Requirements Model for an Integrated Attendance Monitoring System (IAMS)

Joshua C. Nwokeji
Interdisciplinary Research Group, Computer and Information Science Department, Gannon University, Erie, Pennsylvania USA Email: Nwokeji001@gannon.edu

Ayodele Olagunju
Department of Geography & Planning, and Gwenna Moss Center for Teaching & Learning, University of Saskatchewan, Saskatchewan, Canada

Anugu Apoorva, Steve Frezza, and Mei-Huei Tang
Interdisciplinary Research Group, Computer and Information Science Department, Gannon University, Erie, Pennsylvania USA

***Abstract*—Attendance monitoring systems (AMS) are important educational systems used to monitor student attendance and interest in a given course. The expected benefits of AMS are, among others, to improve student engagement, performance, and retention. The functionalities of most traditional AMS are however limited to recording and reporting attendance. Beyond these, they provide little or no other functionalities that are capable of streamlining student engagement, performance, and retention. To fully realize their expected benefits and meet contemporary pedagogical needs, traditional AMS can benefit from extended innovative functionalities such as 'Automatic Disengagement Notification' and 'Attendance Grader'. But the implementation of these functionalities would depend on predefined systems requirements, which unfortunately are very scare, if available at all, in extant software engineering literature. The significant amount of work, resources, and cost required to develop systems requirements, especially for the optimization of expected benefits, can discourage software/education systems developers from developing such innovative functionalities. We contribute to addressing these limitations by identifying, modeling and describing functional requirements for an integrated AMS. These requirements can be adopted and re-used by AMS developers, and thus reduce the time, cost and other resources expended in requirements development.**

***Keywords*—Learning management system; attendance management systems; feature tree model; student engagement**

I. INTRODUCTION

Monitoring student attendance (henceforth called attendance monitoring) is an important and beneficial practice in higher education [1]-[3]. Universities and colleges monitor attendance for many obvious reasons such as to detect disengaged students at an early stage and initiate strategies to re-engage them [3], thereby improving overall student retention [4], [5]. Attendance monitoring can motivate students to attend learning events (classes, lectures, and labs) [6], and as a result enhance their academic performance and success [2]. Other benefits of attendance monitoring include catering for students' wellbeing and preparing them to be accountable professionals [3]. In addition to academic purposes, immigration regulations in some countries require most higher learning institutions to monitor and report academic progress of students on study visas, part of which is attendance in class and other learning events.

Given the above importance and benefits of attendance monitoring, one would expect popular learning management systems (LMS) such as Moodle[1] and Blackboard[2] to provide precise and well defined functionalities for automated attendance monitoring. Unfortunately, this is not the case [7]. As a result, most instructors resort to manual methods e.g., rolls calls using paper-based attendance registers. These manual methods have limitations such as inconsistency, inaccuracy, and propensity to encourage fake or proxy attendance [6]. Furthermore, passing around attendance register while learning events are going on can distract students and waste valuable learning times [8] and impracticable in large classes.

Attempts have been made to address these limitations through the development of attendance monitoring systems (AMS), which are rapidly becoming traditional. For instance, MyAT[3] and AccuClass[4] are developed by practitioners, while others (see [7], [9], [10]) are developed by researchers. A careful review of these traditional AMS (see Section II and Table 1) shows that they are primarily used to record and report attendance. Beyond these, they provide little or no innovative functionalities that can be used to optimize student engagement, academic performance, and retention. Hence, they lack the ability to realize the full potentials and benefits of attendance monitoring, and, with time, may not be able to meet contemporary pedagogical needs. The authors believe that AMS should transcend mere recording and reporting attendance, and instead provide extended functionalities such as 'Automated Disengagement Notification' (ADN) and 'Attendance Grader' (AG).

