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Innovative Hospital Management:
Tracking of Radiological Protection Equipment

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ABSTRACT

The healthcare industry is consistently developing a constant supply of medical equipment, e.g. radiation protection wear. These must be inspected regularly to ensure safety and quality. As this equipment keeps on moving from department to department, it has to be located in one place for annual inspection and must be properly documented after quality check. Conventionally, barcodes, QR codes, and manual entry of the required data are used as a tracking method which requires tedious human efforts without delivering the expected results for registration, tracking, and maintenance. A fully or semi-automated computerized system would be desirable in this case. Radio frequency identification systems which consist of tag, reader, and database can be used for tracking. This article presents new innovative RFID based system which is dedicated to quality assurance of radiological protection wear specifically lead aprons. This process facilitates the service management of hospitals.

KEYWORDS

App Development, Biodesign, Database, Information System, Inventory, Maintenance, Medical Devices, Radiation Protection Wear, Registration, RFID

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INTRODUCTION

Registration, maintenance and service of medical equipment is an important aspect of safety and quality assurance. When it comes to radiation protection equipment, any minor defect can cause severe damage to patients and medical staff. Therefore, such equipment must be checked regularly. Currently, this is achieved by visual inspection test along with a radiation test. In order to acquire quality assurance these equipment and devices are managed by data entry of serial numbers and bar codes using excel sheets. As quality check is supposed to be done periodically which make it quite time consuming as entering departments, examiners, dates, defect, defect type with pictures is hectic job to complete proper documentation in tabular form. This acquisition works relatively well for limited number of articles but normally in Germany every hospital has huge amount of articles such as vests, aprons, thyroid guards and cover plates.

To tackle with this problem, the development of the interfaces was performed in two phases considering the use case requirement in each case. The use cases are derived from the existing manual process. Considering the effort put by an individual in completing the whole process. The time taken by a user in manual format is around 10 minutes for inspection of each item. And an additional time of 30-45 minutes to enter the test results into an excel sheet thus making the task complicated.

By introduction of this mechanism the time is expected to be reduced down to 5 minutes per inspection with an ability to fetch multiple type of reports giving the user more flexibility with the data stored. All this is achieved by assigning each equipment with a unique RFID tag allocated with a 24 hexadecimal ID, herein referred as tag ID. Every article is checked by hand and is located, sorted and processed according to the serial number. There is a need of more efficient, accurate and precise RFID tracking system that can be used to register, track and maintain unlimited number of articles. RFID based system have a lot of applications in many industries and can achieve accurate results. Purpose here is to develop an easy to use system which can encounter every kind of management issues for such equipment. A guided process by support of a computer program and handheld reader can serve the problem or else NFC technology can be used to identify all the devices placed in closed vicinity. This paper will discuss how to set up such a system and how handy and time efficient the application is.

BACKGROUND

One of the case studies form Wayne Memorial Hospital, USA, the “Radar Find” was used as a relevant base example for this survey. This application incorporating RFID is mostly used by medical and support staff to keep track of the location and status of tagged assets including: infusion pumps, diagnostic systems, blood warmers and computers on wheels, wheelchairs and other equipment (Journal, 2018). First few related examples where surveyed in which RFID system has several applications deployed in hospitals and medical clinics. National Cheng-Kung University, Taiwan:

This study showed the usage of RFID for the management of workflow in an emergency department. There the application of the RFID system increased the operational efficiency (Wang, Chen, Ong, Liu, & Chuang, 2006). University Hospital Geneva, Switzerland: RFID-enabled garment tracking application (1995- 2008) was confronted with a specific logistical problem: how to manage working garment within and across the newly merged hospitals (Oranje-Nassau et al., 2018). Royal Alexandria Hospital, United Kingdom: A Wi-Fi tracking system was developed to keep track of and locate portable devices used within the medical block using RFID tags attached to equipment. The review showed and presented individual approaches and benefits for the use of RFID systems, but it unfortunately did not provide a solution for a system that can be used to register several aprons at the same time and quickly access the database to guarantee a user-friendly application interface.

