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Automated attendance management systems: systematic literature review

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Abstract: Attendance systems have been rated as amongst the critical issues that reflect domain achievements, and their performances have contributed better to organisations, industries and universities compared with traditional methods that are time-consuming and inefficient. Different automatic identification technologies have become trends, and extensive research conducted and many applications produced to maximise technology features. To address issues related to attendance system technologies, including the advantages, schemes and methods and obstacles, we present a structured review of attendance management systems, with high potential for managing, recording and tracking the presence of users in different domains. Additionally, this study introduces a detailed literature survey schema for article categorisation. Out of the 204 identified papers, 90 were found relevant in the context of this review. The selected articles are comprehensively reviewed, criticised and assessed in accordance with Kitchenham's guidelines for systematic literature review. Lastly, we highlight the significant direction required for future research.

Keywords: AMS; attendance management system; attendance systems; automated registration; automatic; RFID; barcode; biometric; magnetic stripe.

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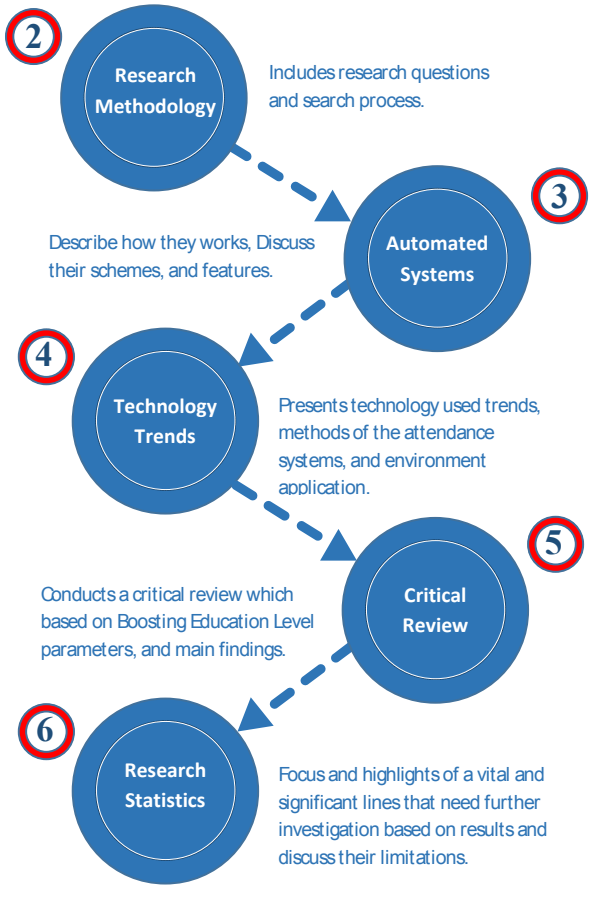
1 Introduction

Information Technology (IT) systems have become one of the primary tools for many organisations to support, sustain and increase their businesses (Zakaria et al., 2018). Universally, IT represents an essential tool that helps countries enhance their respective economies in the educational and industrial sectors (Yuru et al., 2013; Sunehra and Goud, 2016; Oliveira and Martins, 2011; Alathari et al., 2019). Therefore, an Attendance Management System (AMS) is a critical standard that measures organisations' efficiency.

AMS enables these organisations to keep track of attendance; assess their employees, university staff and students and promote consistent attendance (Sayanekar et al., 2016; Noor et al., 2015; Shoewu and Idowu, 2012). In academic institutions, managing student attendance can encourage on-time presence, improve learning outcomes and boost education levels (Kohalli et al., 2016; Kurniali, 2014; Alhilali et al., 2019). From the industrial sector perspective, attendance systems can be used to analyse human resources, control daily attendance, monitor leaves and absence records and transfer overtime information to payroll systems (Jacob et al., 2015; Shakil and Nandi, 2013). In the digital era, several automatic attendance systems have been proposed to reduce the use of traditional attendance methods, which have numerous disadvantages, such as being time-consuming, lost attendance sheets and unauthorised people possibly signing for others (Agrawal and Bansal, 2013; Verma and Gupta, 2013; Ali and Alyasseri, 2017). These systems use different technologies, such as Biometrics, Radio-Frequency Identification (RFID), magnetic stripe and barcode, which are characterised as having high-level data accuracy, speed, security and extensive usage (Walia and Jain, 2016; Patel and Priya, 2014; Arif et al., 2018). However, the biometric purchase and operating cost are higher than those of other technologies (Rjeib et al., 2018). Figure 1 shows the organisation of this paper, particularly the research protocol consisting of five sections.

Figure 1 Research Protocol



2 Research methodology

This study follows the guidelines of the systematic literature review of Barbara Kitchenham (2004). Particularly, the current research aims to provide a systematic literature review of automated attendance-based system and their corresponding research technologies. This study will also focus on the related techniques and scheme-based approaches.

2.1 Research questions

This study answers the following Research Questions (RQs):

1 What are the currently available automated systems used to register, track and monitor attendance?

2 What are recent technology trends that have produced and used attendance systems and their classification?

3 Which techniques and domain fields use an attendance system?

4 What are the main findings and limitations of the proposed attendance system in diverse domains and settings in the literature?

