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STUDYING DECISION MAKING MECHANISM FOR GROUP FORMATION IN A MULTI-AGENT SYSTEM

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ABSTRACT: *In recent years, Group Decision Making has been studied and applied in many fields. In a complex system, there is a lot of components that change time by time, dynamic, multi-dimension, etc. There are a lot of challenges for researching about this system. The system can't be centralized controlled. So, the distributed approach is the core of the studying. Inspired by reality, we propose an approach for forming the group through local interaction in the multi-agent system. The research mention three main elements that are, criteria to identify a group; choose the representative; the representative make a decision. The paper only describes the stage for forming the group based on the position of the agents in two-dimensional space. This study is the first stage of making the multi-level multi-agent system that we are studying. The model is applicated for describing behaviors of passengers in the departure lounges at the airports when an evacuation situation occurs.*

Keywords: *Group decision making, multi-agent system, collective behaviour.*

I. INTRODUCTION

The successful group decision-making among alternatives is fundamental to tasks that require coordination among agents. The agents in a group make a choice among alternatives allows the representative of the group makes a collectively decide. This approach is begun by a lot of different inspirations, such as inspiration from animals group as a honeybee swarm, a fish school, migratory birds. Indeed, animal groups are formed by the purpose of migration, foraging, and evasion, with speed, accuracy, robustness, and adaptability. In these systems, each individual acts autonomously and interacts only with local neighbours, while the global system exhibits coordinated behaviour and is highly adaptive to local changes. In fact, there are many studies about making a collective decision that depends on the different application fields.

In the evacuation situation, detection and monitoring the crowd's behavior is needed to manage, control, direct the crowd for the purpose of reducing risks. The group decision making is a core problem of detecting and capturing the group's behaviour. For example, in evacuation environment, the agents attempt to find valid paths in complex environments to a safe goal location. But if an agent does not enough knowledge about the environment then its decision about paths to the goal or safe goal location is not exactly. In this situation, the agent has to interact and coordinate with neighbour agents in order to receive information about the paths to the goal or imitate other agents to change its behaviours.

Inspired by the trust for delegating the decision of the individual to other. We based on relationships available between individuals in the group to choose the representative that make a collective decision. In the model, group decision making depends on the decision of the representative. Individuals in the group interact with each other to have more knowledge and interact with the representative to delegate making a decision and identify agree with that decision or no. The decision of the representative is a decision collectively of the group. The result of group decision making is manifested by collective behaviours.

In the paper, we propose a multi-agent system (MAS) approach. The group decision-making process can be conceptualized as consisting of three main steps: 1) determine the group, in which give criteria for defining a group; 2) choose the representative, in which the agent choices the representative based on criteria and rules; and 3) the representative make a decision that based on the common decision of the group.

The structure of the paper is as follows: section 2 covers related works; the background is presented in section 3; the proposed approach is presented in section 4; conclusion and discussion are covered in section 5.

II. RELATED WORKS

There are many papers have been studied on the decision-making for various purposes application and have approached in various types of multi-agent systems. There are two aspects are interested as the mechanism to make the model and inspirations to study. The mechanism form background based on roles, tasks, and rules of the individual in the group and method to build a group, method to interact with the individuals in the group. There are a lot of inspirations such as animal groups, the fact in the crowded environment of human, the transport networks, sensor networks in the complex environment, etc. In [2,4,5] inspired by biological studies, [1] study of mechanism collaborative decision making for a group of agents. In the model [1], the decision process is a multi-stage process, there is not representative of collective, the members in the group has the role the same, using the mathematical model to aggregates the trust values, then the highest value of the trust is selected as a collective decision. In [2] collective decision-making by implicit leadership through local interaction. The collaborative decision-making process depends on agents and the agent responsible for the component decision-making process. Trust is one of the most valuable group components and is essential to the process of influence and collaboration [20, 21, 22]. There are many papers in which presented and tested on making a collective decision. Our model is applicated for describing behaviors of passengers in the departure lounges at the airports when an evacuation situation occurs. We propose the model from the trust of the individuals that have closed relationships or available known to choose the representative. The individuals choose and delegate the representative to make a decision based on suitability criteria.

III. BACKGROUND

3.1. The related definitions

In this section, we present some mentions of a group, multi-agent group, group decision making, collective product, emergence. They are related to each other and are basic subjects for our study.