METHODOLOGY

Stanford Biodesign process Identify/ Invent/ Implement (Yock, Zenios, & Makower, 2015) was used for the design of this approach. To identify the unmet clinical need, observational studies were conducted in the hospital. During study of current situation, it was noticed that the service staff were searching and checking radiation protection wear by hand which consumes a lot of time. Moreover, the process was tedious while output results were not precise and accurate. After the observation, interviews and meetings with the responsible person from different medical departments as well as the supervising engineers from the radiation protection department for requirement analysis and feedback at each stage of the project was carried out. Is appeared equipment e.g. a vest shown in Figure 1, worn serial marking, guidelines, regulations and time consuming excel sheet registration by hand were identified as the biggest pains. Bar codes, Serial numbers and QR codes have registration limitations, based on that and the technology review, selection of RFID based system was made to help, streamline and simplify the entire process which is time efficient approach. The project development was focused on following tasks:

1. Clarify the medical guidelines and regulations;
2. Based on guidelines and regulation, finding a hardware solution i.e. RFID tags/ reader with appropriate specifications;
3. Create a database which outputs all required information in a meaningful order and link it to a user-friendly app interface with intuitive operation.

MEDICAL GUIDELINES AND REGULATIONS

The development of an RFID system for the tracking of radiological protective equipment and their physical condition has to follow the DIN 6857-2 guideline in Germany. “DIN 6857-2 states that, for the first time, a standard in Germany regulates the regular quality inspection of X-ray protective equipment in use, which protects the

body Radiation user against X-ray radiation with X-ray tube voltages up to 150 kV in medical radiology. DIN 6857-2: 2016-08 specifies test procedures, characteristics and test periods, from the background: The expert test guideline (SV-RL) demands in almost all medically oriented test report samples (exception to the Veterinary medicine) the presence of personal X-ray protective clothing for the staff and also of patient protection. Protective clothing and Patient protection products must be without defects." [4] As per guideline an automated system for tracking of radiological protection wear is required which can perform quality check in time efficient and in an accurate manner.

RFID- RADIO FREQUENCY IDENTIFICATION

For radio frequency identification, radio waves are used to transfer signals from the tag to a reader. The RFID tag can be active or passive depending on the application. Passive tags are battery-free tags and require high-power readers. The readers send out a low-frequency radio signal that transmits energy over the air that the tags collector antenna picks up the radio waves through force. The tag then transmits back to the reader using a different frequency. The readers gather location data from each tagged device and send this data to the cloud. A location algorithm is then used to triangulate the position of each object being tracked. The tags only have a small memory of just a few bytes to store the required information for tracking. For the application a passive tag was selected as they are very economical and effective for bulk tracking. Tagging objects, such as medical equipment, drugs, etc., is a potential area for use of RFID in hospitals and health sector. RFID is expected to help boost supply chain efficiency, improve security, cut down on theft and counterfeiting, increase asset visibility, enhance inventory control, automate stock replenishment, etc. (Quaadgras, 2005). The use of

Figure 1. Radiological protection vest in Innovation Laboratory for Image Guided Therapy at University Hospital in Magdeburg

RFID based tracking system in health care sector and in particular hospitals will help to create Smart Hospitals, which are in line with ongoing Industry 4.0 initiatives.

Two different RFID readers depending upon different application requirements were selected:

1. The Chain-Way C72 UHF Reader, as mobile based and hand-held reader compatible with developed android application. Mobile is attached with reader which has Android 6.0 as operating system and has wireless connectivity and built-in camera;
2. The IPRO Black Box ERM Desktop Reader USB, which is a compatible with web application interface as in Figure 4. This reader would be helpful at time of registration of devices which could be hectic job with handheld reader and to change the Tag ID names in easy manner. It has features like UHF Plug Play Hardware Keyboard Wedging and Reader (1x ANT / USB).

Fast access and easy registration of more than one RFID tag- so the appropriate registration and check- up of the equipment is possible simultaneous. Then, the Android Phone without the C72 UHF can be used for individual inspections. The IPRO Black Box ERM Desktop is a USB powered desktop compatible reader for initial registration of the equipment.

