Automated recording and processing of lecture attendance data using RFID student cards

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Automated recording and processing of lecture attendance data using RFID student cards

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***Abstract*—Aspects of the ongoing project to automate the recording of students' lecture attendance using RFID cards and automate processing of the records without a university wide infrastructure are presented and discussed.**

Keywords – students' attendance monitoring, RFID cards, automated data recording, automated data processing.

I. Introduction to the Project

A. *Project Motivation*

Often when completing an assignment in the lab a student would ask "I do not understand how does X work, could you please explain?" Sometimes this X was discussed in detail during a full lecture. A short answer would leave the student unsatisfied, but going through the lecture for just one student would leave little lab time available to the others.

With the lecture attendance register on hand, the lecturer could reply "We have dedicated to X a whole lecture, which you unfortunately have missed. Here in the lab I have Y minutes per a student on average. If I could present X in Y minutes, I would do it at the lecture at the first place. Please have a look at the lecture handouts first, some additional resources are mentioned at the learning portal for the module, and I will be happy to have a short discussion afterwards". This would not only help the student who missed the lecture, but also be fair to the students who were present for the topic in lecture theatre.

B. *Reasons for not monitoring students' attendance*

There are good reasons ***not*** to monitor students' attendance. First, any monitoring procedure would take time and attention away from the lecture's content. It would also unnecessary reduce flexibility for time planning of some generally well attending students, lowering their satisfaction. Additionally, some students may believe (rightly or not) that they can cover the lecture material on their own, especially if they perceive (again, rightly or not) the lecture's content or the presenter as not addressing their needs sufficiently. Finally, students at this education level are believed to be responsible adults who do not need their attendance to be policed.

C. *Reasons for monitoring students' attendance*

Most people would agree that better attendance leads to better attainment. Surprisingly, convincing studies on this topic with solid evidence are difficult to come by. A strong correlation between attendance and attainment is evident from a reliable subject neutral dataset, collected from several school children of various ages [1]. Whether attendance is the only or the most important factor in greater attainment cannot be judged purely from the correlation data. Both attendance and attainment could be simultaneously influenced by some fundamental, difficult to quantify causes such as student ambition, background, attitude *etc.*

Another reason for introducing attendance monitoring is related to the students' behaviour as a group. When some students can consistently get away with non-attendance, it lowers the morale and motivation of the attending students.

There are several instances when attendance monitoring at an educational establishment is required by law in the UK.

Parents are held legally responsible for their children's attendance at school, and can be fined by local authorities for non-attendance of more than five days or arrival at the school after the close of registration [2]. The number of parents fined was approximately 90,000 in the academic year 2015/16 [3]. Truancy cases are continuously contested in courts (nearly 20,000 cases in England in 2015 alone) with the most famous case being that of Jon Platt. He, despite several preceding court rulings in his favour, was eventually found guilty of truancy by the Supreme Court at a total cost to the taxpayer of £140,000 [4].

Another example of legally required attendance monitoring concerns students outside of the European Economic Area who arrive in the UK on Tier 4 (general) student visas [5]. The educational institutions, which sponsor these students by issuing unconditional offers to study, must monitor the students' attendance. An institution may lose their sponsoring status (and thus the ability to admit new foreign students) if they fail to produce attendance records on request.

Finally, attendance monitoring is required for higher degree apprenticeships currently being developed. Students' learning time is paid for by their employer, and proper timekeeping becomes an obligatory part of the contract among the parties involved.

Another consideration is fairness. In most workplaces not attending a scheduled activity is misconduct. If tuition fees are paid out of public or sponsored funds, not attending scheduled learning activities could be considered misconduct as well. Even if funding comes from a commercial student loan or family funds, most future employers or customers would like to have assurances that their surgeons or pilots spent all the scheduled hours learning their trade.

D. Methods to monitor students' attendance

At present paper registers are used at our university (SHU). The register contains a photograph of each student and signature fields for scheduled sessions. Sometimes the register is passed from one student to another and some sign for themselves and also for their friends. If each student comes to the lectern to sign in person, a substantial time is required.

Alternatively, the lecturer can call every student and mark the register herself/himself. This procedure becomes time-consuming for large classes where attendance rates are usually lower compared to the small group classes where each student is visible to the teacher clearly. The lecturer could do random checks a few times during the term and use the sample data, for example, to allocate additional questions at oral examinations. However oral exams have become a rarity, thus this approach has lost its appeal to lecturers.

The paper register could also be kept by appointed student representatives, but this approach is not 100% accurate either.

A reduction in time, along with increased accuracy of recording, could be expected if automated tools quickly identified any student in the class. One can envisage simply taking a picture of the class and identifying all the students present by some means of artificial intelligence. However, such a scenario is unlikely to become viable in the near future, and a biometric or unique token identification is used instead. Biometric sensors (such as fingerprint or iris) require more time to operate compared to the alternative, and might raise privacy concerns.