Definition 1: A group is a set of agents that are in the same a region and interact with each other to share knowledge, authorize to make a decision. They have common goals.

In the group, we describe two observation levels which are the individual level and the social level.

At a level, we mention roles, tasks, and rules. Only one role is assigned to an agent, however, a role may be is assigned by several agents [25]. In the model, we mention two kinds of roles, the roles of representative and roles of normal agents (single). The task is a job that the agent must execute while interacting. The rules are built to resolve problems. The rules can consider as the organizations and the tasks can consider as interactions in the AEIO model.

Definition 2: A multi-agent group is a group in which representative of the group interact with representatives of other groups to share knowledge and make a decision at the higher group level.

Definition 3: Group decision making is a common decision of agents in the group. The representative makes a common decision base on a large number of the decisions of the agents in the group.

Definition 4: A collective product is an observable result at the collective level which can be outcomes of the collective decision process.

Collective product characteristics: a collective product is not formed by a fixed set of agents. It is the result of interactions between different agents. A collective product can be described in different ways depending on the observer position and its distance from the local level.

Figure 1

We mention three kinds of collective products that mention [23]: the collective structures, the collective behaviours and the collective properties [23]. A collective structure refers to the manner in which agents are organized, observed at the collective level (such as passenger line up to wait for their turn as figure 1). A collective behaviour is a collective function at the collective observation level, it can be seen as a primitive action by the team as a whole. It results from interactions between agents leading them to adapt their behaviours/goals relative to their neighbour agents and/or their environment [23] (such as flocking the crowd as figure 2). A collective property is a singularity observed at the collective level and that can't always be seen as the composition of the agent' individual characters [3] (such security of a passenger in the emergency situation).

Definition 5: The emergence is formed unpredictable, it exists at levels in the system but it is shown at the macro level and it is not explicitly implemented.

The emergence makes a system harder to analyze and design. The MAS has been suggested as a tool to resolve this issue. Depend on features of the system, a MAS corresponding is proposed.

Figure 2

3.2. The multi-agent system for the proposed model

We use the Vowels decomposition model of Demazeau - AEIO, A - agent, E - environment, I - interaction, O - organization [31].

The multi-agent system is seen as a collection of the agents and objects of the environment. All aspects of multiagent systems are implemented by the Agent in the Environment based on Interaction and through the Organization. There are two types of agents as single and representative, and there are two kinds of roles are single and representative. There are some interactions such as representative - single, single - single, representative - representative.

1) The Agent

Every agent has some properties such as *id, position*, *role*, *idgroup*, *task*, *listneigbour*, *knowledge*, *listmessage*.

+ *id:* identifier of an agent.

+ *position: the* current position of an agent.

+ *role:* the role of agents. There are two kinds of the role that are the role of the representative and the role of the single.

The role of the representative interacts with the single in the same group to exchange, share the information to make a decision. The representative interacts with other group's representatives to gather information to increase knowledge. The single interact with each other to gain more knowledge and make decisions themselves.

+ *idgroup* identify the group in which agent belongs.

+ *task:* the task of the agent, including send and receive the messages, make a decision.

The tasks depend on the role of agents. The single sends the messages to the singles and the representative in the same group. Similarly, the single receives the messages from the singles and representative in the same group. But the representative sends the messages to the singles in the group and the representatives of another group.

+ *listneigbour*: list of available relationships with an agent.

+ *knowledge:* knowledge of agent.

2) The Environment

The environment is a common space for the agents, objects, resources. An environment is a place where agents are impacted by objects and interact with other agents.

3) The Interaction

The Interaction is actions send and receive the messages between agents. There are three types:

+ A message is sent from the single to the single, the representative to representative is a knowledge.

+ A message is sent from the single to the representative is a private decision.

+ A message is sent from the representative to the single is a common decision.

4) The Organization

The organization is the mechanism formed the interaction between agents, the singles interact with others and the representative, the representative interacts with singles and other group's representative.