Figure 2. C72 UHF RFID hand-held reader

Figure 3. IPRO Black Box ERM desktop reader

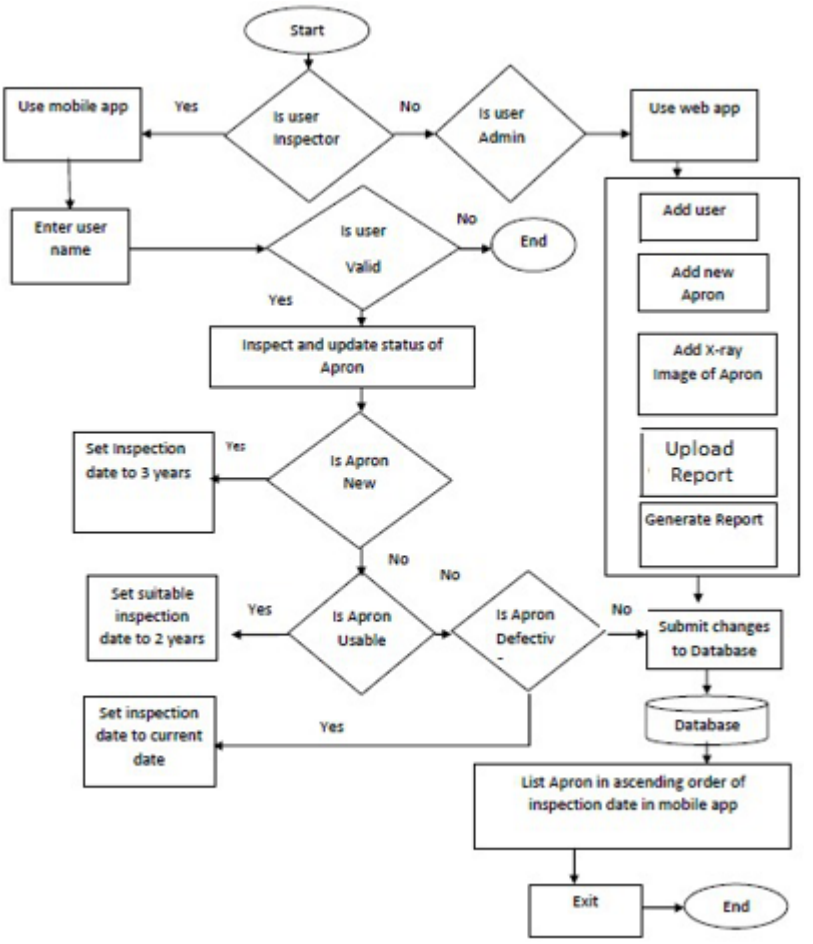
APPLICATION INTERFACE DEVELOPMENT

To achieve the result, two applications were created: a web-based solution and a mobile based solution. The activity diagram for the system is shown in Figure 5. Web interface is used for registration of new equipment along with updating the existing data. Moreover, it contains user management and also user can download the reports. The Web Interface is shown in Figure 7. Requirements: Node-JS, MySQL, React-JS, Android Programming (Java). User friendly navigation, easy accessibility. Development of the Web Application: the application is designed in a way, such that the user has easy accessibility to all the options given within it. The application is supported with a login authentication, keeping it more secure. Registration of a new product: Each item in the inventory needs to be registered once with all the details. First step includes allotting an RFID tag with a unique hexadecimal ID. Each tag is supplied with a default ID which is rewritten using desktop RFID reader. This is done with help of an application supplied by the vendor Tagitron. The assigned tag ID is then used to complete the registration process. Further attributes in it include location/ building where the equipment will be kept, the department, manufacturer details like size, lead content, serial number etc. For the collation of reports: two types of reports can be fetched with the application with scalability for other versions. Detailed report for given date range. This report lists inspections done between two dates with detailed information and remarks as given by the examiner during examination. The Report for Given Date, this report fetches details of total inspections done on a specific day. Web Interface is depicted in Figure 6. All reports are fetched in CSV file format.