On the other hand, each student is supplied with a student ID card, which is used for borrowing books from the library, accessing premises, *etc*. Common student ID cards use barcodes (ubiquitous for goods in shops) or RFID (radio frequency identification) tokens, or both (for example, SHU cards). Barcode readers require close optical proximity to the card and particular viewing angles; RFID tokens are non-sensitive to the orientation, thus should operate faster.

The token identification system can be deployed over the entire institution (like the University of Westminster, UK) but deploying and maintaining the required infrastructure in every teaching room may be rather costly. Alternatively, a lecturer could have a standalone reader with sufficient memory to take records in the teaching room and process them later in her/his office.

E. Aim of the project

To develop a quick, easy to use procedure for recording student attendance at lectures using their RFID cards, and later automate the processing of the collected data. Hardware should be fully integrated and autonomous, and any software should not be tied to a particular platform or operating system and require minimal effort to install, maintain and use.

II. PASSIVE RFID BASICS

Passive RFID cards were developed to facilitate small frequent payments, e.g., for transport fares [6]. The cards are based on an electronic circuit with an antenna that absorbs energy from an RFID card reader, located in close proximity, to power the card. The antenna is also used to return requested data to the reader by altering levels of energy, absorbed from the reader.

There are three distinct operating frequency bands utilised with RFID cards of different types. Moreover, within every frequency band there are several non-compatible data exchange protocols introduced by different manufacturers and later standardised internationally (such as ISO 14443 standard with type A and type B cards [6]).

The most commonly used RFID cards seem to be Mifare Classic cards, compliant to ISO 14443 type A specifications. These cards feature globally unique four-byte card numbers, allowing the use of approximately 4.3 billion unique cards. More recent RFID cards utilise considerably longer addresses, allowing more cards to be used globally. The address is not hidden or encrypted, thus can be read by any compatible RFID reader. There are reports that addresses of some Mifare cards can be set at will [7]; therefore, these addresses themselves should not be used with anything related to security or value.

In addition to their unique addresses, the cards have encrypted read-write non-volatile memory, where, for example, personal or financial information can be stored securely. The level of security, offered by common RFID cards, is trusted by transport operators for fare collection (Oyster cards are used by Transport for London), defence ministries for granting access to restricted premises (Common Access Card in the USA), leading financial institutions for authorising payments (Visa and Master Card) and many governments (biometric passports). The details of encryption are proprietary for obvious reasons (security by obscurity), and RFID card issuers are not keen to make any of these public.

Widespread use of RFID technology brought about the associated risk of card misuse or fraudulent access to stored information. At the consumer level there is the possibility that fake purchase authorisation can be initiated by a fraudster, equipped with a mobile RFID payment terminal. Cautious RFID card users who do not want to risk a contactless payment taken covertly can place a piece of aluminium foil, acting as an electromagnetic energy shield, into their wallets. This makes the interaction of a covert RFID payment terminal with their cards more difficult. To limit the possibility of accessing sensitive information, the US Department of Defence ordered over 4 million sleeves to shield the Common Access Cards of military personnel in 2010 [8]. Because of potential vulnerabilities, any RFID reading equipment should be sufficiently trusted not to read, alter or erase any information stored on the card. An additional complication in the case of SHU cards is their use as a payment card at the university. This increases both the cards' vulnerability to security breaches and potential liability for altering or damaging the card by faulty or malicious RFID card reader. If damage occurs during attendance recording liability needs to be met by the card's manufacturer, SHU card vendor, RFID reader manufacturer, or the software/firmware developer. The university's or lecturer's liability can be avoided completely if all transactions are conducted by an external RFID card vendor, maintaining and operating the complete RFID card infrastructure, but this is costly. We believe the use of open source hardware and software for the reader, that can be audited independently if required, can be an assurance of the reader's safety for all relevant stakeholders (students, RFID card vendor, and university administration).

Using the above considerations we concluded that using student RFID cards as unique tokens for attendance monitoring is viable, but the associated development should be based on open source designs as much as possible to avoid potential security breaches and excessive liabilities.

III. Past progress and outcomes

The viability of the project was established in the academic year 2015/16, when a student as his final year project developed a device, which used workplace issued RFIDs to lock and unlock equipment for safety purposes. It was found that an inexpensive MRF522 module could reliably read the SHU RFID card numbers. An MSc student completed the design of an Arduino-based RFID card reader as part of his project in January 2017. Since then the reader has been used to record attendance at lectures for a significant number of students (50–60). The development was reported at the annual SHU teaching and learning conference in June 2017 [9]. In December 2017 a departmental teaching enhancement grant was awarded to support this project.