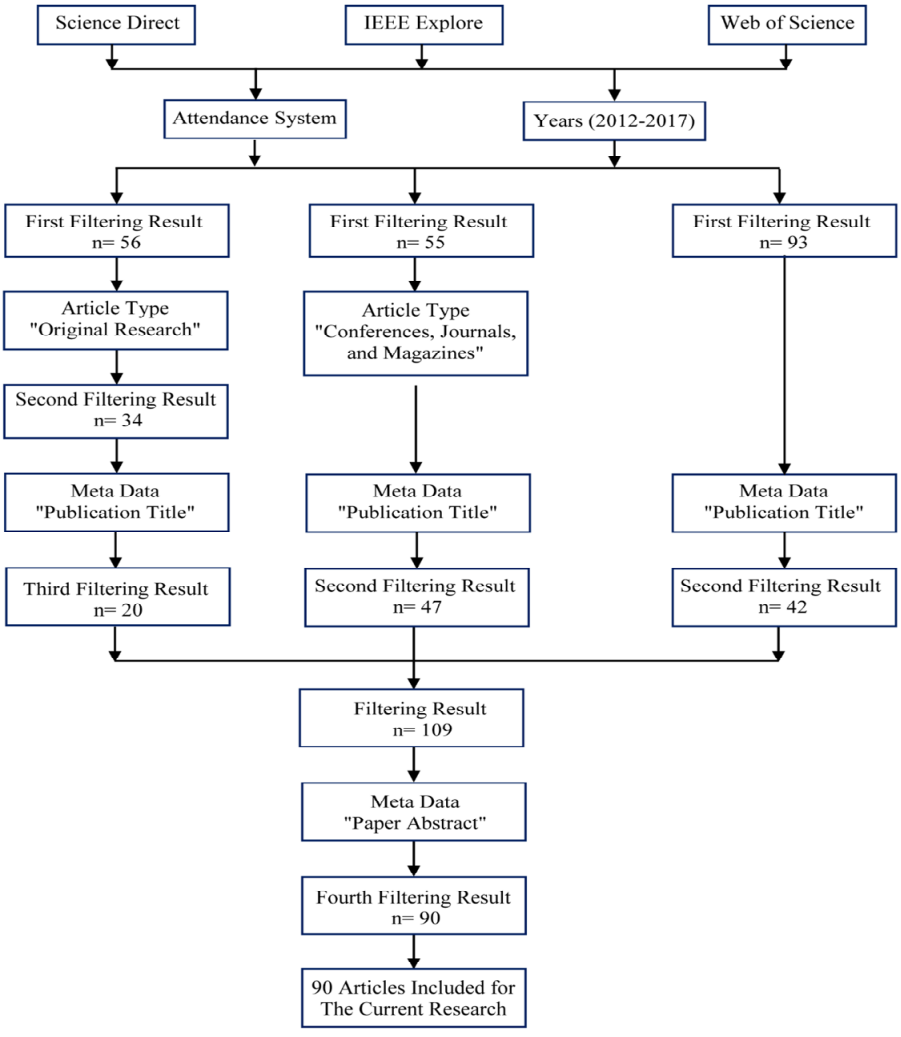
5 What type of information is required to identify and focus on the critical line of existing technology? How could such an information assist future research?

To address RQ1, we conducted a search process and filtering of several scientific databases, such as Science Direct, IEEE Xplore and web of Science. The details of these search process and screening are presented in the next subsection (Sub-section 2.2). To answer RQ2, we developed a list of criteria, such as system-based, technology used and scheme to focus and classify each attendance system (see Section 4). To process RQ3 and RQ4, we produced a comprehensive information table in Section 5 to clarify and categorise techniques and domain application, thereby boosting education level parameters and main findings of the systems. Lastly, RQ5 is answered in Section 6, which identifies and highlights the critical and vital direction of previous research for the benefit of further studies.

2.2 Searching methods and filtering iterations

This study used data collection methods based on multiple sources. The first attempt aimed to find all synonyms of attendance systems and use them as a searching standard (Ali, 2018). The selected primary keywords related to the research scopes are ‘attendance systems’ and years from 2012 to 2017. Search methods were performed on reliable databases, such as web of Science (ISI), Science Direct (Scopus) and IEEE Xplore (IEEE), covering the period 2012–2017, as shown in Figure 2.

Figure 2 Search methods and filtering iterations



The methods used for data collection was based on multiple sources and four iterations of filtering, as shown in Figure 2. The first iteration aimed to find all the attendance criteria. In this iteration, the selected keywords, which include 'attendance systems' and 'years (2012–2017)', was related to the study scope. Searches on reliable databases, such as web of Science (ISI), Science Direct (Scopus) and IEEE Xplore (IEEE) from 2012 to 2017, were undertaken. After applying the main keywords filters, the search engines derived 56 papers from Science Direct (Scopus), 55 articles from IEEE Xplore (IEEE) and 93 studies from web of Science (ISI). Hence, the result of the first iteration and filtering was 204 studies. The second filtering or iteration was based on 'publication types' with time duration (2004–2017). The search engines derived 34 research from Science Direct (Scopus) after filtered results focused on 'original research' as an article type, and 55 papers from IEEE Xplore (IEEE), although filtered search results were

based on ‘conferences, journals and magazines’ as publication types. Subsequently, the results for the second iteration and filtering were 182 studies. The third iteration and filtering was on ‘publication title’ as metadata and found 20 research from Science Direct (Scopus), 47 papers from IEEE Xplore (IEEE) and 42 studies from Web of Science. The third filtering result is 109 papers. Excluded were 19 studies after reading their abstracts, thereby leading to the fourth filtering result of 90. Hence, 90 articles are included in this study as the basis of conducting a critical review and evaluation.

3 Automated attendance systems

3.1 RFID

RFID technology is a wireless sensor technology that depends on electromagnetic signals detection (Domdouzis et al., 2007; Kumar et al., 2016). An RFID system typically includes three main components: RFID reader with antenna, RFID tags and a database to store the records (Younis et al., 2013). RFID attendance systems can be used for identifying and tracking the attendance of workers in any workplace. For example, each person can have an ID card integrated with an RFID tag that has a unique number (Patel et al., 2012). These ID cards should pass near an RFID reader that covers up to at least 100 feet to register the attendance records.

3.2 Biometric

Various biometric technologies can be used to implement automated attendance systems (Rjeib et al., 2018). These technologies are used to verify and recognise living persons’ identities based on two characteristics, namely, behavioural and physiological (Walia and Jain, 2016). Behavioural symptoms include fingerprints, facial images and iris prints. The other attributes, such as voice and signature recognition, represent the physiological attributes (Chiagozie and Nwaji, 2012). The fingerprint is one of the most used biometric technology for AMS because each person has a unique fingerprint, whilst security and cost efficiency make the attendance systems that use fingerprints environment-friendly (Walia and Jain, 2016). Fingerprint-based AMS use particular devices that have the ability to record attendance and store fingerprints in a database. Individuals will place their respective thumbs on a fingerprint device, in which the captured fingerprint will be compared with a pre-registered list of users stored in a database. When a match is found, the particular person will be marked present (Shoewu and Idowu, 2012).

3.3 Barcode attendance system

Barcode technology is commonly used to implement attendance systems because of the efficiency of individual tracking provided by this technology; in a barcode-based attendance system, every individual will receive a badge or card that has an integrated barcode; a barcode scanner device integrated with a configurable time clock can be used to check in or out of the organisation by swiping the badge or card on it. Accordingly, the system administrator will be able to update and maintain all the attendance data captured by the device’s internal storage (Chiagozie and Nwaji, 2012).

