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Group Cohesion for a Coaching System in Co-located Collaborative Environments

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Abstract. Technologies that support co-located collaboration must not only provide a shared workspace, but also support collaboration. From an observational study, some collaboration problems were identified in groups of people working in a system with a Tangible User Interface. Some of these problems could be identified and prevented with the support of Coaching System. This system encourages interactions between group members through Social Interventions. To develop a Coaching System, it is necessary to know the cohesion between the members of the group, in order to decide the appropriate Social Interventions. In this paper, a model is proposed to represent the social interactions that occur in a group of people when performing a task. Interactions can be analyzed to determine the degree of cohesiveness of a group and support the collaboration.

Keywords: Co-located Collaboration; Group Coaching; Technologies supporting collaboration

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Сплоченность группы для системы коучинга в совместной среде

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Аннотация. Технологии, поддерживающие совместную работу, должны не только предоставлять общее рабочее пространство, но и поддерживать коллаборацию. В ходе наблюдательного исследования были выявлены некоторые проблемы совместной работы в группах людей, работающих в системе с материальным пользовательским интерфейсом. Некоторые из этих проблем можно выявить и предотвратить при поддержке Coaching System. Эта система поощряет взаимодействие между членами группы посредством социальных вмешательств. Чтобы разработать систему коучинга, необходимо знать сплоченность членов группы, чтобы принять решение о соответствующих социальных вмешательствах. В данной работе предлагается модель для представления социальных взаимодействий, происходящих в группе людей при выполнении задачи. Взаимодействия можно анализировать, чтобы определить степень сплоченности группы и поддержать сотрудничество.

Ключевые слова: совместная работа; групповой коучинг; технологии, поддерживающие совместную работу

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1. Introduction

Collaboration means that groups of two or more people work together to complete a task or achieve a goal [1]. In order to support working groups to achieve effective collaboration, technological tools have been built under the approach of Computer-Supported Collaborative Work (CSCW). Considering the taxonomy of Ellis et al. [2] and its two dimensions of place and time, collaboration can take several forms: 1) Co-located (same time/same place), 2) Distributed (same time/different place), 3) Asynchronous (different time/same place) and 4) Asynchronous distributed (different time/different place).

One problem that has been identified is that CSCW developments that support collaboration have been mostly focused on remote collaboration and few works aim to support collocated collaboration [3]. However, in this collaborative scenario, some conflicts may also arise in the group that affect the results of the collaborative activity. For example, there are failures in communication, poorly coordinated tasks are executed, some people collaborate less than others, and so on.

Our goal is to support groups of people in collaborative activities in collocated environments. To do this, we have executed an observational study in which we identify some possible problems that could arise in a collocated collaborative activity and how it could be computationally supported.

Based on the work of Van Leeuwen, et. al. [4], we believe that a possible way to support groups in this sense is with the support of an expert facilitator [5] who encourage collaboration, as happens in a classroom through a teacher. The teacher analyzes the behavior of the groups of students and if he detects any problem in their collaboration, he executes a Social Intervention, that is, an expression that the teacher makes to students to encourage collaborative learning. Thus, our goal is to have a computational system that encourage collaboration in groups, just as a teacher would.

Proposals have been made in the literature to support collaboration by providing a shared physical space; facilitate collaboration, considering usability issues in the design of these tools; and invite collaboration, showing users information about some collaboration indicators, such as the number of participations per user or graphical representations of the group's progress. However, there are still few works that contribute to encouraging collaboration.

According to Olson et al. [3], to encourage collaboration, it is necessary to motivate or persuade people to start interacting or maintain continuous interaction. The techniques that have been used to promote collaboration have been through Tutoring Systems, Orchestration Tools or through Guide System interventions with personal agents such as a Coach [6]. In particular, the Coaching Systems observe the interaction of the users and provide them with suggestions, help and/or comments that help improve collaboration while they try to complete their activity [7]. Coaching mechanisms monitor group activity and make recommendations if they detect anomalies in collaboration.

