacles. The use of this range will be problematic in environments where there are many metallic objects or in fluids;

Table 2. Usability of RFID frequencies[4].

Bandwidth	LF	HF	UHF	MW
Reading distance of passive tags	Up to 0.6 m	Up to 1.5 m	Up to 5 m	Up to 100 m and more
Characteristics	Low data transfer rate, large wavelength, large antennas and RFID tags if greater scanning distances are required	Higher data transfer rate, metal obstacles reduce the scanning distance	High data transfer rate, more than 100 tags can be read simultaneously, but metal, water etc. greatly reduce scanning distance	High data transfer rate and high reflectance, but tag size is small. Allows to read data from fast moving objects
Application cases	Animal identification, contactless smart cards	Identification systems, identification of persons	Stocks in warehouses, supermarkets and supply chains	Collection of tolls, container identification

- The use of HF (High Frequency) in different regions is similar. Unfortunately, the use of this solution is problematic when the scanning distance has to be greater than one meter. Since the wavelength is significantly greater than UHF, RFID antenna size increases dramatically. By reducing tag size, scanning distance decreases significantly and does not exceed several tens of centimetres. An advantage is relatively low wave reflectance which permits HF solutions to be used to identify goods in warehouses and stores;
- The future development of LF (Low Frequency) solutions is doubtful because the use of LF does not provide sufficient scanning distance and data transfer rate. However, for building access and usage rights control systems (payment card authorization, automatic pass control, etc.) LF RFID solutions are sufficiently useful.

Tag performance is also affected by other factors:

- Tag sensitivity: The ability of the microprocessor to take full advantage of the power provided and enhance the strength of the response signal;
- Tag size: A bigger tag usually means a greater scanning distance;
- Form of the antenna: Different shapes of antenna can affect tag performance;
- Number of antennas attached to a tag: Two bipolar antennas attached to a single tag can reduce sensitivity to antenna orientation which is important in scanning environments that are difficult to control;
- Performance: The speed with which a scanner can read a tag. A higher speed improves the effectiveness of business processes. The reading speed of modern RFID tags is from 20 to more than 1000 tags a second;
- Tag placement: If tags are too close to each other, it can affect the reading process. Tags can have a different successful reading distance. Good tags can even be scanned if they are 2 centimetres apart from each other and even closer;
- Interference: Thoughtfully designed tags and scanners also work well in environments where the carrier frequency is also used by other devices[8].

RFID technologies are being used in practically every economic sector[9]. Some of the biggest RFID users in the USA are the supermarket chain *Wal-Mart* (more than 200 suppliers that participate in the RFID program), the US Defence department (more than 4000 suppliers), the *Target Corporation, Metro AG, Tesco* and other organizations. However, *Gillette, Procter & Gamble, FedEx* and other international corporations also use RFID solutions.

One typical use of RFID is the identification of a set of goods and items in warehouses and assembly units.

3. Huge amount of components – some problems with product assembly

The final stage of the 20th century was characterized by new means of manufacturing and design provided by new sectors of the national economy – IT, flexible manufacturing systems (FMS), robotics, and computer aided designing (CAD), computer aided software environments (CASE), enterprise resource planning (ERP) tools and etc. The achievements of microelectronics ensured a higher level of electronic element integration. Computers have become even smaller and closer to people, keeping functionality and increasing performance. Microprocessor development gave way to the overall automation of operations of domestic equipment and popular consumption production. The use of microcontrollers improved car and washing machine quality parameters. The exchange of existing information has grown greatly, from tables and graphs to VR/AR objects. New information transmission and processing facilities were created – from networking technologies to the Future Internet. Forms of providing service became more advanced – e-commerce, e-business, e-procurement, e-governance etc. But...the success of a company or event was still determined by the quality of the logistics process.

One of the main sectors of developed national economies is the car-manufacturing industry. If assembled components in PC design are not that large, then it is absolutely the opposite in automobile, for example, truck manufacturing. The maintenance of storage facilities requires financial resources, influencing the cost of production, therefore every manufacturer tries to avoid useless space utilization. Presumably, there is only one possibility to ensure the delivery of necessary constituent parts and auxiliary materials accurately at the time they are needed on an assembly line. This is not an easy task, because you have to ensure the delivery, placement, storage and movement of parts in the correct chronological order. Used containers and packaging of constituent parts, their disposal and optimal planning of turnover create additional problems.