These functionalities[5] can benefit attendance monitoring in many ways. For instance, the ADN can be implemented to automatically notify/alert instructors and academic advisers of students with risky attendance trends or poor attendance records (which are signs of disengagement). This notification can be sent at regular intervals, e.g., bi-weekly or monthly, thereby helping instructors and advisers to detect disengaged students at an early stage, and then develop strategies to

[1] https://docs.moodle.org/29/en/Features
[2] http://tinyurl.com/zqvh4xn
[3] http://tinyurl.com/zwfjvu6
[4] http://www.engineerica.com/accuclass/features
[5] The terms 'functionalities' and 'features' are used in this paper to refer to the functions, behaviors or operations of a system [11].

reengage and retain them. Equally, the AG can be implemented to automatically convert attendance records into summative grades and provide easy interface for instructors to award points to students who engage and participate in learning events. These can serve as a valuable source of motivations for increased student attendance and engagement. While these and other similar functionalities can be useful and desirable, their implementation would depend on predefined systems requirements. By 'requirements' we mean the functions, behaviours, and features that should be implemented in a system or software [12], [13]. Unfortunately, such systems requirements are scarce, if available at all for re-use, in extant software engineering literature. The significant amount of work, resources, and cost required to produce systems requirements can discourage (software/education systems) developers from identifying and implementing these new and other functionalities that are capable of streamlining attendance monitoring and thus optimizing the expected benefits of AMS.

As a foundation for addressing these limitations, this paper contributes a set of high level functional and user requirements for an integrated attendance monitoring system (IAMS). We apply requirements elicitation techniques to identify these requirements. Then we use a feature tree model (FTM) to describe functional requirements and a use-case model to capture the key user requirements of IAMS. We expect software and education systems developers to adopt, customize, and re-use these requirements models to build new AMS that can extend traditional AMS with more beneficial features. By re-using already identified requirements, they can reduce the time, cost and other resources expended in requirements development. To enhance readability, this paper is structured as follows: Section II provides a review of traditional AMS, while Sections III and IV discuss the inherent limitations in traditional AMS and the techniques used to identify the proposed requirements respectively. In Section V, we present and describe the proposed functional requirements using a feature tree model (FTM), while user requirements are captured and described with a use case model in Section VI. Finally, we conclude our work, highlight limitations, and our future work in Section VII.

II. Review and Limitations of Traditional AMS

A. Review of Traditional AMS

Various attendance monitoring systems (AMS) have been proposed by practitioners and researchers. Usually, these are designed to target specific audience such as higher education, high schools, and elementary schools. However, our particular interests are in those AMS that target higher education, hence these will be the focus of our review. Popular among the industry-based AMS are MyAT[3], AccuClass[4], aPlus+Attendance[6], and Jolly[7]. Although most of these are currently in use at various institutions, their scope and functions are largely limited to recording and reporting attendance. In few cases where additional functions exist, they are usually redundant and provide no clarity on how they are used to advance attendance monitoring. For instance, MyAT extended its attendance recording and reporting system with teacher-parent communication, and dashboards for grading student assignments and examinations. Grade books, grading dashboards, and communication features are already included in most learning management systems (LMS), which are rapidly becoming ubiquitous in universities and colleges. Hence, integrating them in AMS can result to duplication of functionalities and redundancy.

In the same vein, research-based solutions provide similar limitations of AMS to attendance recording and reporting. For instance Venugopalan et al. [14] proposed SickleSam, an AMS that primarily monitors the attendance and activities of students with Sickle cell diseases. While this system is somewhat innovative in that it addresses some of the least explored subjects in learning management systems in general and in AMS specifically; the absence of functionalities such as 'Automated Disengagement Notification' (ADN) limits its robustness and efficiency. Integrating such functionality can create awareness of risky attendance trends by sending timely alert to instructors and academic advisers. This early awareness of risky attendance trends can motivate the development of timely remediation, re-engagement, and retention strategies.

In addition to SickleSam, we found other AMS proposed in research publications, e.g., NFC[8] and RFID[9] technology based AMS [15]-[19], as well as bio-metric based AMS [20], [21]. This category of AMS address functionalities that are largely similar to the ones mentioned above, which make them liable to the same limitations. The RFID/NFC based solutions focus on monitoring and tracking students in real-time within school environment. The bio-metric based solutions integrate bio-metric technologies to attendance monitoring whereby students sign attendance using unique human characteristics such as thumps, eye-iris and voice. A major advantage of the latter is that it reduces proxy attendance and fraud. Also both solutions (RFID/NFC and bio-metric) appear to provide functionality that allows students to sign into classes using their identity, chip cards, and personal attributes, thus streamlining attendance recording processes.

