An Agent-based Group Formation Architecture for the Creation of Effective Learning Groups in Universities

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Abstract
The creation of homogeneous student groups is a vital element to the learning process in Universities. Students usually collaborate and work in teams to gain insights, learn from their peers and improve their intellectual abilities. However, forming effective learning groups is a not a trivial activity especially that students vary according to multifold aspects like learning styles, performance, personality, commandment of language. As such differences increase the difficulty of grouping students effectively. This paper suggests an agent-based computational algorithm that aims to achieve the automatic formation of effective groups in a learning environment considering the unique characteristics and differences of university students. To achieve this goal, we propose a two phase research process, wherein the first phase a survey is administered and distributed to university students and instructors to collect information about student learning characteristics and any potential constraints, and in the second phase, these requirements are combined and translated into a smart agent-based architecture by leveraging the advantages of the multi-agent paradigm. The purported architecture will have the capacity to be customized to accommodate the specific needs of course instructors within various educational institutions and contexts.

Key words:
Group formation, Multi-agent systems, Architecture, Student, Collaborative learning

1. Introduction

Collaborative learning has multiple definitions; however, [1] define it as "a coordinated synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem", and [2] defines it as the "situation where two or more people learn together". This is different to individual learning where each student learns on his own. Moreover, collaborative learning can be seen as an educational strategy to support the learning process of small or large groups of students with the aim of completing a group assignment, the design of a solution, and the implementation of a software or product. Collaborative learning can happen in the classroom or outside the classroom, face to face or virtually through e-learning systems.

Research efforts have demonstrated that collaborative learning offers many advantages and improves the student learning [3]. Firstly, it stems from the principle that learning is an activity that has a social nature and that learners learn as they discuss and exchange ideas between themselves. Secondly, learners increase their knowledge as they are exposed to other opinions by their peers. Thirdly, learners in collaborative learning are pushed to the maximum of their ability to argument and defend their core ideas and opinions about certain topics which incite them to create their own styles of thinking.

The research challenge however lies in the process of dividing and allocating students into cooperative learning teams or groups in an educational environment, especially given the diverse characteristics of learners. To simplify the problem, let us consider the following scenario: “Dr Ahmad teaches System Analysis and Design course which usually attracts a large pool of students. This course has a prerequisite and aims to develop certain analytical skills, and thereby sets a design group project as part of its assessment. In addition, the registered students differ in their intellectual abilities, aspirations, and learning styles. Dr Ahmad encounters issues when distributing students into an appropriate group size and appointing them to the right group to maximize potential learning opportunities”.

In fact, many teachers rely heavily on traditional methods of allocating students to groups. Some of these well-known methods include, but not limited to, random allocation of students to groups, self-selection of students, and selective allocation to the group. All of these manual methods have documented benefits and drawbacks. This research aims to rid of traditional group formation approaches and replace them with a computational approach that is more scientific and beneficial to the students. Therefore, this research attempts to address two important questions:

- Research Question One: what student characteristics/factors should be considered when assigning students to learning teams or groups?
- Research Question Two: what are the properties of a computational agent-based architecture that would assist in the formation of effective teams or groups of students?

Generally, assigning students to learning groups in an ideal way is a daunting task especially when teachers need to consider students attributes and constraints. This research thus constitutes a first step towards a group formation

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architecture that will harness the advantages of multi-agent systems to realize negotiation and cooperation between student agents depending on their learning goals, abilities and constraints. The software agents will represent and defend student's interests whilst indulging in the group formation process.

Answering the posited research questions will enable the promotion of a culture of collaborative learning amongst students, including the improvement of learning outcomes [4]. Moreover, the architecture would assist teachers in creating optimal student groups both for in class and out of class activities, reducing the complexity of assigning students to groups through traditional methods which are either unfounded or cumbersome.

2. Previous Studies

Modern research has suggested that collaborative learning tends to improve the efficiency of below average students [5]; [3]. Student learning in groups is a way of encouraging each other to clarify their queries and explain and justify the opinions, eloquent their reasoning, elaborate and reflect upon the knowledge they have [6]. Learning is mostly driven through conversation with peers [7]; [8]. It can be specifically relevant if it comes to the understanding of ambiguous and complex information. Moreover, collaborative learning fosters diversity understanding and decreases nervousness and builds confidence within students [3].