For the user management: Security of the data being handled was a top priority. The user authentication mechanism allows only a registered user to access the contents of application. A user can only be created by a root or an administrator user. The application programming interface often referred to APIs allow two applications to communicate with each other. The application in our reference are the web application/ mobile application and database. Each interaction with the data needs to be stored in a database and is communicated with an API. APIs for this project were developed in Node-JS using Express Fast, unopinionated, minimalist web framework for Node.js. A total of 13 APIs were created for complete functionality of the application. 9 Post APIs which take certain input parameters in a JSON body format before delivering the result data and 4 GET APIs which deliver result data based on the parameters within the input string. List of Post API End Points are provided below:

1. /api/register/: Registering a new User
2. /api/authenticate/: Login authentication of a user
3. /api/user/changepassword/: Update or Modify user Password
4. /api/registration/: Registration of a new equipment
5. /api/app/gettagdata/: Details of equipment linked to given tag ID
6. /api/app/updatetagdata/: Updating post inspection results
7. /app/imageupload/: tagid/: Upload images for defects

Figure 4. Flow chart for RFID system



8. /api/getreport/: Report for given date range
9. /api/futureinspection/: Report with equipment to be inspected in future different reports

List of GET API End Points are:

1. /api/unamecheck/: username/: Checks existence of given username during user registration
2. /api/app/images/: public/: uploads/: folder/: filename: To download/save image stored in local file system.
3. /api/getdayreport/: date/: Fetches report for given date
4. /api/pingcheck/: Checks connectivity with the server

The project is powered with MySQL relational database. Apart from the registration of equipment the user can also download periodic test reports or tests conducted on

Figure 5. Get and post server-side APIs used to achieve the desirable functionality

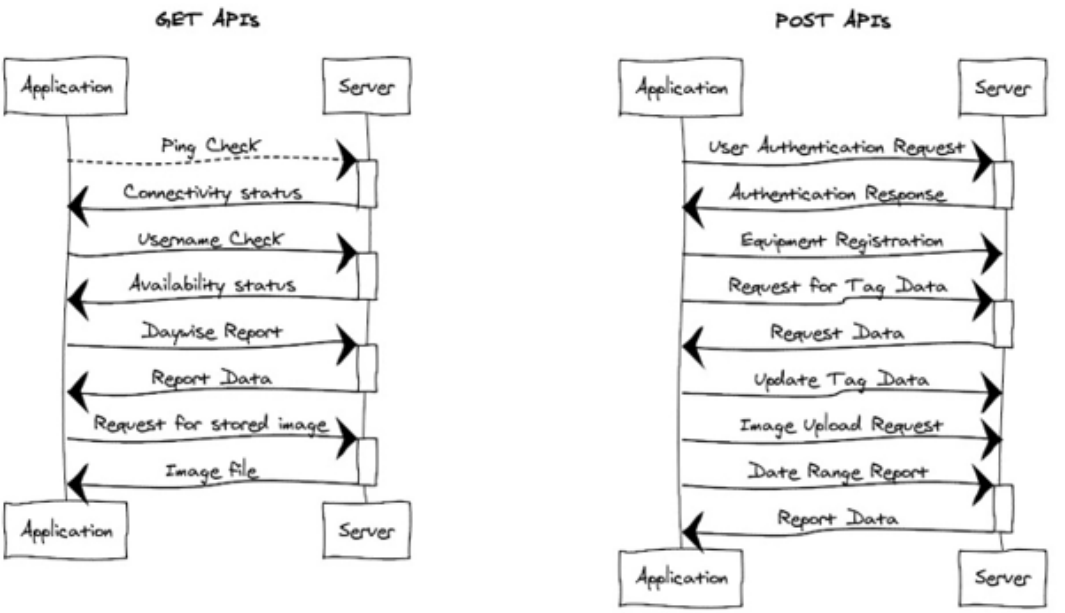
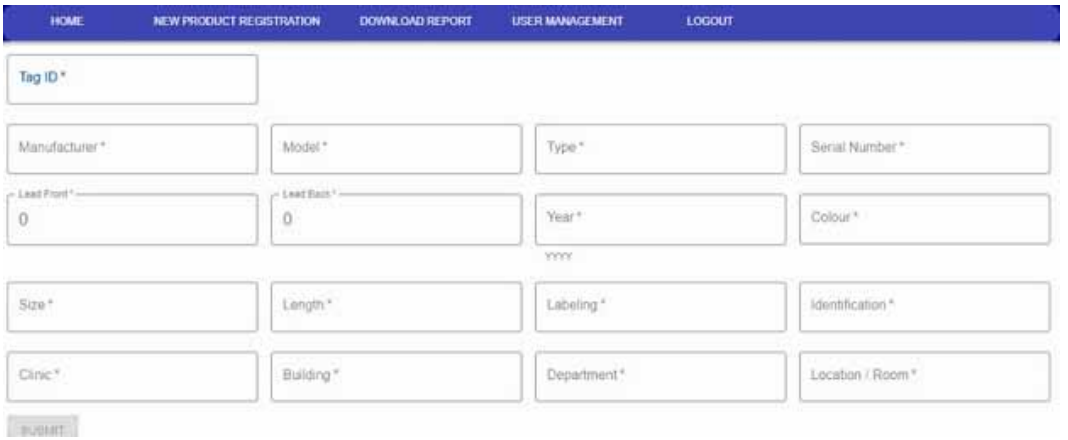