These are meaningful contributions to attendance recording and reporting. But there is no strong evidence that they advance the anticipated benefits of attendance monitoring in the aspects of engagement, intervention, and retention. In addition to the popular features of most traditional AMS (e.g. attendance reports, attendance recording, and tardy attendance capturing), we contend that features such as attendance grader, disengagement notification, and participation points manager will further enrich the deployment of effective AMS in an integrated and interactive manner. In Table 1, we present a summary of these limitations by comparing the features of our proposed IAMS with those of traditional AMS. We use the surd sign (√), letter 'X', and asterisk (∗) to denote features that are *available*, *unavailable*, or *available with limited functionalities* respectively. In the section that follows, we discuss the key limitations of traditional AMS.

[6] http://j.tinyurl.com/z7avue9
[7] http://j.tinyurl.com/hg8gduj
[8] Near Field Communication
[9] Radio Frequency Identification

TABLE I. LIMITATIONS OF TRADITIONAL ATTENDANCE MONITORING SYSTEMS

Traditional AMS → / **Key Features of the proposed IAMS ↓**	MyAt[3]	AccuClass[4]	aPlus+Attendance[6]	Jolly[7]	SickleSam [14]	RFID/NFC [15]-[19]	Biometric [20], [21]
Attendance Grader	X	X	X	X	X	X	X
Profile Picture	√	√	X	√	X	X	X
Attendance Reports	X	√	√	√	√	√	√
Disengagement Notification	√	X	X	X	X	X	X
Attendance Recording	X	√	√	√	√	√	√
Excused Leave Register	X	*	*	X	X	X	X
Tardy Attendance Capturing	√	√	X	*	X	X	X
Attendance Policy Publisher	X	X	X	X	X	X	X
Participation Points	X	X	X	X	X	X	X

Table Legend: Available (√); Not Available (X); Available but does not provide full functionality (∗)

III. LIMITATIONS OF TRADITIONAL AMS

A. *Lack of Attendance Grader (AG)*

In order to encourage students to attend and participate in classes, most instructors usually include attendance and participation as grading components, and hence assign a portion of the total course grade to these. Similarly, instructors usually have a policy that requires a minimum percentage (e.g., 75% more or less) attendance as a prerequisite for achieving a pass mark in a given course. As an illustration, Table 2 presents an example of an instructor's grading distribution.

TABLE II. GRADING POLICY FOR SE 248: DATABASE SYSTEMS

Grading Component	**Marks**
Assignment and Test	20
Attendance	5
Project	30
Participation	5
Exam	40
Total	**100 marks**

***Attendance Prerequisite**: 75% attendance is required for a pass*

This table shows that 5 marks of the total course grade is assigned to attendance, another 5 marks to participation, while 75% attendance is a prerequisite for passing the course. Assume this is a 3-credit hour course, and this instructor has three classes per week. Then in a 16-week semester, this instructor would have 48 (i.e. 16*3) attendance records. Usually, at the end of each semester, this instructor collates these records and determines the attendance mark for each student, and whether or not a student meets the percentage attendance prerequisite. It can be very difficult to do these without automation and systems support. 'Attendance Grader' functionality therefore becomes valuable to automatically convert attendance records to summative marks and determine if a given student satisfy the attendance policy.

However, traditional AMS lack the 'Attendance Grader' functionalities. Consequently, instructors are often expected to export attendance records into a spreadsheet and manually or semi-manually compute attendance' marks or determine students who satisfy the attendance prerequisite. Often, such computations are complex, time consuming, and error-prone, which can discourage instructors from using attendance records as grading components. Using attendance records as grading component and enforcing attendance prerequisite can be the key motivator for some students to attend and participate in learning events (classes, lectures, labs, etc.). Newmanford et al. [2] found a significant correlation between class attendance and student academic performance and concluded that students who attend and participate in learning events, regularly, are more likely to achieve higher grades and success than their peers [2]. Therefore, systems functionalities, such as Attendance Grader, are useful in motivating students to attend and participate in learning events. Extending traditional AMS with such functionalities can thus help to optimize student academic success and retention, which are an integral part of a robust and efficient AMS.