Despite their benefits towards student learning, the implementation of collaborative learning environments that are supported by technology is indeed a bigger challenge [9]. For instance, wikis represent a potential platform with their inbuilt features that support collaborative-writing and societal communication; however, in the absence of an effective learning design, collaborative learning supported by wikis cannot be functional. Well thought online learning groups with appropriate enquiring and feedback form online tutors and facilitators can improve meaningful and productive interaction and learning [10].

Early research studies in the area of collaborative learning confirm the need for automatic appointment of students to groups to create a sound collaborative learning environment [11]; [12]. The authors in [12] proposed a system that is reliant on the concept of 'Intended Points of Cooperation'. The tested system formed groups of students based on the collaboration context including the size of group, type of activity and materials to be used. A specific interface based learning system [37] based on the learning style model has been developed so that the different learning preferences can be revealed through the interactions of the end user with the system. This interface is then used to diagnose different learning styles from the behavior patterns of the learner using Hidden Markov Model and Decision Tree approaches [13]. The authors in [11] implemented an open source model for automatically forming collaborative learning groups in informal environments when teachers are unavailable. Furthermore, authors in [14] proposed an innovative technique in which an automatic dynamic group formation takes place based on Group Technology (GT), an approach to engineering and manufacturing management[15]. This approach helps to manage diversities by exploiting underlying commonalities in the products and activities.

Previous group formation models and algorithms include the use of fuzzy c-means clustering method wherein students could belong to other groups [16], the use of semantic data and logic programming to satisfy the learners' constraints [17]; [18], the use of genetic approach considering multiple criteria [19], and the use of particle swarm optimization [40]. The authors in [35] summarized existing algorithms for group formation within the context of computer-supported collaborative learning. Their systematic study in this field showed that approximately 41% of the algorithms utilize probabilistic models.

The authors in [19] suggested a genetic algorithm-based approach for grouping learners into homogenous and heterogeneous groups. This approach uses three characteristics namely, estimated knowledge level, estimated communicative skills, and estimated leadership skills. In [20], the authors suggested a framework that implements two varying optimization algorithms that seek to maximize diversity within learning groups by raising the number of students who interact with high ability peers. However, our proposed research argues that existing group formation systems cannot be applied directly to all contexts and settings (i.e. different cultures). Instead, additional factors like the learning styles and commandment of language ought to be identified and included into an appropriate model.

The authors in [23] created a genetic algorithm that uses students' programming skills to create efficient groups. The idea simply involves groups with balanced programming skills so that students manage to complete their projects successfully. Testing demonstrated that genetic based approach was more productive than manual allocation of students to groups. The authors in [24] described an approach that uses student behavior to form groups. In achieving this, case-based reasoning was utilized to model student behavior. The output of this process is used as key criterion to place learners into appropriate groups. The authors in [39] investigated the ways to form balanced collaborative groups to maximize students' learning. The authors proposed a unique genetic based algorithm which they claim will help instructors to form collaborative groups with increased learning. This algorithm has the capacity to form inter-homogeneous and intra-homogenous

collaborative learning groups based on several characteristics of the students.

Contrary to the existing approaches, our architecture relies on the multi-agent paradigm. Cooperative multi-agent systems refer to several agents interacting together to maximize the utility or to jointly accomplish a task [25]. The influence of multi-agent systems is spreading across almost every field including electronic learning environments (e-learning). Multi agent learning has spanned a broad spectrum of areas, such as agent-based modelling, robotics, reinforcement learning, evolutionary computing, game theory and complex systems. Multi agent learning supports team learning and concurrent learning. Whilst team learning enables a single learner to discover cooperative solutions to multi-agent system problems, concurrent learning enables several simultaneous learners, frequently one per agent. Agent based systems represent a viable technology for dealing with distributed and collaborated such as learning platforms and environments for it enables masses to receive quality education without being restricted to specific place or time [26].