3.4 Magnetic stripe-based attendance system

A magnetic stripe-based attendance system has two main components: a card with a magnetic stripe containing the encoded data of a person, and a time clock reader that stores the check in and out records bypass the card through it (Chiagozie and Nwaji, 2012).

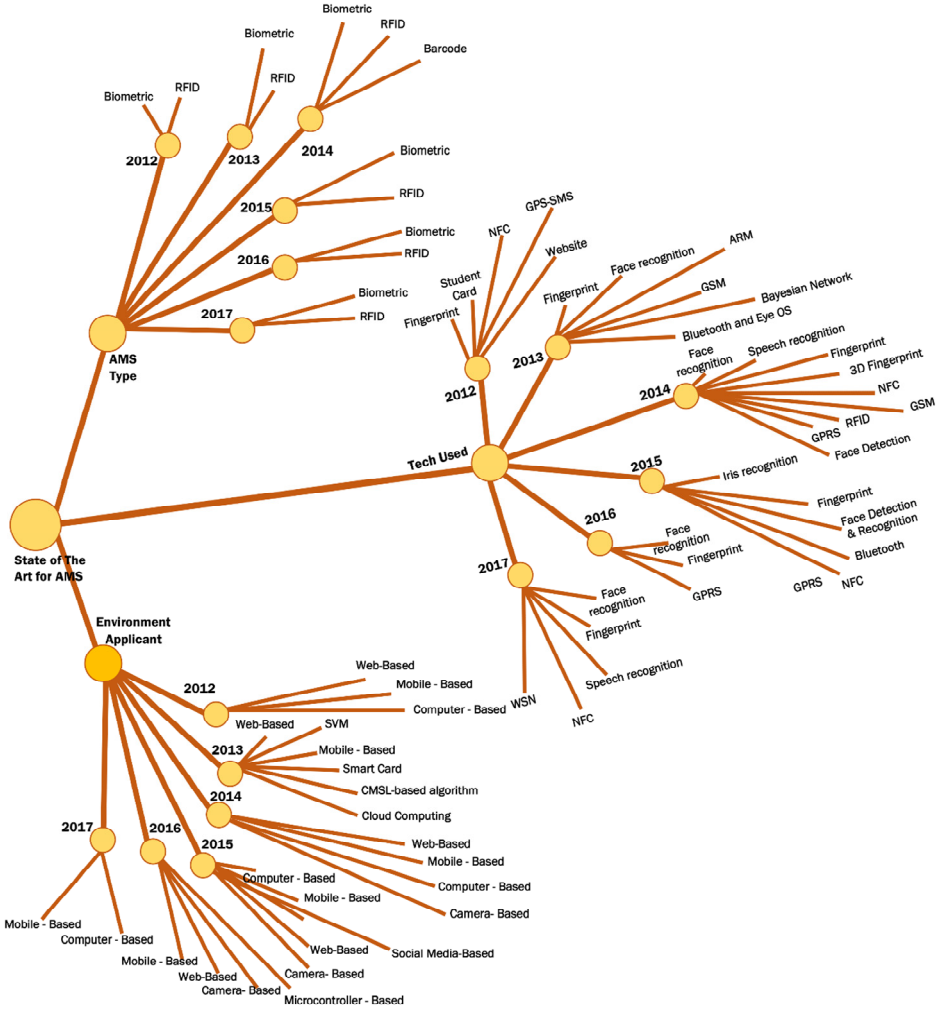
4 Research investigation on the trends of the technology used for attendance systems

This section provides the details of previous studies on attendance studies that have been conducted. These systems record, manage, track and monitor attendance in the academe and organisations. Diverse research has been conducted on a wide range of systems. Systems developed to improve the performance of the education sector, including schools, colleges and universities; and enterprises and corporations aim to replace traditional methods of attendance registration and management using such developed technologies as biometrics, RFID, smartphone, Bluetooth, QR code and barcode. Therefore, we present a detailed research on the technology used, trends and aspects of existing AMS introduced from 2012 to 2017. The current research identifies and focuses on AMS, the relevant technology used and application environments by categories of previous studies based on several aspects, such as year of proposal, technology used, trends and plans, AMS types and application environments. Figure 3 presents a comparative analysis and classification of the state of the art (Literature) for AMS research categorisation related to the types of AMS, technology used and application environments.

Several studies have been conducted to implement developed technologies for attendance systems from 2012 to 2017. These studies are useful for the education sector and organisations because they improve performance through the ubiquitous monitoring, tracking, managing, attendance recording and positioning of their students and employees, respectively. The use of such technologies will reduce human resource effort, saves time, secure, affordable, protected from data manipulation and user-friendly. Figure 3 shows that numerous studies have been conducted from 2012 to 2017 based on biometrics attendance systems, which deal with the physiological and behavioural characteristics of the human body. These biometrics technologies include fingerprint (Basheer and Raghu, 2012; Benyo et al., 2012; Peter et al., 2013; Zainal et al., 2014; Huang et al., 2014; Soewito et al., 2015; Kamaraju and Kumar, 2015; Ahamed and Rasedujjaman, 2015; Cruz et al., 2015; Mittal et al., 2015; Srinidhi and Roy, 2015; Soewito et al., 2016); facial recognition (Chintalapati and Raghunadh, 2013; Park et al., 2013; Siswanto et al., 2014; Kainz et al., 2014; Cruz et al., 2015; Cao and Li, 2015; Wagh et al., 2015; Varadharajan at al., 2016; Kumar and Kumar, 2016; Lukas et al., 2016; Veer and Momin, 2016; Malik et al., 2016; Jayant and Borra, 2016; Pss and Bhaskar, 2016; Rekha and Ramaprasad, 2017; Arsenovic et al., 2017); speech recognition (Dey et al., 2014; Soewito et al., 2016; Yang et al., 2016; Tunbunheng, 2017); facial recognition (Sajid et al., 2014; Rathod et al., 2017); 3D fingerprint (Huang et al., 2014) and iris recognition (Khatun et al., 2015). Mobile-based technologies were proposed in 2012, 2014, 2015, 2016 and 2017 with different technologies, such as NFC (Benyo et al., 2012; Subpratatsavee et al., 2014; Zhi et al., 2014; Jacob et al., 2015; Mohandes, 2017; Baykara et al., 2017); GPS-SMS (Venugopalan et al., 2012); Android camera sensor (Noor et al., 2015); smart WiFi (Choi et al., 2015; Lodha et al., 2015), Bluetooth (Akram and Rustagi, 2015; Lodha et al., 2015; Noguchi et al., 2015) and web application. Moreover, web-based attendance systems involve several trends and