B. *Lack of Automatic Disengagement Notifications (ADN)*

Another expected benefit of attendance monitoring is to detect disengaged students at an early stage, so that early intervention strategies can be developed to re-engage and retain them [3]-[5]. To optimize this benefit, faculty and staff responsible for student engagement and retention should have knowledge and easy access to student attendance record at regular intervals. These can be supported by the ADN functionality. For instance, disengagement notification can be sent automatically to faculty and staff, biweekly or monthly, if the attendance record of a given student falls below a stipulated threshold, say 75%. This can make it easier to detect and respond to students that show signs of disengagement (e.g., poor attendance record) at the beginning of an academic year or semester, and then develop early intervention strategies to re-engage and retain them. Table 2 shows that available traditional AMS lack such ADN functionality. Instead attendance record is usually collated and analyzed during the end of a semester; by then most intervention and mitigation strategies would have little or no effect on the students. Thus, traditional AMS can hardly be used to optimize early intervention benefits of AMS.

C. Other Limitations

Besides those described above, other limitations of traditional AMS, as shown in Table 2, include lack of 'Attendance Policy Publisher' (APP) and 'Excused Leave Manager' (ELM) functions. It is a common practice for institutions to allow a certain amount of excused absent/leave, to account for unavoidable situations such as sickness and accidents. Students are normally expected to apply for excused leave, and in most cases provide documents (e.g., doctor's report) to support their applications. Traditional AMS do not usually support these. Hence the application, review and approval of excused leave are mostly paper-based or done via e-mail, and many times belatedly. These can be time consuming and error prone; for instance, an instructor can approve a student leave but forget to record it as an excused absent. Likewise, lack of APP functionality is another limiting factor in available traditional AMS. Useful and consequential information about student attendance, e.g., required attendance threshold for a given course, are usually described in attendance policy document. Moreover, this document often explains the attendance criteria for students on study visas to comply with immigration rules. Hence, it can be important for AMS to provide functionality to manage (e.g., create and publish) attendance policies. Such functionality can facilitate easy dissemination, access, understanding and level of compliance with institution's attendance policies.

IV. Requirements Elicitation Method

The aim of this paper is to identify high level re-usable requirements or functionalities that can be implemented to address the limitations discussed above. We apply requirements elicitation techniques to identify the proposed requirements. Requirements elicitation technique includes activities, e.g., brainstorming and observation, carried to identify the requirements to be implemented in a system [22], [23]. To ensure quality, rigor and wide coverage of requirements, we combine four (4) elicitation techniques, as summarized in Fig. 1. The elicitation process started with reviewing existing attendance documents, such as attendance records, policies, syllabus, and grading policies, in the authors' institution. The aim of this review is to identify relevant information e.g., functionalities, to be included in the proposed system. Secondly, we identified and interviewed instructors from the authors' institutions. Six (6) instructors accepted to participate in the interview. Since these instructors are from our institutions, we adopt the informal and unstructured interview process, which does not include questionnaire. Instead we verbally asked questions relating to their experience in attendance monitoring and recorded their responses.

Thirdly, the cumulative expert knowledge and experiences of the authors in attendance monitoring based on several years teaching at postsecondary level provided additional input to requirements elicitation. Final, the series of research project meetings offered brainstorming opportunities to collate data gathered through other methods, and harmonize perspectives and evidences that emerged from the data. The proposed functional and user requirements are based on the aggregate of these analytical techniques.