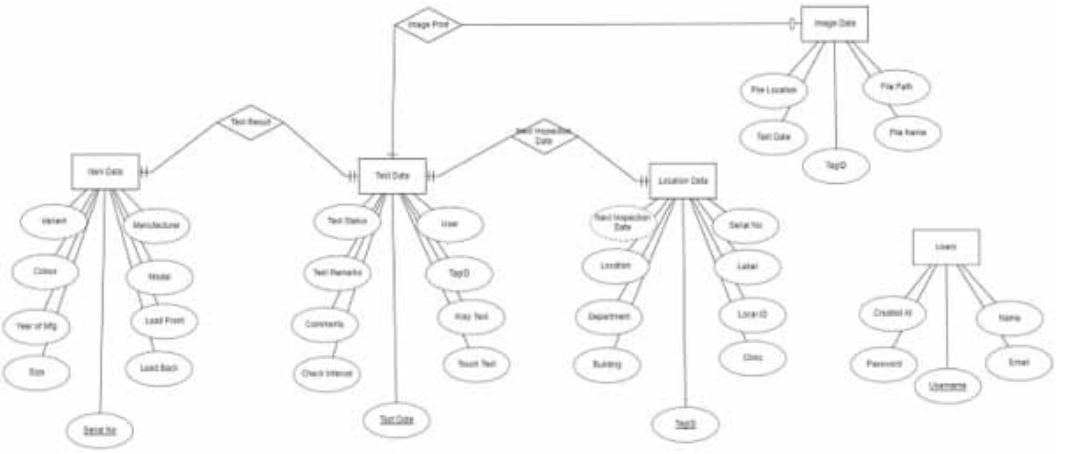
Figure 6. Web interface for registration of new vest and interface for printing



a selected date which are generated as a csv file. Besides this there is also a user-management section where one can change their password or create a new user who can access the web app interface. Entity relationship diagram for database is shown in the Figure 8. The frontend is driven by strong backend APIs which support as a backbone to access data or create new entries to the data in database. Database schema can be seen in Figure 9.

The android app RFID UHF App is another part of the RFID management system. The app is used for the time management of inspections date for the Aprons. Mobile application is built on java using Android Studio IDE. Once application is open, in

Figure 7. Entity relationship diagram for database



the landing page of the application, firstly, the tag on the aprons are scanned with the RFID reader using the android app. If the scanned Tag ID is available in the database, after scanning they are populated in ascending order of date of inspection as shown in Figure 12.