IV. PROPOSED APPROACH

4.1.. An analysis of the problem by MAS

In figure 3, the stars are considered as agents (singles) moving in the environment, able to communicate, having a certain autonomy and owning specific information they have to update. The blue circle is represented for a group, the square is represented for a representative of a group. The line joins from the star to the square is represented by the interaction between single and representative in a group. The dashed line join from the square to the square is represented by the interaction between the representative of groups. In addition, there are the interactions between the single and the single in a group. The purpose of interaction is an exchange, share information inside and outside the groups, and delegate to the representative to make a decision.

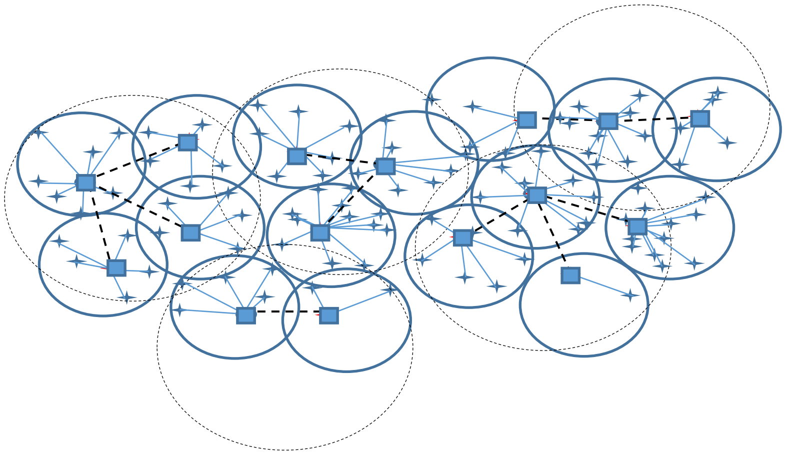

Figure 3.

In the model, we mention two different levels: the individual level and the social level. In the individual level focuses on the internal aspect of an agent defines its own properties, a list of actions that individual can perform, and what it knows (its knowledge of other agents, of the environment, of the interaction and of the organization elements). In the social level focuses on interactions among individuals and organizations. The use of interaction protocols allows achieving exchanges of data or tasks settled from the individual behavior needs. To analysis the problem, we mention four phase: the global phase, individual behaviour phase, social phase (organization and interaction), and social behavior phase.

The global phase aims to identify what is represented by an agent? what are objects of environment? In our case, agents are represented by the passengers and there are some active entities that agents can interact such as, the screens, announcement boards, speakers, and there are some passive entities such as, doors, paths to the goal, blockages, exits etc.

The individual behaviour phase defines individual objectives, individual tasks (requiring only local knowledge and environment acquired data). In our case, there are some possibilities for an agent that waits for information, looking at the screen, announcement board, listen from the announcement speaker and recognize the information, form intentions and make a decision.

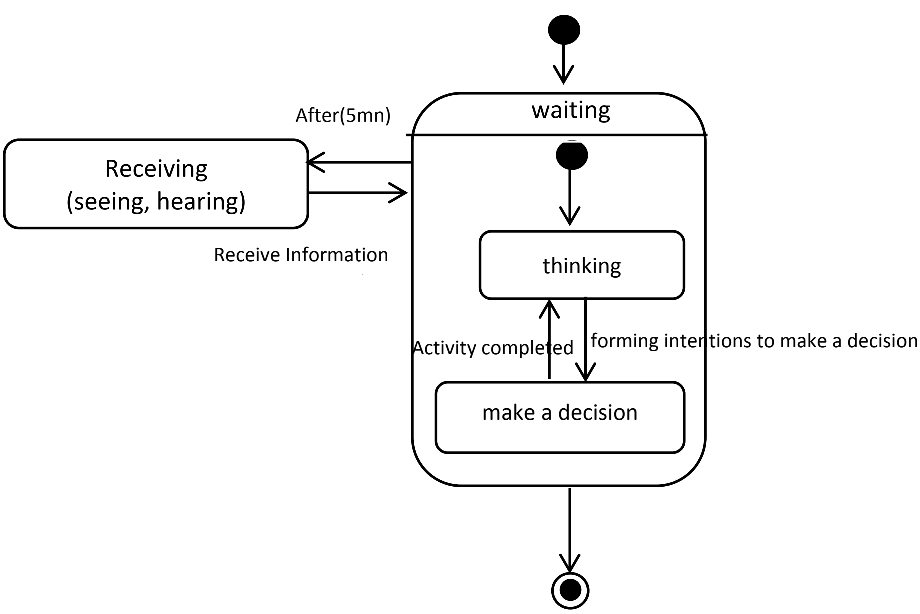

Figure 4. The state-transition diagram for the individual phase

The social phase defines cooperative tasks such as requiring interaction with other agents, negotiation with other agents, negotiation with the representative.