3. Requirements Elicitation Methodology

In this research we applied a mixed-method approach [42], combining three differing research methods, namely literature analysis, expert evaluation, and student survey. Mixed method research refers to a methodology that uses multiple research techniques with the aim of collecting both qualitative and quantitative data [42]. The literature argues for various benefits of combining qualitative and quantitative research methods such as the triangulation. Qualitative data refers to the open ended data (e.g. documents, text, and discourse) that are normally collected using interviews and observations. However, quantitative data refers to the closed ended data (e.g. checklist, user ratings, performance results… etc.) that are normally collected using questionnaires and surveys. Usually such data are analyzed using means of statistical analysis such as correlation and one way Anova, allowing to test the validity of research hypotheses. Arguably, qualitative research is appropriate for forming a new model or theory, whilst quantitative research is more suitable for testing the newly-developed model or theory.

At first interviews with instructors and a survey with prospective students were conducted to identify the characteristics and profiles of learners along with any potential constraints. The criteria to examine range from educational level, languages, intellectual abilities, age, to commitment (e.g. Figure 1). The survey was developed using Google forms and distributed to participants in the faculty of Computer and Information Systems. Next, the responses were compiled and analyzed using descriptive statistics to decide about the learners' criteria and requirements to include in the design of the architecture.

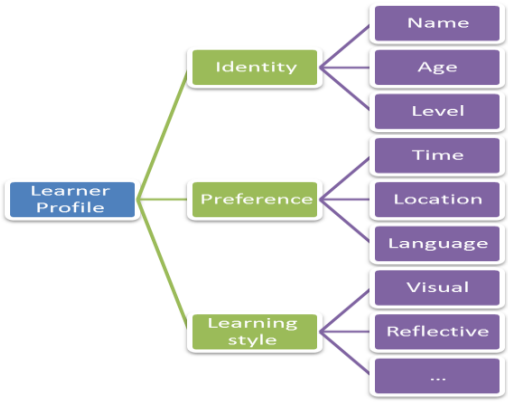

Fig. 1 Initial learner profile characteristics

Once the requirements for the effective group formation were defined, the next step involved the design of the agent based architecture for realizing automatic clustering of students based on their profiles, characteristics and any constraints specified by the course instructors.

Each of the methods was used to inform the outputs of the next phase to complement the results and help answer the research questions (see Figure 2). These methods also explored the research problem from various angles, elaborated any unclear concepts, and excluded any potential contradictions or inconsistencies.

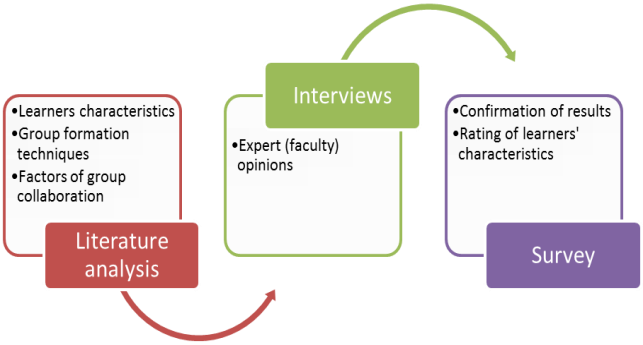

Fig. 2 Requirements Elicitation Methodology

The systematic review of the literature analyzed the past studies that investigated the features that determined how students learn together in groups. Similarly, the interviews probed course instructors about what they think is relevant when forming groups of students in their courses, with the aim of answering the following research question:

- What student characteristics/factors should be considered when assigning students to teams or groups?

However, the student survey confirmed the findings from the systematic review and interviews in respect to the students and groups characteristics that impact the learning outcome. The findings from these research methods enabled answering the following research question:

- What are the properties of a computational agent-based algorithm that would assist in the formation of effective teams or groups of students?

4. Results and Discussion

This section presents the results of the data collection process followed by the architecture of the multi-agent group formation system. More precisely, this section describes the key characteristics that are relevant to effective student learning as identified from a comprehensive literature review. It then moves to gauging expert opinions about these factors through lively discussion. Finally students' opinions are taken into account to validate the factors and establish an agent based architecture for organizing student groups effectively.

4.1 Results of the Systematic Review of the Key Factors of Group Formation

Collaborative learning placements are the methods of learning in which the students are grouped for certain purpose and each group works towards learning for the same academic achievement [27]. Heterogeneous grouping of the students results in the improvement of the performance of students quite considerably, in which their learning style and personality traits are considered to be an essential forecaster for the participation of students in the groups. The selected method to form groups can have a considerable impact on the performance of the group and the required outcomes. Authors in [28] explored various methods of group formation and discussed the following methods of group assignment:

1. Random assignment method: this method is typically used by a large number of instructors where each student has equal chances of getting selected into a group. The decision mainly is based on the required number of groups. Once decided, the instructor randomly assigns students to each group.
2. Self-selection method: in this method the students are given an option to choose their own team members. The first choice for students is generally their friends and after that their decision is based on the seating proximity.