A typical example is Toyota. In 1933, *Kiichiro Toyoda* converted his father's textile operation into an automotive manufacturing business. This marks the humble beginnings of what would become the world's fourth largest auto manufacturer by the end of the twentieth century, Toyota Motor Corporation. Today, Toyota is truly a global entity with production throughout North America, Europe, Asia, Oceania, Africa and Latin America. Toyota invested $1.2 billion in the two million square-foot facilities of Toyota Motor Manufacturing (TMMI) to produce the full-size, V8-powered pickup truck, the Tundra. Production of the *Tundra* began in late 1998. TMMI has 2,300 employees and the 132 suppliers that provide more than 2,000 parts that compose the *Tundra*. In conformity with daily production approximately 800 000 parts must be delivered every day[10]. And these parts must be delivered in a correct order and accurately in time. And of course, the parts must be stored in storehouses and selected in the right order in conformity with the many requests. Sometimes that is not that easy.

The situation in aircraft manufacturing is even more complicated because the number of components is significantly higher. For example, the wing of an *Airbus A350* consists of more than 30 000 parts. Airbus uses RFID technology to track the history of thousands of key components from the moment they enter the Airbus manufacturing stream, are placed on a particular jet, and all the way through the component's product lifecycle. This asset lifecycle includes the component's maintenance and repair history, right up to the time it is replaced with another part. With RFID, much of the end-to-end genealogical history will be stored right on the chip. These chips can hold full documents, such as PDFs of diagrams showing the intended location of a part and other portions of a parts manual, the entire repair history of the part, and even the technicians involved in maintaining the part. After a faulty part has been removed, the data can help Airbus to track common problems, resulting in higher-quality planes being built in the future. The Airbus program deploys ruggedized high-memory RFID tags on flyable parts, allowing improving aircraft configuration management, repair shop optimization, spare parts logistics, and the monitoring of parts with a predefined lifespan[11].

Let us imagine a responsible employee who has to find a necessary part in a multi-stage warehouse. Parts are stored in boxes that are arranged on shelves. The computer system knows where every part is located but errors are possible because there is a weak link in the delivery chain – a person. Therefore, additional features are required so that the person responsible for part delivery can make sure that the choice is correct. For example, he should see a visual representation of the part which should look as close to the real object as possible.

4. VR/AR – an integral part of modern visualization systems

One of the essential actualities is the display of objects in a form that is understandable to domain specialists and as close as possible to the specifics of the business sector and also recognizable by storehouse staff.

There are several different definitions of virtual reality, but one of the formulations determines that it is the simulation of the goal system using computer graphics and providing the user with the ability to interact with the researchable system by using three and more levels of freedom[12]. It all depends on the object. If reality is the object of research, the virtual constructions complement the visible object, and then this is an augmented reality solution. Currently, VR/AR questions relate to a scientific sub-sector, which combines various fields such as computers, robotics, graphics, engineering and cognition.

The basic element of a VR/AR system is the authoring platform which provides the import of models from other 3D graphics tools (AutoCAD, Maya, 3D Max etc.), the generating and rendering of scenes, and the building and operation of scenarios. Although the construction of VR/AR systems is still expensive and time consuming, which is caused by the incompatibility of hardware and authoring platforms, gradual development is taking place[13].

5. Augmented reality platforms review

The main task of an augmented reality environment is to provide the staff with a computer generated 3D image of the target object and connect it with the visualization of objective reality. The display of reality in the background is not obligatory. However, a person's perceptual ability is better, if the 3D object visualization is carried out in a natural environment, preserving the real background.

HIT Lab NZ (http://www.buildar.co.nz) developed *BuildAR Pro* - an integrated AR environment where 3D images are generated within the platform. It is possible to generate custom markers or use images. Compatibility with several 3D formats is ensured, but FBX is preferred. It is possible to create a logo on your image. However, *BuildAR Pro* does not provide the compilation of applications. In order to solve the business AR versions security issues, a free of charge *BuildAR Pro* Viewer version is offered which is capable of running scenarios created in *BuildAR Pro*. This saves costs because, to run scenarios, the purchase of the full *BuildAR* version is not necessary. It is possible to simultaneously work with multiple markers and visualize several 3D models; however, under such heavy loads software stability problems may arise. One major drawback of *BuildAR* is the incompatibility with Intel graphics chipsets. This limits the usability of an otherwise good product.