methods, such as RFID (Arbain et al., 2014; Kurniali, 2014; Abas et al., 2014; Srinidhi and Roy, 2015); and Google forms and sheets in 2012, 2015 and 2017. Automated AMS, such as RFID, were used in several systems with various schemes. These systems include ARM (Yuru et al., 2013), GSM (Krisha et al., 2013), GPRS (Nagothu and Anitha, 2016), RF (Azasoo et al., 2014), Arduino (Arbain et al., 2014), ASP.NET web-based setting (Nagothu and Anitha, 2014), Java-based (Kuriakose and Vermaak, 2015), web-based applications (Kohana and Okamoto, 2015), facial verification (Pss and Bhaskar, 2016), IoT (Sharma and Aarthy, 2016), GSM with Li-FI (Arulmozhi et al., 2016), WSN (Ling-ling et al., 2017) and WSN in mobile (Park et al., 2013) in 2012, 2013, 2014, 2015, 2016 and 2017. Bluetooth and barcode were also produced in 2013, 2014 and 2015.

Figure 3 Research categories of the technology trends used of previous AMS



5 Critical review of previous automated AMS

This section presents a critical review of previous studies in detail and highlights their main findings, techniques and sectors involved, apart from boosting education level metrics that include encouraging people to be present on time and enhance learning outcomes. Additionally, this section conceptually provides insights into previous and existing standards. These studies, which were conducted from 2012 to 2017, aimed to determine and eliminate the lack of traditional methods and techniques related to AMS. Table 1 presents a critical review of the proposed system in AMS with several technologies, and highlights their main findings, technologies and domains implemented.