The authors in [29] observed various aspects of group formation when they asked students to form their groups based on their proposed criteria including: common topics of interests, compatible working periods, similar background and culture, you know or you like the other persons in the group, you selected a group because you had to form a group.

The author in [30] analyzed the impact of group work on students' learning. He argues that group tasks can promote learning amongst students. The size of the group also matters towards achieving the outcomes of the assigned tasks. A group of 4 to 6 students is generally considered successful to promote collaborative work. However, in more complex tasks a larger group of 8 to 10 students can also produce good outcomes. The author suggests that the group formation should be done on the following basis:

1. Forming a group with diverse set of students: in this method a diverse group should be formed including students from a wide range of intellectual abilities, academic interests and cognitive styles.

The authors in [41] discussed various problems that instructors face to form student groups to enhance the productivity and efficiency of the project. The authors explored many group forming methods including students' own choice, student number code, heterogeneous mixture of sex, age, nationality, specialization, personality type and learning style. However, their researched focused on analyzing team formation using following two methods:

1. Enabling students to choose their own teams: in this method students choose team members based upon random factors. However, there seems to be no specific personality style that students consider while choosing the right member for their teams.
2. Selecting team members based on the personality types: in this method the students can choose their team members based on the personality types. A number of personality tests can be potentially useful for students to choose the right member.

The overall results showed that the groups formed considering the personality types of students resulted in better performance in the design projects. However, the groups that were formed by allowing students to choose their own teams performed better in the research projects.

Another interesting method of forming groups has been discussed in [31]. Following is the discussed method:

1. Selecting team members semi-randomly: groups are formed in this method by following two steps. In the first step, students choose a group member on their own will and in the second step the instructor combines three such groups randomly.

The authors claim that with their proposed method the overall group and individual learning improved quite significantly.

In [32][32], the authors discussed the impact of team skills on business. The authors argue that in order to increase the

impact of teamwork the workload should be balanced and enough class time should be allocated for students' project work. Peer evaluation was found to improve the team experience for students. A case study was presented in [33] focusing on the learning styles and their impact on student grouping and collaborative learning. Learning styles were found to directly impact the group collaboration and learning gains. Similar findings were reported in [34]; [37]; [38].

The authors in [36] discussed the differences between the level of students in terms of their motivation and attitudes towards teaching and learning. They suggested that if instructors have a better understanding of the different levels of students they will be in a good position to meet the diverse learning needs of their students. The authors pinpointed three categories of the diverse cultural needs:

- Students' learning styles
- Learning approaches
- Intellectual development levels

For a better classification of learners, the authors in [21] suggested the inclusion of learner profiles and information on learner context to improve the quality of grouping. The authors in [22] have argued for the importance of cognitive load theory in educational psychology and that it could be exploited to generate principles for the design of collaborative learning.

A succinct summary of the major relevant factors that emerged from our literature analysis are grouped into two categories, namely student characteristics and group characteristics.

1. Student characteristics
   - Major (e.g. Computer Science, Information Systems … etc.)
   - Study level (freshman, junior, senior … etc.)
   - Gender
   - Language (Arabic, English … etc.)
   - Performance level (e.g. accumulative GPA)
   - Skill level (programming, communication … etc.)
   - IQ levels
   - Personality traits / type
   - Availability and convenience
   - Interest
   - Learning style

2. Group characteristics
   - Group purpose (enhance communication skills, team work, leadership … etc.)
   - Group size (small (2/3), large (6 and more) … etc.)
   - Group type (homogeneous, heterogeneous)
   - Group task complexity (easy, difficult)
   - Group roles
   - Group duration
   - Group formation strategy (random, student, teacher)

4.2 Results of the Expert Opinions

Next, faculty members were consulted about the importance and relevance of the above criteria to forming effective groups in an automatic way. To this end, an interview was conducted containing the following questions:

1. For what purpose are student groups formed?
2. What student characteristics do you consider important when forming student groups for learning activities in your class?
3. Typically, how long do these student groups last for?
4. Typically, what is the size of your student groups in you class?
5. Are the groups formed homogeneous or heterogonous in nature?
6. Usually, how are the student groups formed (randomly …etc.)?