Sequence diagram for query protocol (asking neighbors about information) is described in figure 5. Sequence diagram for negotiation protocol, interact between the representative and single is described in figure 6.

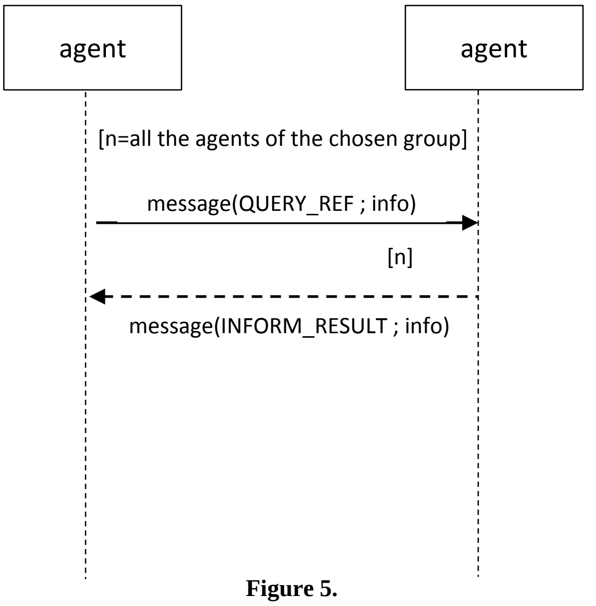

Figure 5.

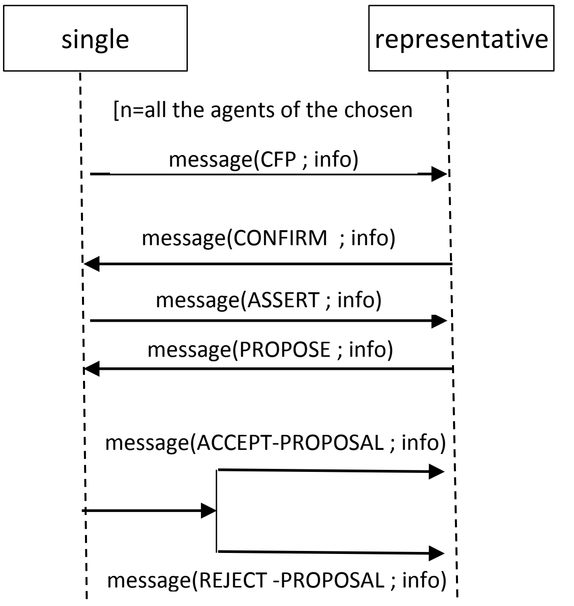

Figure 6.

The social behaviour phase adds the social capabilities (tasks) and knowledge to classes and these are described in the state-transition diagram (figure 7).