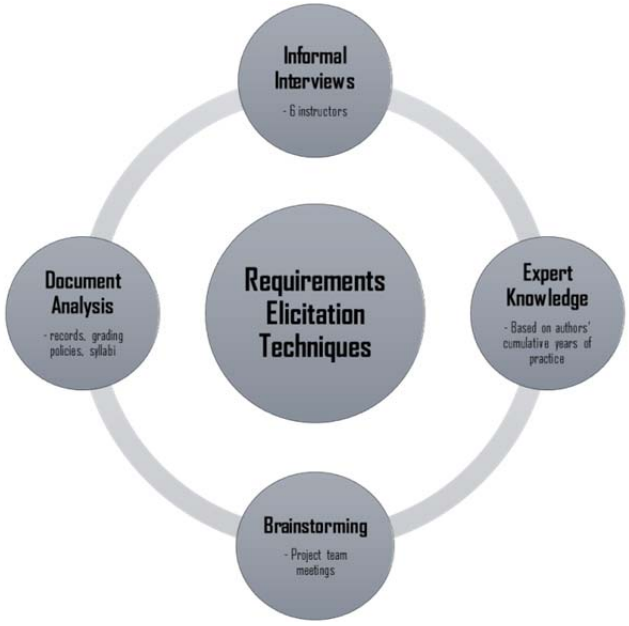

Fig. 1. Description of requirements elicitation techniques.

V. Requirements of the Proposed IAMS

The limitations described in Section III motivate the identification of requirements for an integrated attendance monitoring system (IAMS) that extends traditional AMS with systems new functionalities. In this section, we use the feature tree model (FTM) shown in Fig. 2 to model the functional requirements that can be re-used to implement an IAMS that can address the limitations of traditional AMS. A FTM provides the means to capture, structure and describe requirements at various levels of hierarchy or at an increasing level of details and granularity [11], [24]-[26]. Using a feature tree model we structure the functional requirements of the proposed IAMS into three main levels, *viz*. L1 or main features, L2 or sub-features, and L3 or specific functions [25].

Main or L1 features are the top-level systems functionalities that encapsulate other features, and are usually abstract functions which may not be directly implemented in the system. There are four (4) main features in the proposed system; these are represented with purple rectangular boxes as shown in Fig. 2. Each of these main features includes L2 or sub-features, written in 'olive green' colors in Fig. 2. These L2 features may be implemented as menu or pane containing specific and related systems functions or L3 features. For instance, the 'Notification Configuration' feature can be implemented as a drop-down menu containing related functions such as 'Create Notification' and 'Set Notification Frequency'. In the sections below, we describe the uses of each feature. Features such as account management, attendance recorder, and attendance reporter are not described here, since they are already included and described in traditional AMS.