Then, inspector can go into inspection management activity by touching in one of the Tag ID shown in Figure 13. The description of various fields in the inspection management activity are as follows:

1. **Date:** Displays current date;
2. **User:** Field to enter the identity of the person conducting inspection;
3. **Tag ID:** Field where tag ID from is read by the mobile app using RFID reader;

Figure 8. Diagram for database schema

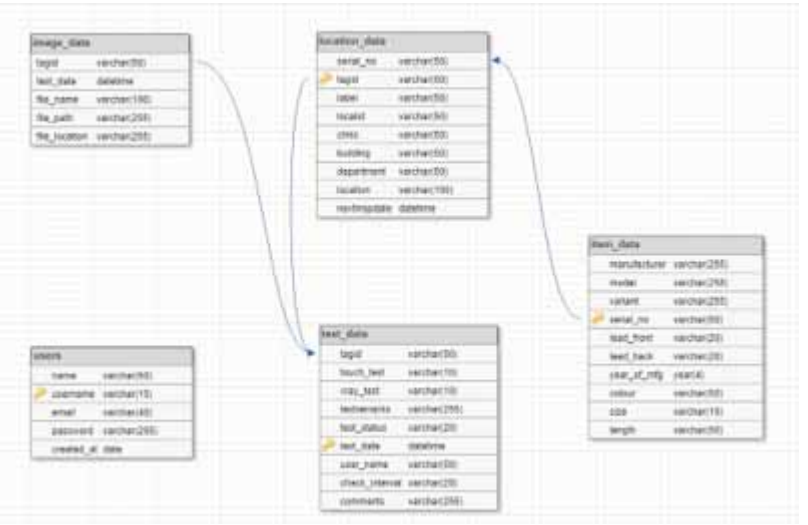


Figure 9. Classes: RFIDINFO and UHF ReadTagSegment

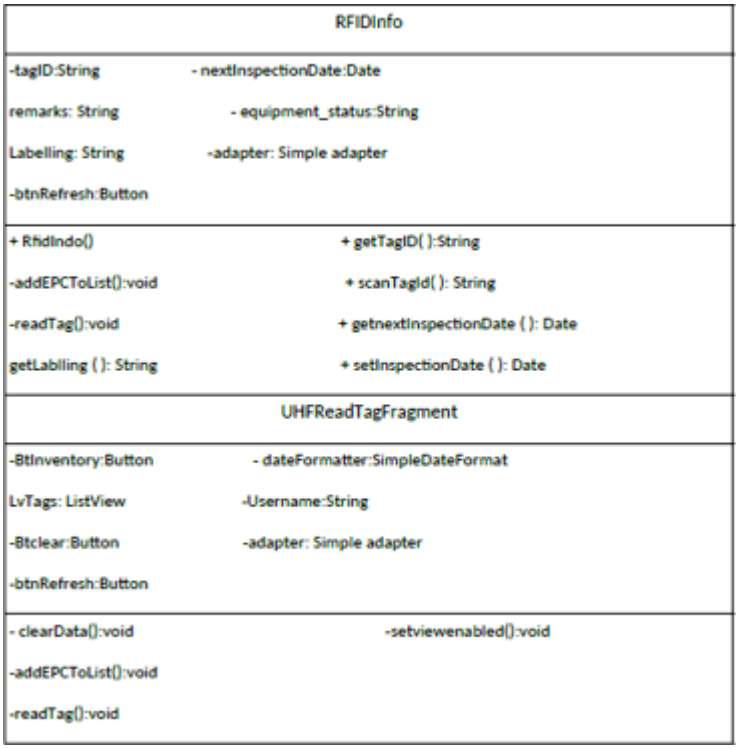
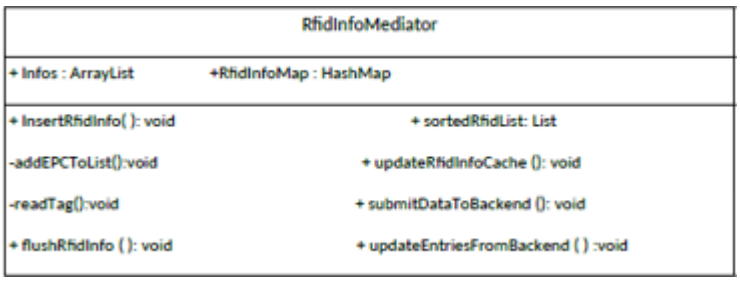