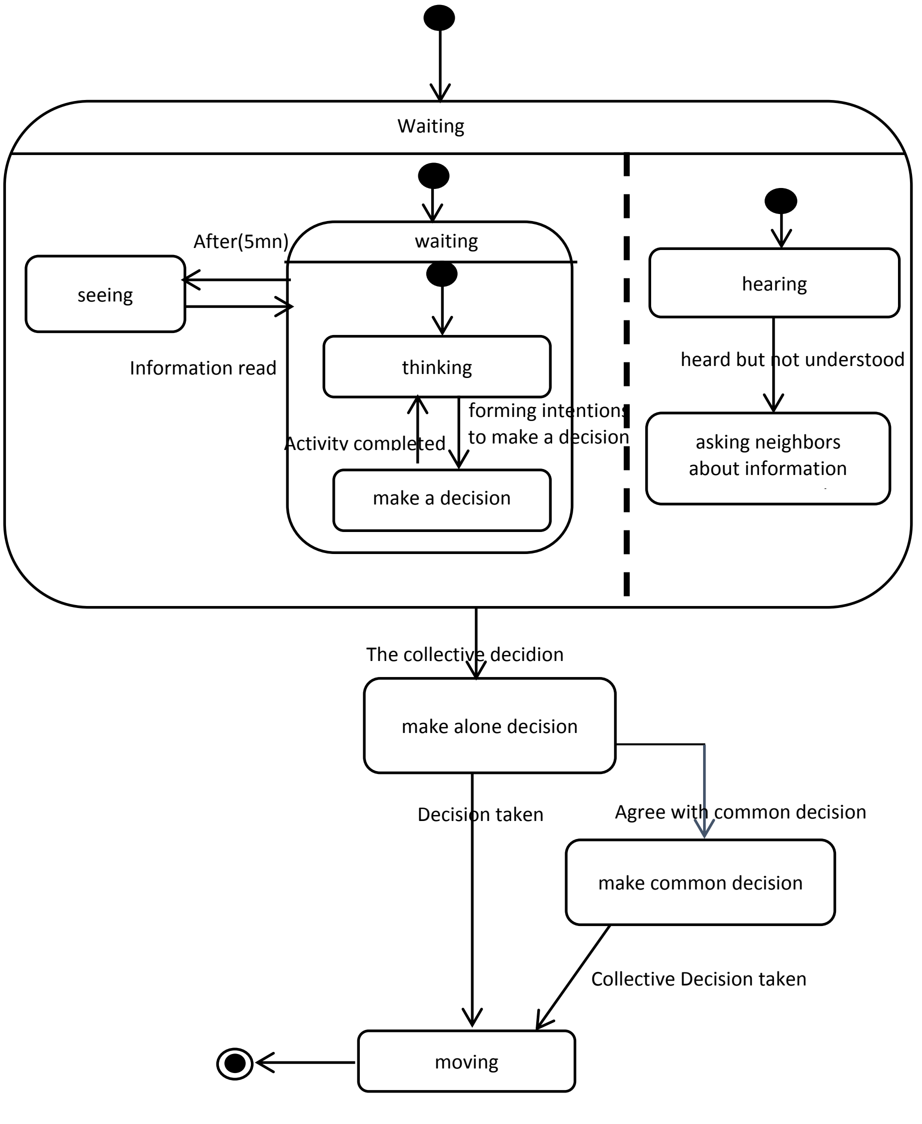

Figure 7.

4.2. Some algorithms for the proposed model

Our model presents the mechanism to capture the group in the next section. We mention the criteria of a group, the algorithm chooses the representative, and the algorithm makes a decision of the group.

1) The criteria for defining the group

- Each group is defined by the range (a circle with radius r), initially, the agents in the specified range belong to that group.
- Groups overlap, but each agent belongs to only one group.
- Each group has only one representative.
- The members of the group can be added or removed by time.

2) Choose the representative in a group

The Algorithm 1. Choose the representative in a group.

Suppose there are n groups, m agents in a group, with group Gi(i=1..n)

1. ComputeScore($S_{j(j=1..m)}$): compute the score of $Single_{j(j=1..m)}$ base on a number of available relationships with other agents in the group.

2. Compare(Score($S_{j(j=1..m)}$): compare the score of Singles in the group *i* and choose the Single who has the highest. If more than one Single agent has the same highest score then go step 3.

3. CompareKnowledge(S_{Cs}): compare the knowledge of Singles that are chosen in step 2.

4. Choose the Representative: the Single that has delegated in step 3.

5. End.

Example: In figure 8.

Agent 1 has 3 acquaintances in the group with agents {2, 4, 5}, $score_1 = 3$

Agent 2 has 4 acquaintances in the group with agents {1, 3, 4, 5}, $score_2 = 4$

Agent 3 only has agent 2 is the acquaintance, $score_3 = 1$

Similarly $score_4 = 2$, $score_5 = 2$

So the representative of the group is Agent 2.

In case of adding a new member or remove a member, the score of members is recomputed and reselected the representative.

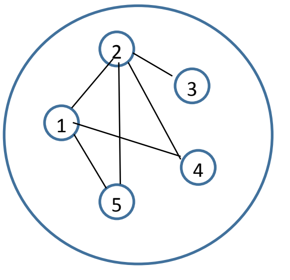

Figure 8.

3) Group decision making and identify group formation.

The Algorithm 2. Group decision making and identify group formation.