The expert opinions were collected and analyzed to form a better understanding of the characteristics deemed important to forming effective groups for performing learning exercises. Our pool of experts included faculty from various computing disciplines including computer science and information systems. The results of the interviews, in the form of key themes, are concluded in Figure 3.

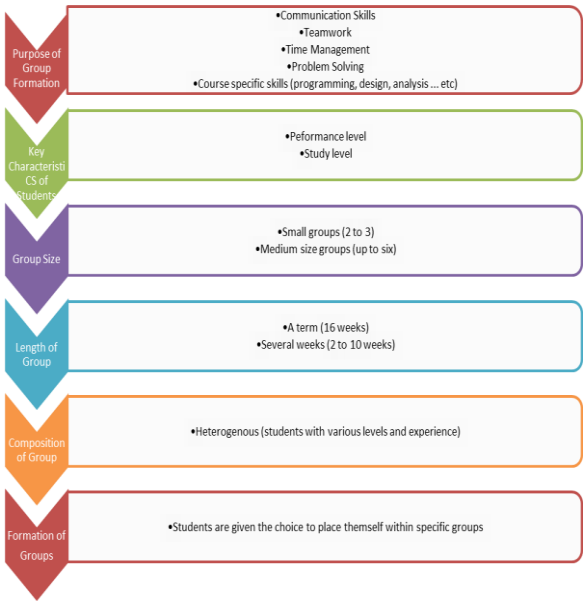

Fig. 3 Grouping criteria identified by the experts

4.3 Results of the Student Survey

Next, a survey was formed combining the results of the literature survey and interviews and given to computing students who were asked to rate the importance and relevance of the collected factors to the formation of effective study groups using a 7 points rating scale ranging from strongly agree (=7) to strongly disagree (=1).

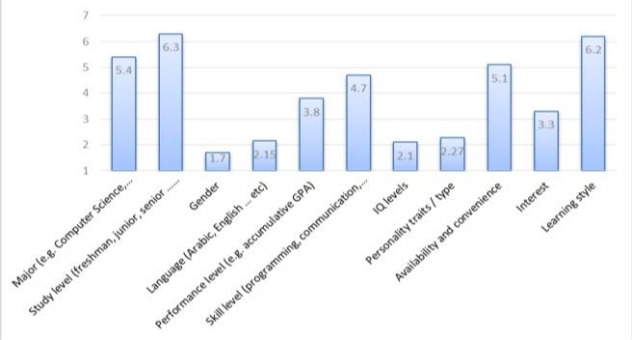

Fig. 4 Student characteristics that are relevant to forming groups

Scores of student characteristics revealed that groups are usually formed by taking into account five key features (those that average above 4). The most important factors to forming student groups, according to the survey, are the study level (m=6.3), learning style (m=6.2), availability of fellow students (m=5.1), and skill level of students (m=4.7). On the other hand, gender, language spoken and IQ level were considered as the least relevant to the purpose of this research.

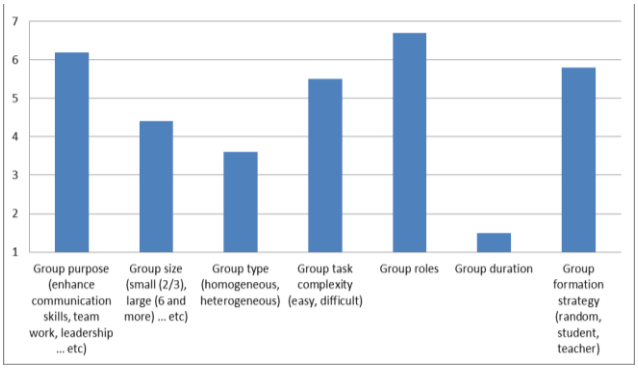

Fig. 5 Group characteristics that are relevant to forming groups

When requested to give opinions about what matters most for forming effective learning groups, the responses showed that the roles needed (m= 6.7), purpose of the group (m=6.2) and type of formation strategy (m= 5.8) were the most important. Duration of the project however was deemed as the least importance.