Figure 10. Class: RFIDInfoMediator



4. **Touch test:** This field has three possible choices in drop down menu: Ok, Defect and Mangel. One of the status is chosen by the inspector. In case of Defekt, further X-ray test is conducted;
5. **X-ray test:** This field also has three possible choices in drop down menu: Ok, Defekt and Mangle. One of the status is chosen by the inspector;
6. **Next inspection date:** This field displays next inspection date based on the current date and choice in the X-ray test;
7. **Remark:** In this field, remark about the particulars about wear or defect is given as input by typing;

8. **Comment:** This field is used to give overall comment for the status of the vest/ equipment;
9. **Photo capture, storage and upload:** The photo can be taken from the inbuilt camera of the RFID reader, touching on camera field. And current photo can be uploaded, with enabling check mark in the Upload current field;
10. **Cancel:** This field is used to cancel any changes made without updating it;
11. **Submit:** If the inspector is satisfied with the input, he/she can press submit and the data is sent to the server and stored in the database.

The major classes for the android application are shown in the figure below: When inspector chooses the condition of the Vest from the Touch test and X-ray test, depending upon the choice (Ok, Mangel and Defekt), the next inspection date is set. If Mangel is selected, next inspection date is set for 2 years and in case of Defekt, date is set for current date. This is then fed into the database, which automatically updates inspection dates.

For defective Vests, pictures can be taken from camera, which can be then uploaded to server using the RFID UHF App. Once new entry is made to the application, it can be submitted and sent to the server. When the same tag ID is visited by the inspector, past history of particular saved Tag ID can be seen in the application.

After the software and database development, multiple trials were performed for registration of radiation protection was at the Innovation Laboratory for Image Guided Therapies from the Chair for catheter technologies in Magdeburg, Germany

Figure 11. Mobile interface populating scanned vests

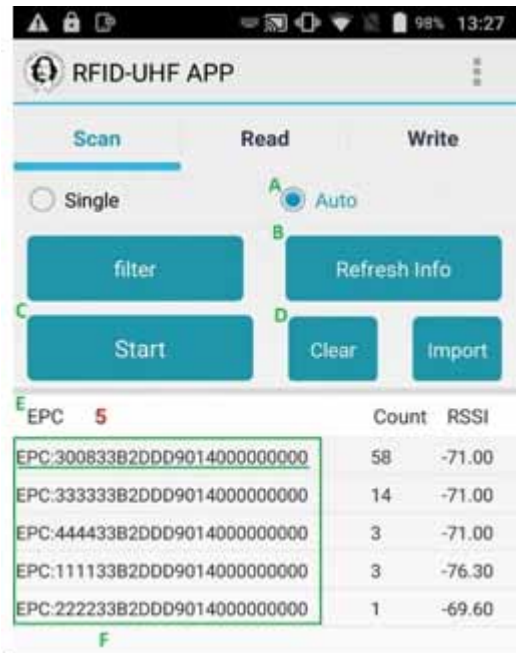
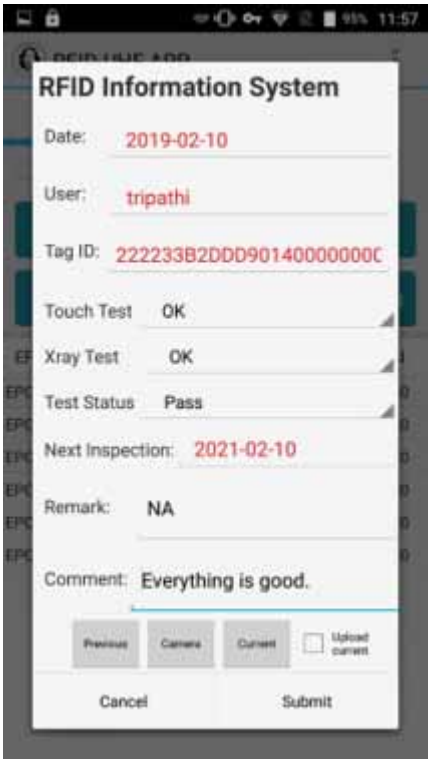


Figure 12. Mobile interface for updating the status of vest after inspection



under supervision of technical officer from University Hospital. Four units of different radiation protection (vests) were read and tested successfully. It was possible to read all of them simultaneously or perform individual tests with fast access to the data from the database which guarantees a user-friendly application interface.