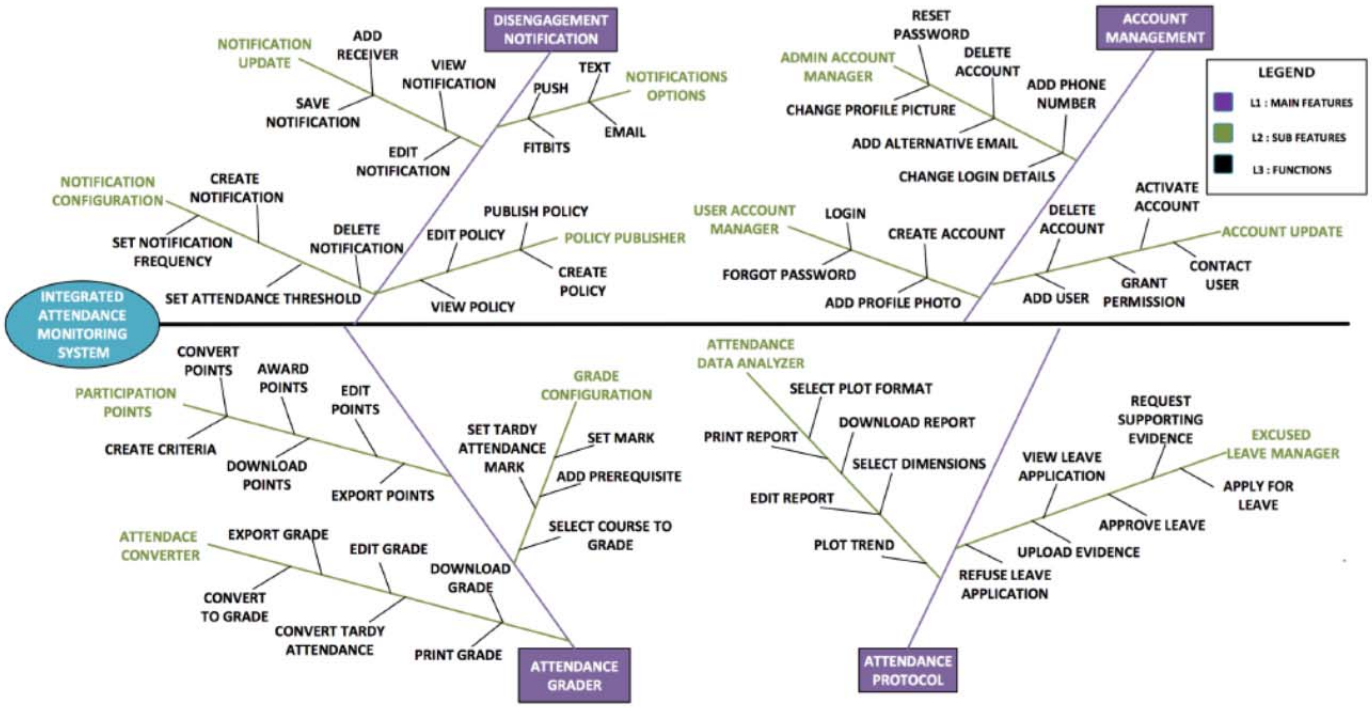

Fig. 2. Feature tree model showing the requirements of the proposed IAMS.

A. Attendance Grader (AG)

This feature encapsulates the functional requirements that can be implemented to address the limitations in Section III-A. It provides functions that can automatically convert attendance record into grades and precisely determine students who meet the attendance prerequisites for a given course. It also provides easy interface that can used by instructors to award credit for participation. These functions can make it easier for professors to use attendance records as summative grades and enforce attendance prerequisite for a course; thereby motivating students to attend, engage, and participate in learning events. Table III describes the uses of specific functions included in this feature. We consider the frequently asked question (FAQ) functions to be self-explanatory, and hence did not include their description in Table III.

TABLE III. DESCRIPTION OF ATTENDANCE GRADER FEATURE

Sub/L2 Feature	L3 Features /Function	Uses/Description
Grade Configuration	'Set Mark'	Can be used to set the desired 'mark' assigned to an attendance record. e.g., 5 Marks as shown in Table 1
	'Select Courses to Grade'	Allows instructors to select the course they wish to grade
	'Add Prerequisite'	Can be used to set the percentage attendance required to pass a given course
	'Set Tardy Attendance Mark'	Allows instructor to assign marks for tardy attendance records, e.g., lateness
Attendance Converter	'Convert to Grade'	Automatically converts attendance records to grade, using the mark predefined in the 'Set Grade Mark' function above
	'Export Grade'	Allows converted grade to be exported in various format e.g., docx and pdf
	'Convert Tardy Attendance'	Converts tardy attendance records to grade, based on the mark assigned in 'Set Tardy attendance Mark' function above
	Others	Other functions such as 'download grade', 'edit grade', and 'print grade' can be used to respectively download, edit, and print grades
Participation Point	'Award Points'	Provide interface, e.g., grade sheets, that can be used to award credit points to students who participated in learning activities
	'Create Criteria'	Allow instructors to define criteria (e.g., answering questions and completing in-class activity) for awarding participation points, and the number of credit points that aggregates to 1 mark
	'Convert Points'	Sums up the total participation points, per student, and covert these to marks using criteria defined in the 'Create Criteria' function above
	Others	Other functions such as 'edit, download, and export points' can be used to respectively edit, download and export marks for participation point

B. Automatic Disengagement Notification (ADN)

This feature provides functional requirements that can be implemented and used to address the limitations discussed in Section III-B, as well as the attendance policy limitations discussed in Section III-C. These functions can be used to configure, update, and send automatic alert to faculty and staff, at regular intervals, if the attendance record of a given student falls below a stipulated threshold. In this way, students with risky attendance trends can be detected on time and strategies can be developed to re-engage and retain them. In addition, it includes functions for creating and publishing attendance policy. The uses of specific functions included in this feature are described in Table IV.