Table 1 Critical review of the proposed AMS

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Basheer and Raghu (2012)	N/A	N/A	Designed fingerprint-based attendance system and data management that has several advantages, such as automated management of attendance, prevents fake attendance registered and no time wasted when taking the attendance and absence of students.
Kassim et al. (2012)	N/A	N/A	RFID-based attendance system was proposed for academic field. This system aims to track students through their lecturers anywhere and anytime via accessible online system, improves teaching quality and monitors students' performance.
Benyo et al. (2012)	✓	N/A	Introduced and developed an autonomous student attendance system through the NFC technology.
Venugopalan et al. (2012)	N/A	N/A	Introduced an effective automatic monitoring system (i.e. SickleSAM). This system monitors students' activities and attendance records daily, as well as the activities of adolescents with sickle cell disease to remove human bias and inaccuracies.
Othman et al. (2012)	N/A	N/A	Discussed the development of online attendance systems based on the concept of a web-based system architecture for higher academic institutions.
Peter et al. (2013)	N/A	✓	Conducted a biometric fingerprint student attendance system. The automated system provides attendance monitoring records for staff and students in tertiary institutions in developing countries. The integrated proposed system minimised time and effort in attendance checkmating during lectures and other activities for students and lecturers.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Chintalapati and Raghunadh (2013)	N/A	N/A	Biometric facial recognition system was proposed to detect students in classrooms and automatically mark their attendance. This system is based on facial detection and recognition algorithms, as well as time-saving, secured and identifies unknown persons. Additionally, it has better recognition and low false positive rates, which are advantageous for facial recognition techniques in real-time scenario LBPH. This system has also been proven to be a better classifier via the use of SVM and Bayesian.
Yuru et al. (2013)	✓	✓	Designed a class attendance checking system based on embedded ARM and RFID technology.
Younis et al. (2013)	N/A	N/A	Researchers designed and implemented a completely automated attendance system based on scalable RFID technology. This system (i.e. IAAS) is an intelligent scheduling technique, and provides various advantages, such as auto scheduling technique and load balancing, thereby saving effort, time and costs.
Krisha et al. (2013)	N/A	N/A	Introduced a prototype development to record and track student attendance based on RFID technology with GSM module. This system can be implemented for several purposes, such as vehicle and personnel identification, building security and access control.
Itoh et al. (2013)	N/A	N/A	Recording data and grade data in the past was proposed to forecast students' future academic records with improved forecasting accuracy. The developed system uses smart card time to record data and grades based on the Bayesian network model.
Vázquez et al. (2013)	Virtual Attendance	-	This study presented a virtual attendance system based on the concept of ubiquity and virtual reality via video conferencing services. This Audio-Visual over Internet Protocol (AVIP) system was implemented and analysed at the Spanish Open University (UNED) in Spain. The analysis results showed a high value for both sectors in improving the mentoring process of distance learning.
Park et al. (2013)	N/A	N/A	The authors presented a system that can check student attendance and human tracking via the use of multiple Kinects in a smart class. Sensor fusion mechanisms are deployed seamlessly and involves consistent human monitoring amongst Kinects.
Avireddy et al. (2013)	N/A	N/A	Wireless technology is used to track and efficiently store student attendance. These technologies involve Bluetooth and EyeOS cloud computing to achieve automation and scalability characteristics, respectively.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Lv et al. (2013)	N/A	N/A	Implemented a campus smart card-based attendance system to track and monitor individual student attendance record. The presented management system reduces workload and provides absence monitoring efficiently and accurately.
Sajid et al. (2014)	N/A	N/A	Facial recognition-based automated attendance system was proposed via a conceptual model to enhance model reliability using an integral validation process.
Siswanto et al. (2014)	N/A	N/A	Provided a best facial recognition algorithm for attendance system in the academic sector. The proposed algorithm includes Eigen face and Fisher face, which achieved better results and 90% similarity for genuine facial images.
Dey et al. (2014)	N/A	N/A	A speech biometric-based attendance system was developed and implemented for students. This method used the system for mobile phone calls. A group of 110 students was deployed by the system and resulted in a 94.2% recognition rate.
Zainal et al. (2014)	N/A	N/A	Presented a security and portability attendance system by design and developed attendance monitoring and management system using biometric fingerprint technology and Arduino microcontroller.
Huang et al. (2014)	N/A	N/A	Fingerprint biometrics technique was used with the principle of 3D fingerprint acquisition to obtain specific features of 3D data of the finger and the corresponding colour texture information. The presented system is based on fringe projection technique.
Subpratatsavee et al. (2014)	N/A	N/A	Proposed a flexible, reliable results and secured important data using NFC technology, as well as built a system reliant on it to provide an efficient student attendance system.
Yadav and Nainan (2014)	N/A	N/A	An automatic AMS presented for students and teachers, as well as using GSM to send notifications to parents.
Arbain et al. (2014)	N/A	N/A	Proposed an attendance system to record and manage student attendance automatically in the lab by using the RFID-ARDUINO approach in web-based laboratory settings.
Kurniali (2014)	N/A	N/A	Developed a web-based attendance system based on RFID technology in higher education institutions. The system process was more efficient and time-saving. Additionally, workload requirements, paper consumption and system failure decreased.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Tiwari et al. (2014)	N/A	N/A	Built a GPRS-based student attendance system, which can be easily accessed by lecturers via the web to check and monitor student attendance.
Azasoo et al. (2014)	N/A	N/A	A student attendant management and information system was presented and implemented. The prototype was based on RF and RFID technology. The mechanism provides an accurate, secure and rapid process to address the inefficiencies involved in the manual processes of collecting, storing and processing student attendance information.
Abas et al. (2014)	✓	N/A	The author discussed an AMS system to enable lecturers to monitor students in class. The proposed tool is rapid and portable based on RFID technology and implemented via an ASP.net programming environment.
Kumar et al. (2014)	N/A	N/A	A monitored and tracking attendance system was presented for the educational and industry sectors using GPS-denied environment by using self-contained and autonomous inertial navigation system to reduce multipath, fading issues and the unavailability of satellite signals of GPS.
Nidhyananthan and Kumari (2014)	N/A	N/A	Presented a student attendance system with the noisy environment by using RASTA-MFCC characteristics to efficiently identify speakers.
Sulaiman et al. (2014)	✓	✓	Presented an efficient AMS in a university environment based on the barcode technique. This system is useful because it is time-saving, easy to use and access, reduces student cheating and produces for students and administration staff. This system likewise reduces the workload of the administration staff.
Zhi et al. (2014)	N/A	N/A	The authors proposed a secure attendance-tracking method based on the MD5 hashing algorithm. This system uses cryptology algorithm to address the issue of signature forgery and secret codes. Additionally, this system is efficient and effective.
Kainz et al. (2014)	N/A	N/A	This system presents the monitoring of student attendance via object tracking methods in a university environment. The attendance mechanism determines the actual identification of persons (students) based on facial detection and recognition algorithms. Additionally, this system monitors and evaluates attendance automatically.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Singh et al. (2015)	N/A	N/A	The developed system is simple and efficient owing to several functions, such as low cost, small size and low power consumption. The proposed system is also an embedded attendance system deployed for managing attendance in schools and colleges.
Soewito et al. (2015)	N/A	N/A	The introduced system is a fingerprint-based attendance system with GPS via the use of smartphone integrated with a payment system. This system addresses several attendance issues, such as reduced attendance cheating, avoidance of long queue attendance, and integrated human resources application to prevent increasing the workforce to calculate overtime salary and payroll. Lastly, this system can use GPS to record the attendance of those who work outside.
Kamaraju and Kumar (2015)	N/A	N/A	Proposed a real-time AMS for easy and time-saving employees attendance in any organisation using ZigBee and fingerprints-based attendance.
Ahamed and Rasedujjaman (2015)	N/A	N/A	An intelligent system proposed based on fingerprint technology, which can be acquired, stored and crosscheck fingerprints of individuals using a portable microcontroller that is handy, affordable and reliable. Additionally, the proposed attendance system is efficient, secure, fast and reliable.
Cruz et al. (2015)	N/A	N/A	Implemented automatic and accurate detection and recognition biometric techniques for managing faculty staff attendance system. The Viola-Jones Face Detection Method was used to provide facial recognition technique and principal component analysis (PCA) integrated with fingerprint technology based on Arduino microcontroller.
Cao and Li (2015)	N/A	N/A	This efficient attendance system is based on facial detection and recognition algorithms in a classroom. The system is capable of high performance because it is highly accurate, easy to apply and simple.
Wagh et al. (2015)	N/A	N/A	An automated and smart attendance system was proposed for classroom attendance based on facial recognition using Eigen face and PCA algorithms.
Khatun et al. (2015)	✓	✓	Adopted and implemented an iris recognition-based attendance system to record and manage student attendance. This system sends a report to a predefined e-mail address in a MATLAB programming environment.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Alotaibi (2015)	Virtual Attendance	-	Proposed a new prototype system for student attendance based on the Internet of things for supporting blended learning services in a secure and efficient manner.