Continuous use of the card reader led to hard learned lessons:

- the register is best taken at the end of the session when the students want to leave the room as quickly as possible; taking it at the start of the class is not convenient as some students will be late; taking it in the middle requires more time as students tend to get their card out only when the lecturer is in front of them;
- make sure students leave the room after swiping their card without attempting to swipe a card for another student; the best place to take the register is near the room's exit, if students need to come to the lectern or somewhere else it causes overcrowding;
- students occasionally forgot their cards, damaged the card's antenna, or did not have valid cards at all. There must be a paper register for such students to write their names, which is to be processed manually;
- the prototype device consisted of three pieces—the device enclosed in a splash-proof case, a power bank, and USB A to micro USB B cable. Occasionally one piece of this kit was forgotten in the office and automated registration could not take place;
- processing the collected data in real time was very complicated due to time pressure and difficulty in developing intuitive software to handle the required procedures;
- some students wanted to swipe their wallet but the presence of other RFID cards tended to confuse the reader as collision detection was not easy to implement in the firmware.

These experiences reinforced the need to have a single piece of equipment that is lightweight, battery operated and can be held single-handed.

IV. Recent project developments

The teaching enhancement grant was awarded to develop a better integrated front end electronic RFID reader for raw data collection without inconveniences (a single piece of equipment) and design flaws (despite the MFRC522 module reliably operated with 5V Arduino Uno digital output pins, this voltage level was not specified by the manufacturer of the integrated circuit - IC). Additionally, the back end software to aggregate the collected data into a common Excel spreadsheet needed to be developed.

A. *Custom built RFID logger*

A few options for the sensing IC and associated module were considered, namely MFRC522 (reads type A tokens), PN532 (type A and B), and THM360 (type A and B). Any of these ICs can be used to build proximity readers, which read tokens at short distances. A much better range, desirable for this application, was observed in CR95HF transceivers, which read not only types A and B tokens but also support longer range ISO standards for vicinity readers. There are code examples and hardware options available to implement an RFID reader based on this IC (for example, various software, hardware and firmware options listed on the product page [10] and third party compact PCB module [11]). This transceiver must be complemented by a microcontroller (MCU) in order to build a standalone device. We selected STM32F103 MCU from the same manufacturer STMicroelectronics. LiFeO4 rechargeable cell with a compatible charger powers the design. This cell chemistry was selected as its voltage is safe to use with both the reader and MCU ICs without any additional circuitry, allows more charge cycles and the cells are generally safer to use compared to cells utilising other energy denser Li-ion chemistries.

B. Off-the-shelf RFID reader

This option was only attempted for completeness but was found quite robust and convenient for the application. Some of the purchased RFID readers cost as little as £10 and operated as a standard keyboard without the need to download, install or utilise any proprietary drivers, software or software development kits. Of the three readers purchased one operated perfectly with every computer tried, one occasionally put an extra new line character inside the read number, and one was found operating at the frequency of 125 kHz. Sometimes readers of the same design are offered for either 125 kHz (labelled ID) or 13.56 MHz (labelled IC). Two ICs were found inside the 13.56 MHz readers. Unfortunately, their labels (SYC8P1213 and SYC8P1223) were unknown to Google. We believe these readers can be used safely as they do not seem to do anything except read RFID card numbers. However, having control over the reader's firmware (i.e. operating a custom fully developed reader) is a more reliable option to avoid potential liability and data leakage.

The best reader was tested alongside the prototype and recorded the same card numbers in the right sequence. The card numbers were reported in decimals to an Android-based smartphone through a USB on-the-go (OTG) cable. The phone was running a text editor application and the file with the recorded numbers was saved, then emailed to the office computer for later processing. An added convenience of the off-the-shelf reader was an audio beep in addition to flashing LEDs when the number is read successfully.

C. Back end software

We aimed to develop software that can be deployed on a variety of computers (including single board computers like the Raspberry Pi) and operating systems, hence selected Python as the programming language. The attendance records are commonly kept using Excel spreadsheets and can be accessed from custom Python code using a free and open source ***openpyxl*** library written in pure Python (thus there were no dependencies on other modules).

The developed code operates as follows. The user copies the recorded numbers and pastes these into a new column of the spreadsheet following previously processed data. This column is copied into a reserved column by the software, then cleared. Each entry in the copied column is checked against each entry in the valid RFID numbers column, which must be prepared in advance for every class. If the entry is not valid then an error message is generated. Otherwise the entry is placed in the same row where the valid number was found. At the end of processing the numbers for every session will be placed in the same row and blank cells will represent absences.

This custom Python code was tested with the data sets recorded over many lecture sessions, and operated correctly for the class size of approximately 60 students.

V. Conclusions

We believe that encouraging student attendance at lectures by keeping a record is beneficial for learning, the morale of the class, and society. To reduce the time and effort required in keeping attendance records, we are developing hardware and software for individual automated use by lecturers. It reads RFID student card numbers in the class and processes the stored data in an Excel spreadsheet. At this stage we have fully prototyped a custom RFID reader and successfully used an off-the-shelf RFID reader with the developed software for classes of 60 students attending 12 lecture sessions for two academic years.

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