C. Others Features

In addition to the ones discussed above, the 'Excused Leave Manager' provides functions that can be used to apply for excused leave, upload supporting documents, and perform other related functions, thereby addressing the other limitation discussed in Section III-C. Furthermore, the 'Attendance Data Analyzer' can support administrative staff and instructors to perform basic data analysis and generate reports from attendance records. Table V describes uses of the specific functions in these features.

VI. User Requirements

The use case model shown in Fig. 3 is used to capture the high-level user requirements for the proposed IAMS. A user case describes user requirements by showing the activities (usecases) each user can perform. In our use case model, we apply the concept of usecase 'generalization and inheritance' to show the 'usecases' that can be performed by general users and specialized users. Specialized users such as students and instructors can (inherit) or perform same activities, e.g., 'create account' and 'view attendance report' as the general user. However, as shown in Fig. 3, some usecases can only be performed by specific users, e.g., only instructors can 'convert attendance to grade'.

TABLE IV. Description of Automatic Disengagement Notification Feature

Sub/L2 Feature	L3 Features /Function	Uses/Description
Notification Configuration	'Create Notification'	For creating/customizing notifications messages or alert that would be sent to instructors regarding risky attendance records.
	'Set Notification Frequency'	For setting notification frequency, e.g., monthly or biweekly
	'Set Attendance Threshold'	To configure the attendance threshold, e.g., %75, below which IAMS automatically sends notification messages or alert
	'Delete Notification'	Can be used to delete existing notifications
Notification Update	'Add Receiver'	Can be used to add desired or relevant stakeholders, e.g., academic adviser, admin staff, etc., that can receive notifications message
	'View, Edit, & Save Notification'	These can be used to perform normal updating functions, e.g., view, edit, save respectively, on already configured notification.
Notification Options	'Fitbits, text, push, email'	This allows the choice of various devices and options, e.g., fitbits, email, and text, to receive notification messages
Policy Publisher	'Create Policy'	This function can be used by instructors or admin staff to create attendance policy
	'Edit & View Policy'	Provide functions for editing and viewing attendance policies respectively
	'Publish Policy'	This function allows attendance policy to go live online via institution's website after it has been created or edited.

TABLE V. Description of Other Features in IAMS

Sub/L2 Feature	L3 Features /Function	Uses/Description
Excused Leave Manager	'Apply for Leave'	Provide friendly and easy to use interface for students to apply for excused leave
	'Approve Leave'	Can be used to approve leave application
	'Request Supporting Evidence'	Allow instructors to request for supporting evidence/documents, e.g., doctors report, from students who apply for excused leave.
	'Upload Evidence'	Students can use this function to upload supporting evidence/documents
	'View, Approve, and Refuse Leave'	These functions can be used respectively to view, accept, and refuse leave applications
Attendance Data Analyzer	'Select Dimension'	Allow users to select the dimension they wish to generate attendance report. Examples of dimensions include, generate report by semester, by course, by year, etc.
	'Plot Trend'	This function can be used to plot or generate reports from attendance records in different format.
	'Select Plot Format'	This function can be used to specify the format, e.g., tables, graphs, charts, for plotting or generating attendance reports.
	'Download, Edit, and Print Report'	These functions can be used to download, edit, and print reports respectively