GameStudio A8 (http://www.3dgamestudio.com) is a graphics platform for the creation of video games. Although the creators *Conitec Datensysteme GmbH* are not widely known, *GameStudio A8* is a popular tool to create 3D movie applications. It can be used to render digital 3D maps of cities or anatomical objects. Although the graphical models themselves are created in other environments, for example, *3D Studio Max, Maya, Autocad* etc. it is possible to create and compile sufficiently fast applications using the *lite-C* programming language. For a reasonable price, a Software Development Kit (SDK) can be purchased to develop plug-ins for other applications. *GameStudio A8* is compatible with several 3D file formats such as FBX, 3DS, X, OBJ, ASE, MAP, MDL, MD2, FX, BMP, PCX, TGA, JPG, DDS, PNG, WAD, MID, WAV, OGG, MP3, MPG, AVI, WMV. One of the faults is that the software is only compatible with *Microsoft Windows* operating systems. *GameStudio A8* is not an AR system, but it can be used as a 3D model-rendering environment, which allows for the insertion of custom logos.

For this multiple AR plug-in solutions are available. One of the most advanced is the LabHuman – *Human Centred Technology* (http://www.labhuman.com) AR library that provides generation of high quality markers "ninja", 3D object positioning and tracking[14]. With the help of virtual marker buttons, it is possible to enlarge and reduce the size of 3D objects as well as move them around the vertical axis. Other AR plug-in developers provide similar solutions. For example, the *Paradox D&D* (http://www.pdxstudio.com/tecnologia/realidad-aumentada) plug-in will be included in *GameStudio A8.31* (http://manual.3dgamestudio.net/beta.htm). This will create a complex and financially beneficial product.

One of the most widespread 3D video scenario-building and realization tools is *Unity* (http://unity3d.com). *Unity* is a multi-platform tool. This facilitates the use of developed applications not only on *MS Windows* but also on *Android* and *iOS* operating systems. Several third party solutions could be compatible with the *Unity* rendering software. For example, *Qualcomm* (http://www.qualcomm.com/products-services/augmented-reality) AR SDK, which works on *iOS* and *Android* platforms, *AR Toolkit Pro* (http://www.artoolworks.com/products/stand-alone/artoolkitpro), which is compatible with *MS Windows, Mac OS X, Linux* and *Irix* operating systems. It is also possible to use the *Unity AR Toolkit (UART)* (https://research.cc.gatech.edu/uart), as well as AR tools offered by *String* (http://www.poweredbystring.com). The latest is one of the fastest but, in order to fully customize it, one would have to pay a large amount of money, which exceeds the price of Unity several times. Unity provides application compilation but all used 3D models have to be included in this compilation. As a result, the use of such applications on pocket PCs or mobile phones is unlikely because the demand for processing resources is too high and the executable code is too large.

AR applications can also be created on the cheap way by using, for example, *Google SketchUp 8* (http://sketchup.google.com/intl/en) and the *AR Plug-in for SketchUp* (http://www.inglobetechnologies.com/en/). Unfortunately, the stability of AR solutions is low and sensitivity to lighting is high. However, there are also advantages. *Google SketchUp* is not only an authoring platform but can also be used to develop 3D models. In this case, the AR solution will run in interpreter mode.

Esperient Creator provides similar functionality (http://www.esperient.com) together with the *Creator AR Plug-in*, which was developed in collaboration with *ARToolworks*. It is possible to create compiled AR solutions; however, a real AR application development toolkit will cost several thousands of euros.

To choose a suitable AR environment for the visualization of logistics objects, it is recommended to primarily analyse existing environments based on to the characteristics set out below:

- Environments that provide interpretation and compilation – An interpreter, for example*, BuildAR* allows the system to function openly, which reduces security. This means that during the execution of the program the system could be compromised and vital execution parameters can be altered. While using the software, the interpreter environment is also active and uses additional computer resources. However, 3D models are generally stored as files. This facilitates the addiction or exclusion of new models from the AR environment. A compiled version, for example, *Unity* or *GameStudio*, does not allow arbitrary changes. This increases security, although it is more difficult to add new 3D models. Practically, it is necessary to know the number of used models beforehand and add them to the compilation. As a result, module size is significant, which has a negative effect on AR software performance;
- AR environment independence – Several AR solution developers offer online development tools, not stand alone versions, which creates further limitations;
- External and included 3D models – External models are usually stored as files and are easy to add. Included models are part of the application software. The use of included models is only possible in precisely targeted solutions;
- 3D model formats – Most AR environments are compatible with all popular 3D formats, for example, FBX, OBJ, 3DS, MAX, MTL etc. In addition, it is not difficult to find format conversion tools;
- AR environment functionality – Standard AR solutions fulfil two basic tasks. First is 3D model identification according to a specific marker and the determination of its location in space, when the 3D model is usually displayed on screen. The second task is the visualisation of the 3D model. There are complex environments that ensure both functions simultaneously, for example, *BuildAR*. However, it is more common to use solutions where a plug-in from one developer provides 3D model identification and tracking, and the execution of the 3D model is left to a popular graphics platform in which it is possible to develop the necessary scenarios and create graphical applications. Such toolkits are *Google SketchUp* and *ARToolKit*, *Esperient Creator* and *Creator AR*, *GameStudio* and *AR LabHuman* or *Paradox D&D* etc.;
- Operating system – *MS Windows* (32-bit, 64-bit), *iOS*, and *Android*. It is recommended that the chosen AR tool can operate on all of these platforms. Otherwise, low mobility will create additional expenses and the solution will be ineffective;
- Technical support – Despite universalism, video incompatibility can occur. For example, *BuildAR* still does not support Intel graphics chipsets. An important factor is resource consumption, which can not only affect the performance of the AR solution, but also often make portability to pocket PCs and mobile phones impossible;
- Adaptation options – It is important that an AR solution is at least mildly popular. This can help ensure that users will have technical support and bug fixes are or become available. An AR software application developer has to have the option to alter AR platform settings and customize it to his needs, for example, add character sets, add a company logo, create custom markers etc.;
- Marker set – AR solutions must provide the use of previously defined markers and the generation of new ones. There may also be the possibility to use multiple markers simultaneously as well as use a graphical or video image as one. Marker quality has a significant impact on AR solution stability. Usually the most stable are

markers created by the developer of the AR solution. These are often included in the AR platform for demonstration purposes;

- Price – The AR environment price range is vast. Starting with free tools and ending with several thousand euros for an AR plug-in. Some developers offer to rent an AR environment and the price is calculated based on the number of users.

6. AR RFID – logistics items low cost visualization tool based on RFID technologies

To visualise items in a warehouse that must be moved to the assembly bay, an *AR RFID* solution is used to ensure additional possibilities of checking. That allows reducing the amount of potential errors and diminishing possible losses. An RFID scanner reads the component code and a 3D model of the item is visualised on screen (see Fig. 1).

Fig. 1. *AR RFID* - solution for items visualisation.

To ensure identification of the components in a warehouse, it is necessary to (see Fig. 2):

- Ensure an RFID reading distance of about 5 meters while maintaining the possibility to precisely orient electromagnetic wave in a more or less concentrated beam, which is focused on a remote RFID tag;
- Based on the component code written in the RFID tag, it is necessary to find a 3D model of the item in the database;
- The 3D model of the item has to be sent to an authoring platform which provides rendering capabilities in accordance to marker positioning data sent by the AR environment;
- The 3D model has to be visualized on a tablet PC.

Unfortunately, the currently available authoring platforms do not provide effective compilation of the executable code. Attachment and use of external 3D models is also limited. This complicates the use of AR applications under limited computing power conditions. Therefore high enough software costs no longer allow adding the created AR application to the low cost solution set. Finally *BuildAR* was selected and is used as the AR RFID authoring and development environment. Users use *BuildAR Viewer* for to AR applications.

AR RFID eliminates the problem of generating an equally stable and recognizable marker, because a single marker is used only for tracking, not to recognize the 3D model. This makes it possible to use a single marker with the highest stability. To identify the 3D model, an identification code, which is read from the RFID tag, is used. The 3D model is found using the identification code and displayed on the screen of the Tablet pc. A *HTC Flyer* 32GB WiFi/3G tablet with 7" LCD touch screen is used to visualize the 3D model.

Based on the size of the warehouse, scanning range has to be at least 5 meters. Scanning has to be stable and targeted to read the necessary RFID tag. However, as the AR RFID system only functions as an additional visual control tool, the above-mentioned requirement is not crucial. Visualized objects can also be filtered by component identification codes. Because cost effectiveness is important, the use of active or semi-passive RFID tags is rejected. *AR RFID* uses passive RFID tags AD431 (ISO/IEC 18000-6C EPC global C1G2), which work in the UHF 860-960 MHz range (http://www.peacocks.com.au/PDF/Avery_AD431.pdf). One possible scanner is *CS101* by *Convergence Systems Limited*. CS101 is a UHF EPC C1G2 handheld RFID reader (http://www.convergence.com.hk/products_details.php?id=9) with industry leading read range and read rate performance to enable ultra-fast inventory.