Kuriakose and Vermaak (2015)	✓	✓	Proposed an automated attendance registration system using Java-based RFID technology to monitor and manage student attendance in the Central University of Technology, South Africa.
Mittal et al. (2015)	N/A	N/A	The authors proposed a fingerprinting biometric attendance system in a classroom environment. The system deployed is based on access control system and classroom AMS, and provides a scalable solution for identification and authentication. It likewise generates an online report on a website. Amongst the advantages of the presented attendance system is better security, reliability and accuracy.
Kohana and Okamoto (2015)	N/A	N/A	The proposed system confirms the attendance at work via the presentation of information on absence and presence in a room. Furthermore, this system provides information on the schedule of classes, meetings and official trips beforehand.
Noor et al. (2015)	N/A	N/A	The proposed Android-based application uses a sensor by camera device to record and manage student attendance.
Jacob et al. (2015)	N/A	N/A	Introduced AMS for university students by using an NFC mobile-based attendance system.
Akram and Rustagi (2015)	N/A	N/A	Presented an active system and minimal time cost for students and staff attendance management records by using Bluetooth technology and Android application, thereby ensuring student presence and marking student attendance, respectively. The system provides privacy preservation and collision detection attendance.
Choi et al. (2015)	N/A	N/A	Presented a smartphone attendance system based on WiFi technology to check the presentation of users or students. This system results in enhanced scalability with numerous users.
Anwar and Gangodkar (2015)	N/A	N/A	A smartphone attendance-based system designed for student attendance. The marker application is deployed on an Android platform. The app provides usability advantages for attendance marking.
Khan and Ram (2015)	N/A	N/A	A checking and tracking attendance system was developed for an organisation's staff. This method uses an Android-based portable application for login attendance registration. This system is easy to use, user-friendly and time-saving.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Sari et al. (2015)	N/A	N/A	A low-cost system was developed for the personal attendance of Binus University lecturers. The proposed scheme uses a social media platform, such as Facebook, to monitor attendance status by using status messages with a microcontroller (i.e. Raspberry Pi).
Lodha et al. (2015)	N/A	N/A	Implemented a wireless technology (i.e. Bluetooth smart attendance system) to facilitate automatic wireless identification. This system improves attendance time taking, prevents human errors and provides bases for administrators' future managerial decisions.
Srinidhi and Roy (2015)	N/A	N/A	Researchers developed a web-based system with automated technology (i.e. RFID). This system can maintain records of lecturers and students and detect the current location of students. The system results in a safe and secure process and data.
Fan et al. (2015)	N/A	N/A	The authors described high-efficiency and low-cost university attendance system with only a few hardware requirements.
Lámer et al. (2015)	N/A	N/A	A live video stream in a classroom and student optical marker (Aruco marker) were used to provide a student attendance system. Particular students are identified and detected by marker IDs. The system is easy to use and has a high detection rate.
Kim et al. (2015)	N/A	N/A	Presented a novel digital attendance system that can immediately facilitate interactions between students and teachers for sensibility monitoring and counsel assistance. This system specifically uses a remote site and database server to analyse the gathered attendance information.
Noguchi et al. (2015)	N/A	N/A	Bluetooth low energy technology was developed to present a student AMS. The proposed method reduces incidents of student cheating and decreases long queue time when scanning students' cards.
Sunehra and Goud (2016)	N/A	N/A	Conducted a recording and consolidation system for student attendance based on Arduino and Raspberry Pi microcontroller boards. This system is secure, affordable and user-friendly.
Varadharajan et al. (2016)	N/A	N/A	Presented automatic attendance management which is biometric facial detection technique with camera capture. This system prevents human intervention, is easy to maintain and presents less time cost. Facial recognition is done via using Eigen faces. When a students are absent, the system will send a message to their parents.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Kumar et al. (2016)	N/A	N/A	Facial recognition and LabVIEW are proposed to present an automatic attendance system that reduces time consumption and standard errors of the attendance procedure.
Lukas et al. (2016)	N/A	N/A	Automated attendance system proposed in the classroom by using a facial recognition hybrid scheme. The methodology of the proposed method includes combining discrete wavelet transform (DWT) and discrete cosine transform (DCT) to extract the features of students' faces, as well as applies radial basis function (RBF) to classify facial objects. The success rate of this system is approximately 82%.
Veer and Momin (2016)	N/A	N/A	Developed an automated attendance system for students in classrooms by using video surveillance camera individually. The result of the facial detection rate was 100%.
Malik et al. (2016)	N/A	N/A	Facial recognition with camera-based attendance system was designed and developed for attendance purpose from a theoretical perspective. Additionally, this system can be used for authentication in online examination. Hence, the proposed attendance system is efficient and accurate.
Gadhave and Kore (2016)	N/A	N/A	Built a fully automated portable attendance system based on fingerprint scanner biometric technology and Raspberry Pi. This system can be implemented successfully in educational institutions, and achieved low cost and worked precisely to decrease human resource requirements.
Soewito et al. (2016)	N/A	N/A	The system presented can record employee attendance even outside buildings and easily account salaries, including overtime. Fingerprint and voice recognition biometrics technology with a smartphone is used in this system. The false positive of verification fingerprint is 95%, whilst voice recognition false negative is 5.88%.
Adeniji et al. (2016)	N/A	N/A	The authors presented a class attendance register system based on fingerprint biometric technology and web-based hybrid scheme. This system is efficient and effective in tracking student attendance and preventing student attendance cheating. Accuracy and usability are the two results when this system was implemented in the University of Fort Hare Alice, South Africa.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Jayant and Borra (2016)	N/A	N/A	A biometric AMS was proposed to automatically detect and recognise student faces lectures or classrooms. This system uses two algorithms to perform the face detection and recognition: Viola-Jones and alignment-free partial face recognition algorithms. Amongst the advantages of this system are improved teaching time performance via less time system cos, prevents workload, and automatically tracks student attendance and efficient and secure system.
Pss and Bhaskar (2016)	N/A	N/A	RFID and face verification were presented for reliable classroom attendance system. This system has a 98% facial verification rate and 73.28% efficient rate in the front face.
Sharma and Aarthy (2016)	N/A	N/A	RFID and IoT applications are used to propose an attendance monitoring system with the cloud as back-end storage. This system provides better proficiency and flexibility because it can be accessed anywhere and anytime.
Konatham et al. (2016)	N/A	N/A	This system is a reliable and time-saving automatic attendance system. The model used RFID and GSM technologies to automate student attendance marking and parent alerts. Attendance registration is automatically performed through the attached microcontroller in a classroom door with RFID tag.
Arulmozhi et al. (2016)	N/A	N/A	A highly accurate attendance system is explained with local and remote cloud-based data processing. The system has several enhanced features, such as system availability, scalability and controllability. The results registered accurately throughout because we investigated data transmission using the Li-Fi system with RFID to realise heightened cloud performance.
Yang et al. (2016)	N/A	N/A	Real-time location and voiceprint are two techniques used to develop an automated tracking system for student attendance in the classroom. Students use smartphones to indicate their presence in parallel. The presented system shows high efficiency and usability in a real world environment, as well as provides protection for the privacy-sensitive biometric data.
Kohana and Okamoto (2016)	N/A	N/A	A location-based Social Networking Services (SNS) was proposed to present a location registration scheme and location-based schedule registration. This system uses IP address and GPS information to check the origin of access.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Iio (2016)	N/A	N/A	The author presented a study that provides an attendance management framework for students in a classroom. The system is based on a mobile device and a web application hybrid scheme. Attendance registration can be recorded via students' selfie or signature. The system is easy to use (usability) and efficient based on the testing results.
Saparkhojayev et al. (2016)	N/A	N/A	An Android platform was used based on a smartphone system and checks the attendance records of students in universities. The system is flexible, portable and efficient.
Nagothu and Anitha (2016)	N/A	N/A	GPS and GPRS technologies were proposed to monitor, track and register people in institutions or organisations. These persons should wear their IDs for monitoring. MEMS GPS and GPRS are integrated with an ARM microcontroller.
Rekha and Ramaprasad (2017)	N/A	N/A	Integrated facial recognition technology was used using the Eigen face database and PCA algorithm via a Matlab platform environment programming software to produce an automated AMS.
Dhanalakshmi et al. (2017)	N/A	N/A	The authors proposed an automatic biometric attendance system for educational institutions by using GSM-based Wireless Fingerprint Terminals (WFTs). This system can record, monitor and maintain student attendance without any human intervention. Efficiency and transparency in management are two advantages of the system designed and can be improved to achieve academic excellence.
Poornima et al. (2017)	N/A	N/A	Proposed saved time and effort system to automatically check student attendance in a classroom. The developed system captures in real-time the faces of students in class.
Rathod et al. (2017)	N/A	N/A	Proposed a reliable, secure and easy to use method for conducting an automated attendance registration system. The presented system uses facial recognition biometric technology to mark student attendance.
Arsenovic et al. (2017)	N/A	N/A	Facial recognition biometric attendance system was proposed, which achieved high accuracy (i.e. 95.02%) in the testing.