After implementation of RFID system in Innovation Laboratory for Image Guided Therapy from the Chair for catheter technologies in Magdeburg, Germany some new attributes were recommended to be added which were then incorporated. The Client was satisfied after incorporation of his input: one of the main input was that University Hospital Magdeburg has radiological equipment in multiple radiology departments and in sixty different buildings so the fields of departments, building, location and clinic were added later. The RFID tags were attached to the shoulder area of vests using double tape, which prevents them from being obscured and allows constant accessibility and legibility. One of the problems that cannot be solved yet are interference signals. These interference signals can make a data transfer difficult. Also, privacy and security issues must be taken into consideration for future implementations.

CONCLUSION

In conclusion, the project was performed on radiological protection equipment. It was possible to create a complete database-based App interface for reading out the RFID tagged radiation protection wear. The DIN 6857-2 guideline demands that radiological protection equipment is used in all radiology departments in Germany and they're also dealing with the quality assurance. Our implementation saves time by identifying multiple objects in less time. The performance of RFID tagged system was evaluated for further development on a larger scale according to the customer needs. The implementation involves:

1. Registration of new equipment in the database;
2. Periodic checking of status of equipment;
3. Periodic status marking of equipment (whether it is defective or defective free) and assigning timeline for rechecking of material for efficient management of radiological protection equipment as per DIN 6857-2 guideline.

FUTURE WORK

This can ensure that in the future high costs can be avoided in the registration, inspection and service processes of radiation protection and also for other medical devices and streamline the whole process. Up scaling and integration of the developed RFID system with the existing system for our University Clinic in Magdeburg will be carried out in a next development step. In the future, it will be possible to benefit other areas as well: everyday hospital objects can be networked together and coordinate the healthcare sector more efficiently. Systems can independently determine which equipment is missing and therefore need to be re-purchased or if additional tracking facilities/ options help to find it again. Automated scanners can assure that each and every instrument is quality assured and defect free.

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REFERENCES

DIN 6857-2. (n.d.). Mavig.de; http://www.mavig.de/din-6857

Journal, R. (2018). At Wayne Memorial, RFID Pays for Itself. *RFID Journal*. Retrieved from http://www.rfidjournal.com/articles/view?3199

Quaadgras, A. (2005). Who joins the platform? The case of the RFID business ecosystem. In *Proceedings of 38th Hawaii International Conference on System Sciences*, HI. Academic Press. doi:10.1109/HICSS.2005.693

Ustundag, A., & Kilinc, S. (2010, June). Design and development of RFID based Library Information System. In *Proceedings of the 6th international symposium on management, engineering and informatics*, Orlando, FL (Vol. 30, pp. 234-238).

van Oranje-Nassau, C., Schindler, H. R., Valeri, L., Vilamovska, A. M., Hatziandreu, E., & Conklin, A. (2009). *Study on the requirements and options for Radio Frequency Identification (RFID) application in healthcare*. Rand Corporation.

Wang, S.-W., Chen, W.-H., Ong, C.-S., Liu, L., & Chuang, Y.-W. (2006). RFID Application in Hospitals: A Case Study on a Demonstration RFID Project in a Taiwan Hospital. In *Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS06)* (pp. 184a-184a). Academic Press. doi:10.1109/HICSS.2006.422

Yock, P., & Zenios, S. (2015). *Makower, J.: Biodesign: The Process of Innovating Medical Technologies* (1st ed.). Cambridge University Press. doi:10.1017/CBO9781316095843

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