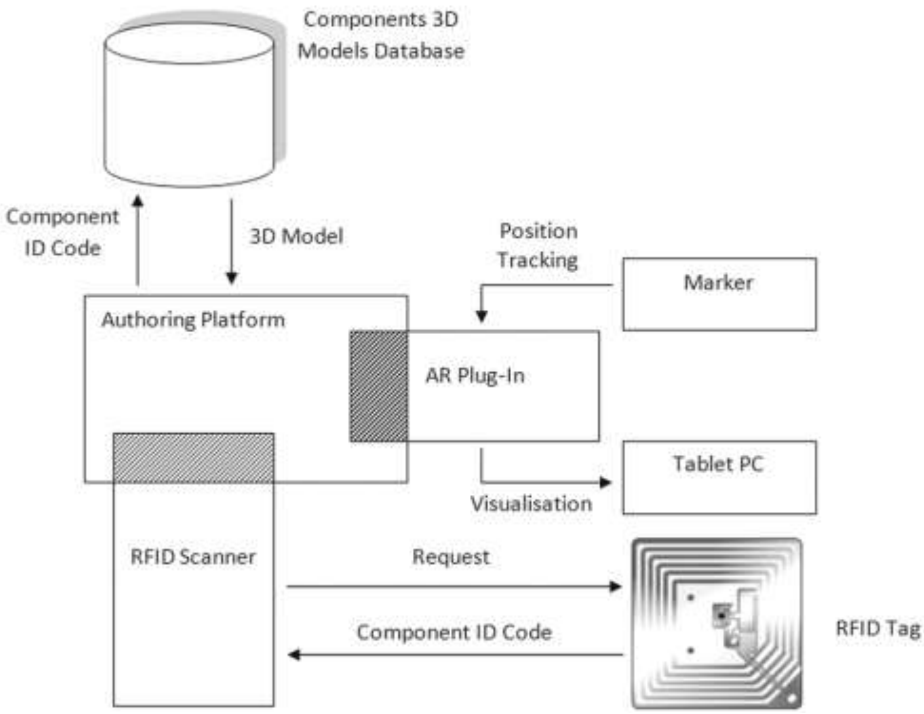

Fig. 2. *AR*. RFID physical structure.

CS101 has a reading range of 11 meters and can be directed sufficiently. A laser pointer can be used to improve targeting. The scanner provides vertical and horizontal polarization of the signal. Scanning is carried out in the 865-868 MHz range. It is also possible to scan barcodes.

This expands the spectrum of possible uses. *CS101* has built-in Wi-Fi, which facilitates communication with the *HTC Flyer* tablet, although it is also possible to use a USB connection. Unfortunately, the *CS101* is a little bit too heavy due to high functionality. Therefore some lighter equipment must be selected and adapted.

The above-mentioned technical feature set is only one possibility. By combining the possibilities of AR and RFID, it allows to create a sufficiently useful solution to identify parts in a warehouse and minimize the possibility of errors.

7. Conclusion

The visualization of results, according to a specific user's perception, which reduces potential errors and costs, is becoming an increasingly topical issue in all economic sectors. It is not wise to lecture a person with visual perception, because such a person only remembers visual material. Logistics is no exception because errors in warehouses can create several millions in damages, even if the component only costs a few euros.

AR solutions are one possible visualisation solution. They allow the user to be immersed in a natural environment and manage the situation and the object. As a result, there is no psychological discomfort, which can be the cause of additional mistakes.

Each solution to the problem has to be economically justified and sustainable. The AR costs cannot exceed the profit of the solution application. This means that the AR solution has to be reasonably priced and functional.

From a scientific standpoint, AR RFID is on the intersection of different industries. It makes sense even if it only brings VR/AR experts and the logistics professionals closer together.

The above-mentioned solution is far from a real industrial application and validation under logistics requirements continues, but these are perspectives for the nearest future.

Parameters of equipment ergonomics and software efficiency and functionality have to be further refined. However, it is clear that such solutions will be used in warehouses in the nearest future and will become a part of large-scale manufacturing systems.

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