Table 1 Critical review of the proposed AMS (continued)

Author(s) and references	*Boosting education level*		*Main findings*
	Encourage presence on time	*Enhance learning outcomes*	
Fu et al. (2017)	N/A	N/A	Developed an automatic attendance registration biometrics system in the university classroom. The automated system uses two integrating algorithms that are MTCNN facial detection and centre-face facial recognition in deep learning. Hence, the attendance system can be recorded and identified, and the accurate facial recognition has a 98.87% accuracy rate.
Tunbunheng (2017)	N/A	N/A	Developed an automatic system for taking attendance time of student by using Google forms and sheets. Additionally, the proposed attendance system can be registered students who came late to the class by using speech recognition technology based on Droid Script.
Mohandes (2017)	✓	✓	NFC mobile application was developed to monitor student attendance in the educational sector. The proposed prototype uses a class AMS. Increased faculty performance, time-saving and provision of positive feedback were the results following an evaluation in King Fahd University of Petroleum and Minerals.
Ling et al. (2017)	N/A	N/A	Conducted a wireless attendance system hybrid scheme to solve several issues of the attendance system, such as wiring, an error-prone information collection with the current systems. This system was designed and proposed based on the RFID and WSN technologies, thereby achieving enhanced performance and functional requirements.
Nguyen and Chew (2017)	N/A	N/A	The authors developed an automated attendance system to record, track and manage attendance registration. This system uses RFID with mobile wireless communication. The mechanism provides collecting, recording and processing data on participants in professional gatherings.
Baykara et al. (2017)	N/A	N/A	Developed an intelligent attendance system with using NFC technology to reduce the error rate. The digital system provides attendance records and signature reposts and can be applied in educational institutions.
Liang et al. (2017)	N/A	N/A	An integrated electronic attendance system applied city government and its subordinate organisations. The designed electronic system integrates several business characteristics, such as reliability, practicality and possess integrity.

Table 1 shows that the majority of the existing studies have been implemented in an academic sector, although some of the systems have been deployed in public areas, such as industries (Huang et al., 2014; Soewito et al., 2016; Arsenovic et al., 2017; Ling-ling et al., 2017); organisations (Zainal et al., 2014; Nagothu et al., 2014; Soewito et al., 2015; Kohana and Okamoto, 2015; Choi et al., 2015; Khan and Ram, 2015; Nagothu and Anitha, 2016; Arulogun et al., 2013; Liang et al., 2017) or enterprises (Kamaraju and Kumar, 2015). The majority of the presented attendance systems use biometrics characteristics and technologies. Moreover, mobile- and web-based techniques were used for such purposes (see Figure 3). Automated AMS, such as RFID system, is crucial in several previous attendance studies, including those involving barcodes and smartcards.

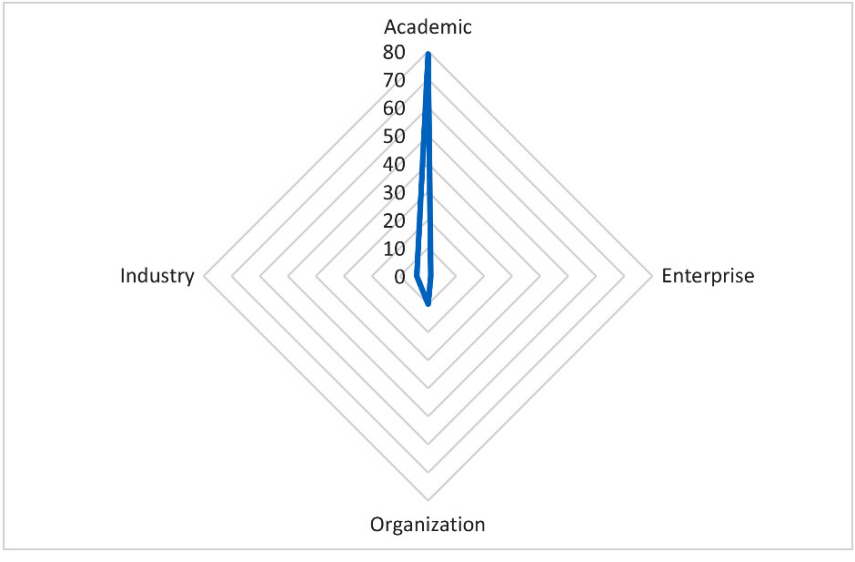
6 Results and discussions

This section investigates and summarises the statistical findings derived from the survey of 90 domain articles. All papers were summarised using the structured search process specified in Sub-section 2.2. Meanwhile, the statistical findings are categorised into three criteria, namely, application domains, attendance system-based and technology trends based on publication years (see Figures 4, 5 and 6, respectively). Figure 4(a) presents the number of attendance systems papers in different domains, whilst Figure 4(b) shows the statistical findings of the 90 domain articles with respect to publication year. Figure 5 presents the general categories of the proposed attendance systems based on years. Figure 6 highlights the recent technology used trends that are significantly used from 2012 to 2017.