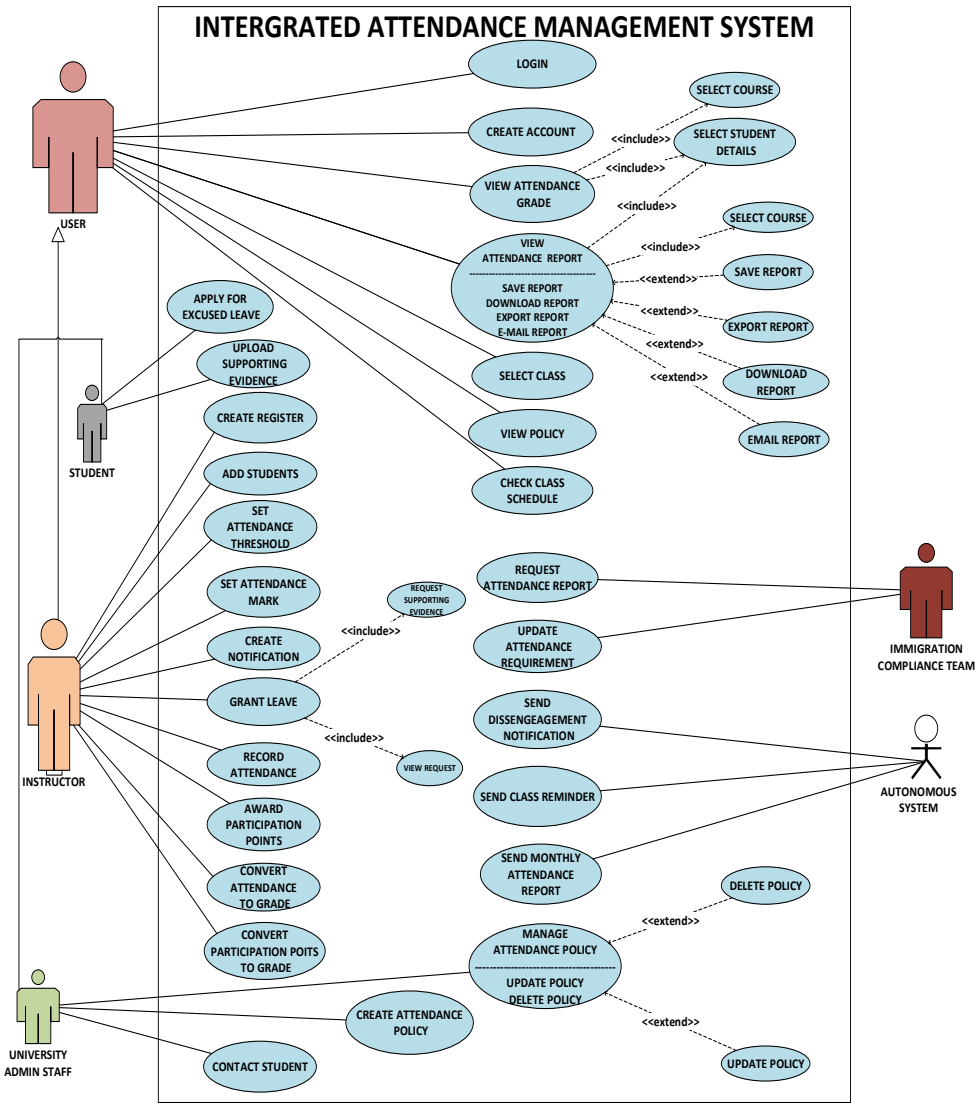

Fig. 3. Use case model for the proposed IAMS.

VII. Conclusion, Limitation and Future Work

Attendance monitoring systems (AMS) are important education systems intended, among other benefits, to maximize student engagement, academic performance, and retention. In this paper, we review available traditional AMS and identify limitations of their functionalities, the most significant being that they are generally limited to attendance recording and reporting. Overall, they lack useful functionalities that can be used to advance attendance monitoring and optimize intended benefits. Hence, they are rapidly becoming traditional, with a high risk of not meeting contemporary pedagogical needs.

This paper contributes to and supports the advancement of attendance monitoring by providing functional and user requirements that can be adopted, customized, and re-used by education systems providers. Its adoption can facilitate the optimization of the inherent benefits of IAMS and its continuous relevance to contemporary pedagogical demands. Re-using the identified requirements can contribute to saving the significant amount of cost, resources, and efforts required to develop requirements. Also we believe that implementing these requirements as an integrated attendance monitoring system (IAMS) can re-position and address the limitations of traditional AMS; thereby contributing towards realizing the intended benefits of attendance monitoring.

While it is possible to customize and re-use these requirements, readers should be aware of certain limitations. One of such limitations is that the requirements elicitation is based on one institution and few stakeholders interviewed. Including more institutions and stakeholders in the elicitation process can help to identify more robust requirements. In the future, we plan to expand our requirements elicitation process to include other institutions, stakeholders, and requirements elicitation techniques such as surveys and prototyping. Afterwards, we will implement, test, and deploy the IAMS. Finally, we will collate and analyze empirical data to validate IAMS.

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