Suppose there are n groups, m agents in a group, with group $G_{i(i=1..n)}$

1. Repeat Exist(G_i): repeat when the group is existed, n>1.

2. $R_{i(i=1..n)} \leftarrow S_{j(j=1..m)}$: *m* messages are sent from *m* Singles in group *i* to Representative *i*

3. Compute($N_{j\,(j=1..m)}$): compute the number of corresponding messages

4. ($N_{j(j=1..m)}$ >K) (K is a constant): test the condition ok then choose this message is a common decision (collective message).

4.1. $S_{j(j=1..m)} \leftarrow R_i$: if the condition ok then the Representative sends a collective message to all Singles in its group.

4.1.1. OK($S_{j(j=1..m)}$)?

$S_{j(j=1..m)} \in G_i$: $Single_{j(j=1..m)}$ agree with the common decision therefore $Single_j$ belong to the group *i*.

4.1.2. Remove($S_{j(j=1..m)}$), n=n-1, return step 1: $Single_j$ doesn't agree with the common decision then remove it

from group *i* then return step1.

4.2. $S_{j\,(j=1..m)} \leftarrow S_{k(k=1..m)}$, return step 2: Singles in the group *i* interact with each other to receive more knowledge

then return step 2.

5. End.

4.3. The experiment with the model

Problem. Suppose there is a crowd of passengers who are waiting for flights, and the crowd is randomly distributed, dynamic. How to do capture, monitor behaviours of the crowd with the purpose of controlling, managing and directing the crowd to prevent the outbreak of crowd crushes? That is necessary to capture the group and observe multi-level. The group decision making through local interaction is an approach to capture and monitor collective behaviours in the crowd. Our work aims at capturing collective phenomena through the group's decision which its outcome is manifested by the group's behaviour. This is the basis for studying and making the multi-level multi-agent system for observing multi-level.

To resolve the problem we made the model based on the multi-agent system approach to model the capture the group. We the have installed the proposed model on MASH (Multi-Agent Hardware Software Simulator) platform [24] with JAVA programming language.

Suppose the space of the departure lounge at the airports includes three entrances, five exits, some blockages, and some paths are shown in figure 9. In a scenario, we test with n agents are randomly distributed and includes k groups. The result of the model is the number of groups that the model capture after removing the groups that don't satisfy the condition.

Figure 9. The interface of the model

We test the model in some scenarios, the results are shown in figure 10. The representative agent is a red circle, the single agent that belongs to the group is a green circle, the yellow circle is the single agent that doesn't belong to the group.