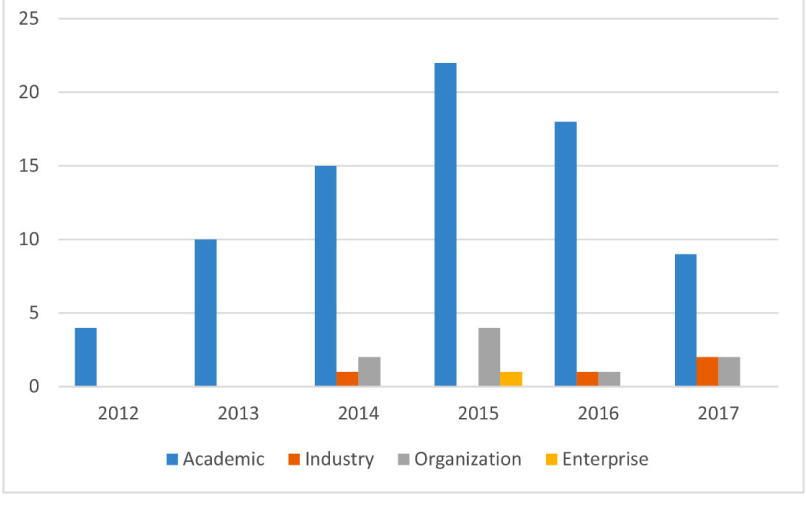
Based on graphical results presented in Figure 4, the majority of the proposed attendance systems were conducted in the academic field (79 articles), 9 studies for the organisation category, four papers for the industry domain and only one article for the enterprise sector (see Figure 4(a)). Various technologies were used in the academic area from 2012 to 2017, whilst the enterprise field one had one proposed system in 2015. Moreover, 2012 and 2013 did not have any proposed system in the organisation category (see Figure 4(b)).

Biometrics and RFID are two attendance systems that were used each year during the survey period (2012–2017). Mobile attendance-based system were utilised in 2012, 2015, 2016 and 2017. Several systems technology emerged in a single year, such as PSN, WSN, Iris, GPRS, GSM, ARM, video conference, Bluetooth and eye OS, barcode, secret code, Internet of Things (IoT), social media-based, multi-module, location-based, voice and print location, Google forms and sheets, Arduino and RassperiPi (see Figure 5 and Table 1).

Figure 4 (a) Domain focus (b) Publication years

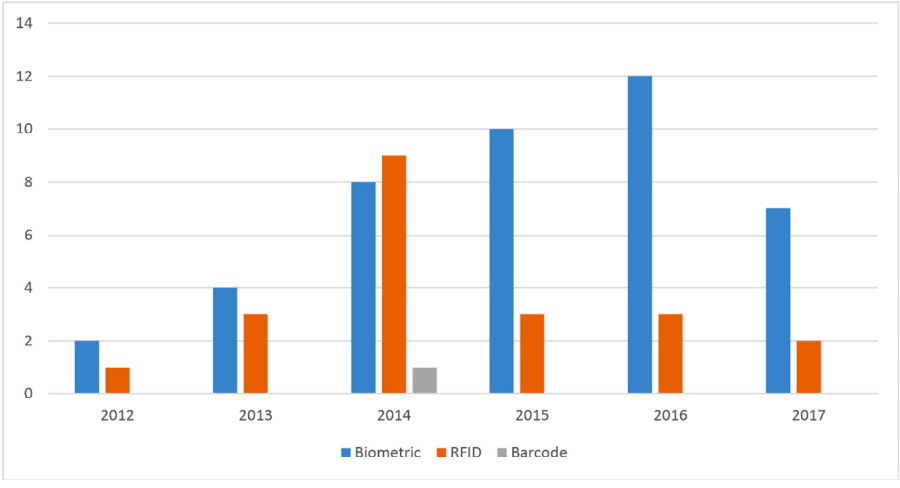


(a)



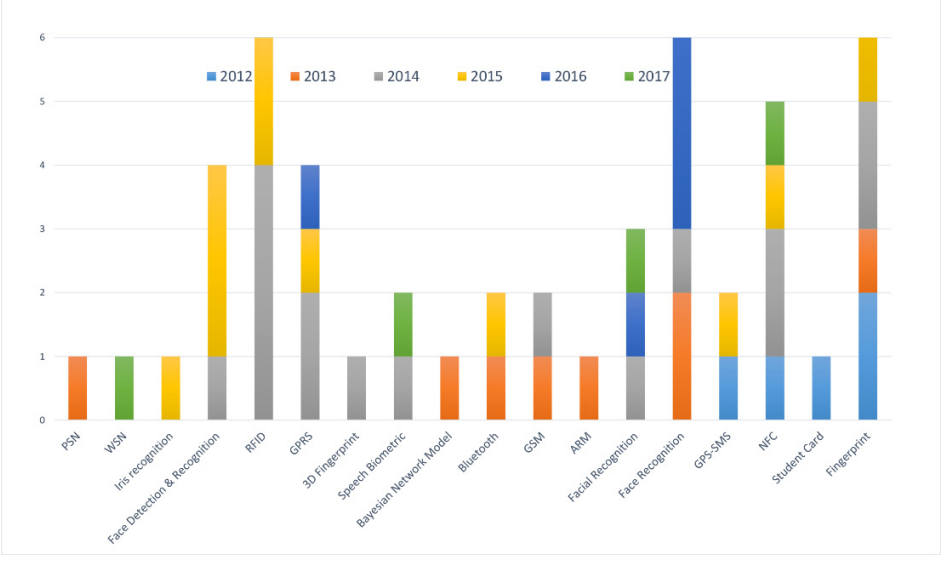
(b)

Figure 5 Categories of the proposed attendance systems



Based on statistical results shown in Figure 6, fingerprint technologies are excellent attendance system used in previous papers from 2012 to 2017. Additionally, facial recognition and NFC are the most used technology attendance during the survey period. Several technologies were proposed for a single year, such as SNS, facial verification, GPRS, RF and ARM (see Figure 6).

Figure 6 Technology used in previous AMS



7 Conclusions and future directions

Developed and emerged technologies could change the future of science that will affect the daily lives of people, such as Wireless Sensor Networks (WSNs). This research presented a structured review of AMS in different domains, introduced a comprehensive literature survey scheme based on a highly granular model for article categorisation (see Figure 1). Out of 204 identified papers, 90 were found to be relevant in the context of this review study. This research also offered a general summary of recent technology trends and their schemes, as well conducted a critical review of previous attendance systems based on several metrics. Accordingly, we provided a unified view of the proposed studies as a future reference, and highlighted the need for further studies on the efficient and effective techniques or approaches. Several main findings of the proposed attendance systems are summarised in a statistical manner (see Section 6). For future research, we intend to conduct a comprehensive critical analysis that includes multi-criteria focus on attendance systems, such as system performance, functionality, throughput and other related issues.

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