4.4 The Proposed Multi-Agent Architecture and Algorithm for Effective Learning Group Formation

The results of the literature analysis, interviews, and survey were combined and used to derive an agent based model for the formation of effective learning groups. As stated before, the agent paradigm is capitalized to achieve this goal. In our case, agents are used to represent the features of students and group characteristics. Overall, five main types of agents were introduced in the architecture as follows:

1. Managing agent: an instance of this agent manages and coordinates the tasks of the remaining agents of the multi-agent architecture
2. Instructor agent: an instance of this agent represents course instructors with details about their personal information (e.g. age, experience, courses … etc.) and teaching strategy
3. Student agent: an instance of this agent represents students with details about their personal information (e.g. age, major, language, GPA, study level, availability … etc.) and best learning strategy
4. Course agent: an instance of this agent represents course details such as course code, course setup, teamwork assignments, and course main learning outcome.
5. Group agent: an instance of this agent represents the key group characteristics and options that need to be considered during the formulation of learning groups

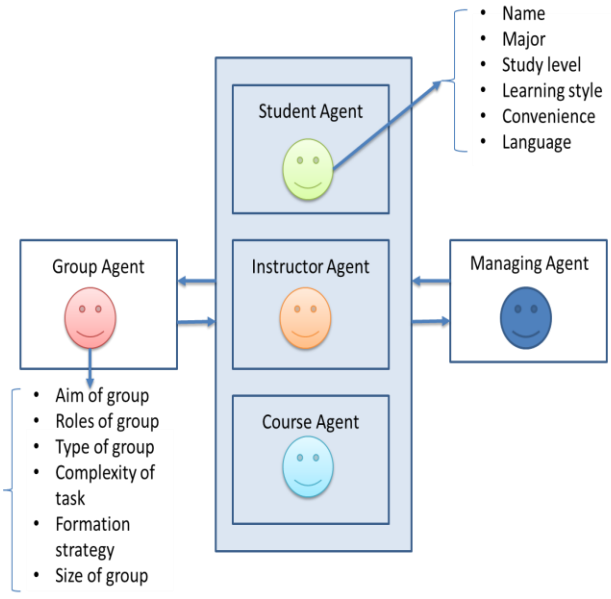

Fig. 6 Multi-Agent architecture for the formation of effective learning groups

The architecture (as in Figure 6) creates one instance of the managing agent, one instance of the group agent, and multiple agents to represent students, instructors and courses as per the needs of the faculty / department. Table 1 summarizes the roles of the agents of the architecture.

Table 1: The types of agents used in the architecture

Type of Agent	Roles
Managing agent	-Initiates other types of agents -Coordinates the activities of other agents -Stops any unneeded agents
Student agent	-Represents students and their characteristics -Negotiates on behalf of students to achieve the best interests and gains
Instructor agent	-Represents instructors and their characteristics (e.g. aim … etc.)
Course agent	-Represents courses and their goals (e.g. code, course, learning outcomes… etc.)
Group agent	-Given the needs and goals of students and instructors, this agent finds resolutions about conflicts and proposes the best groups that ensure best learning opportunities and gains

The algorithm that this research proposes takes into account all relevant factors to ensure efficient student groups are created as follows.

Algorithm Generate Effective Learning Groups

START

Given a course (**C**) with a learning outcome (**LO**) and an instructor (**I**)

- Student Groups (**G**) are empty
- Fetch all preferences (**P**) of the instructor (**I**)
  - Favorite group formation strategy of the instructor
  - Preferred group size
- Fetch all students (**S**) of this course (**C**)
  - Extract the characteristics (**CH**) of each student
- **REPEAT** for each student (**s**) in (**S**)
  - Check the required roles for a given learning outcome (**LO**)
  - Compute the suitability of current student to the required roles
  - Assign the student (**s**) to the group ($\mathbf{g_n}$) taking into account the constraints:
    - Size of group
    - Formation strategy
    - Available roles
    - Student preferences (e.g. availability … etc.)
- **UNTIL** all students are accommodated within a specific group