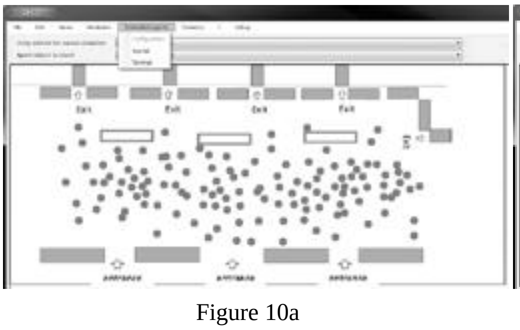

Figure 10a

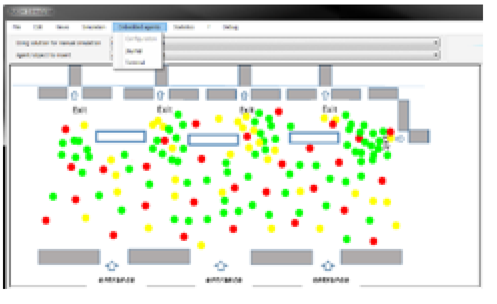

Figure 10b

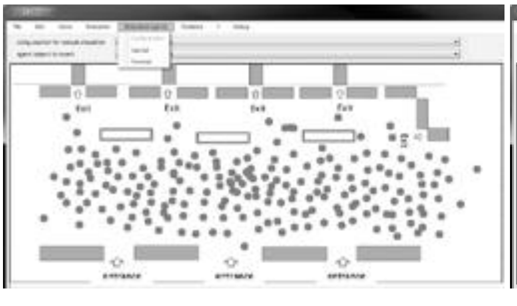

Figure 10c

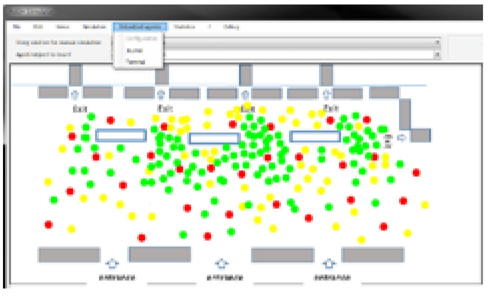

Figure 10d

Figure 10. The results of the model

In figure 10a, initializing the model, there are 130 agents and 27 groups, the agents are randomly distributed. In figure 10b, the agents are distributed focus on the exits and 22 groups are captured by the model. Similarly, in figure

10c, there are 200 agents and 31 groups. In figure 10d, the agents are distributed focus on the exits and 28 groups are captured by the model.

We tested the model with five scenarios and the result is presented by the diagram (figure 11). The initializing groups are presented by the blue broken line, the groups are captured by the model are presented the orange broken line.

Agents	Groups Init	Groups Model
80	21	17
100	29	24
130	27	22
160	31	31
200	31	28

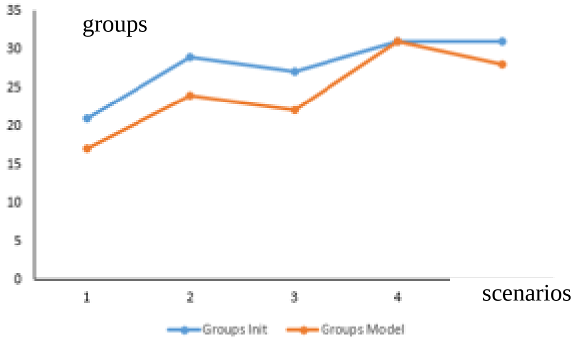

Figure 11. The number of groups that model captures and groups initially.

V. CONCLUSION AND DISCUSSION

This paper proposed a model as a basis for constructing the multi-level multi-agent system to detect collective behaviors with the purpose monitor, manage and direct the crowd. The main idea was to make a mechanism for forming the group base on local interaction. The advantages of this approach, using an adaptation of the model, are: (1) the local vision of the system, (2) the independence of groups (make a decision), (3) the algorithm is simple. The mechanism to exchange messages is simply, this approach brings an advantage of reducing the overload of messages that are exchanged by agents, avoid congestion.

The presented approach is intended to facilitate the multi-level design of the model based on MAS. The second level is formed from the first level that is mentioned in the paper and the next level is formed from the second level. The inheritance and hierarchies in the model are advantage conditions to support for multi-level observation.

In the next work, we are going to use the result in the paper as a basic level to make the next levels for the multi-level multi-agent system and applicate the model for describing behaviors of passengers in the departure lounges at the airports when an evacuation situation occurs.

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NGHIÊN CỨU CƠ CHẾ HÌNH THÀNH QUYẾT ĐỊNH NHÓM TRONG HỆ THỐNG ĐA TÁC TỬ

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TÓM TẮT- *Trong những năm gần đây, việc ra quyết định nhóm đã được nghiên cứu và áp dụng trong nhiều lĩnh vực. Một hệ thống phức tạp có nhiều thành phần thay đổi theo thời gian: động, đa chiều,... Có nhiều thách thức trong việc nghiên cứu hệ thống này. Hệ thống không thể được kiểm soát tập trung. Do đó, cách tiếp cận phân tán là cốt lõi của nghiên cứu. Lấy cảm hứng từ thực tế, chúng tôi đề xuất một hướng tiếp cận cho việc hình thành nhóm thông qua tương tác địa phương trong hệ thống đa tác tử. Nghiên cứu tập trung vào ba yếu tố chính là tiêu chí để xác định một nhóm; chọn người đại diện; người đại diện đưa ra quyết định. Bài báo chỉ mô tả giai đoạn hình thành nhóm dựa trên vị trí của các tác tử trong không gian hai chiều. Nghiên cứu này là giai đoạn đầu tiên trong nghiên cứu chúng tôi về việc xây dựng hệ thống đa tác tử đa mức. Mô hình được áp dụng để mô tả hành vi của hành khách trong phòng chờ khởi hành tại sân bay khi xảy ra tình trạng sơ tán.*