Return a list of optimal learning groups (**G**) with their members

STOP

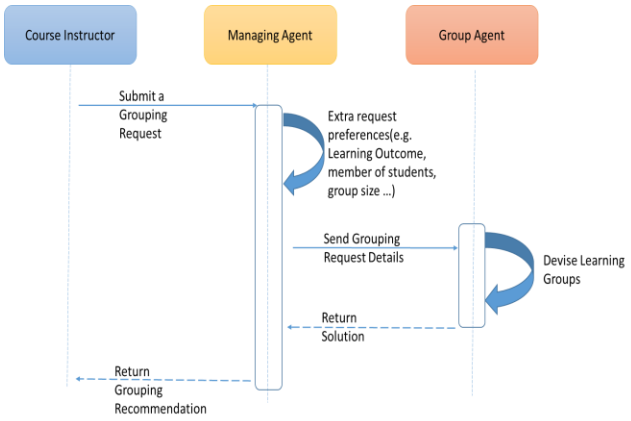

Fig. 7 Interaction diagram between the learning agents

Typically, a course instructor would use the system to activate automatic groups of students as described in Fig. 7. This starts in a form of a grouping request which will be fetched by the managing agent as it represents the entry point of the model. The managing agent will, in turn, extract the preferences as submitted by the instructor. This would include the purpose of the learning activity / outcome, the preferred learning group size, required roles for the task etc. Once deciphered, this request is submitted to the Group agent which will take into consideration the students' learning skills and abilities, as well as group preferences. Once the optimal groups are formed they are returned to the course instructor through the managing agent.

The use cases of course instructors and students are depicted in Figure 8.

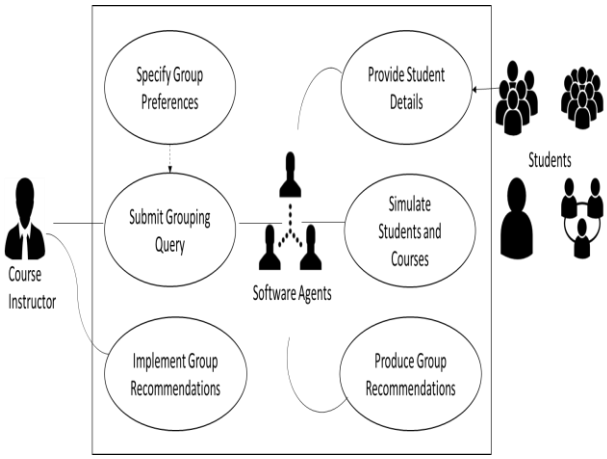

Fig. 8 Use case diagram depicting all major activities

Students submit their requests to join particular groups to the group agent which reviews the characteristics (e.g. abilities and limitations) of the student and checks if it fits well with the existing groups. Subsequently, the group

agent will make a decision to approve or reject the request (as in Figure 9).

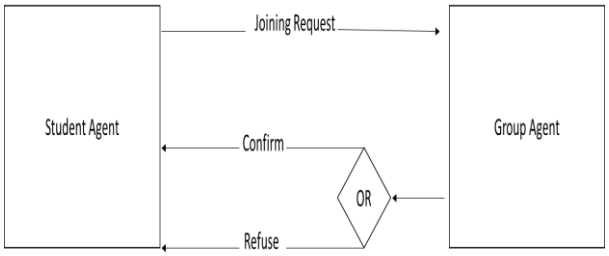

Fig. 9 Interaction diagram between the student and group agent

5. Conclusion and Future Work

The herein research has detailed the architecture of a multi-agent model, as well as the necessary UML diagrams, that exploit the attributes of software agents in the classification of students into an appropriate study group given a set of factors and constraints. The goal is to maximize the learning experience and learning gains of the student (e.g. knowledge, skills, and attitudes). In doing so, this research adopted a mixed method approach combining a systematic review of the literature, expert opinions, and learners' opinions. The outcomes were a set of characteristics and constraints relevant to two elements namely students and groups. The important factors that were relevant to the students included learning style, convenience and availability of students, and skill level of students. However, in respect to the group, the roles needed to achieve the task, purpose of the group (i.e. learning goal), and type of formation strategy were deemed as critical.

In the future, we intend to test the proposed architecture and benchmark it against other existing artificial intelligence (e.g. genetic algorithm) and probabilistic algorithms to verify its performance and ensure that it successfully creates effective groups as part of an exhaustive comparative study. Moreover, we also have plans to extend the architecture to incorporate other personal and sophisticated characteristics (e.g. intrinsic factors such as mood and emotions) to improve the group formation results.

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