We consider that a Coaching System could support collocated collaborative activities, since these systems have supported remote collaboration [7]. To test this hypothesis, a Coaching System centered on a case study will be developed, and then studies will be conducted to compare the outcomes of coached and unsupported colocalized collaboration. The case study will be collocated collaborative activities in systems with Tangible User Interfaces (TUIs) because these interfaces have enabled collaboration in domains of learning, project planning, information visualization, programming, and entertainment [8], but do not yet have computational support to encourage collaboration.

Building a Coaching System to encourage collocated collaboration requires modeling the group it will support. The observational study that we executed also helped us to identify the elements of the group that the coaching system should consider to determining the social interventions that encourage collaboration.

In this paper, we propose a model based on a sociogram to define the degree of Group Cohesion in a collaborative activity according to the number of interactions performed by each member. Six groups of students working in a collocated collaborative activity in a TUI were modeled, based on the results of a study where the interactions of each group were observed. Considering the results obtained, we believe that this model could be used so that in the future a coaching system analyzes the cohesion of a group and decides on the appropriate social interventions to have better outcomes of the collaboration.

The paper is structured as follows, in Section Two the important terms and the related work are described; in Section Three the method of observational study is explained; in Section Four the results are described; in Section Five the proposed model is presented; in Section Six the discussion; and finally, the conclusions and future work are shown in Section Seven.

2. Background

2.1 Collocated Collaborative Learning

Collaborative learning is the educational approach whose objective is to improve learning through joint activities. Groups of two or more students work together to solve problems, complete tasks, or learn new concepts. When students are doing the activity in the same place at the same time, it is collocated collaborative learning.

The most relevant element in a collaborative activity is the Interaction, actions carried out by each participant in a shared workspace. According to Van Leeuwen et al. [4], in a learning activity there are Interactions that support the achievement of the task properly, for example, writing a note, putting an object, drawing, talking, transferring objects, among others; and other interactions whose goal is to guide collaboration.

In a common classroom, to support a collocated collaborative learning activity, Teacher must pay attention to Interactions. For example, a student place a new object, two students converse to agree, one student transfers a paper object to another student and so on. Then, teacher must analyze if there are any problems or facts that interfere with the student to act efficiently. For example: Students do not follow assigned roles or tasks, students interfere with the actions of others, students' participation is unbalanced etc. After the teacher is aware of the problem, his next task is to execute a Social Intervention, an expression that the teacher makes to students to guide collaborative learning. These can be expressed as different types of media, for example, interrogation-type expressions, diagnoses, indications, suggestions, explanations, instructions, or feedback [4].

2.2 Co-located Collaboration CSCW support

Table. 1 Role of technology in supporting co-located collaboration

Role Technology	**Social design objective**	**Related Works**
Enable	Enabling or allowing interaction to take place.	Schneider et al., 2012 [9]; Hamidi et al., 2012 [10]; Sylla, 2013 [11]; Antle et al., 201 [12]; Leversund et al., 2014 [13]; Waje et al., 2016 [14]; Baranauskas and Posada, 2017 [15]; Wallbaum et al., 2017 [16]; Melcer and Isbister, 2018 [17].
Facilitate	Support users' communication and coordination, relieving tension and minimizing negative experiences, and generally helping to make the best of a social situation.	Nacenta et al., 2010 [18] ; Doeweling et al., 2013 [19]; Wise et al., 2015 [20]; Xambó et al., 2013 [21]; Cherek et al., 2018 [22]; Huber et al., 2019 [23]; Koushik et al., 2019 [24]
Invite	Providing additional information to users about their current social situation, so that they freely decide whether to act based on the additional information provided and social cues or not.	Morris et al., [25]; ter Beek et al., 2005 [26]; Kim et al., 2008 [27]; Cherek et al., 2018 [22]; Cepero et al., 2021 [28].
Encourage	Motivating or persuading people to start interacting or maintain an ongoing interaction.	Martinez-Maldonado et al., 2019 [2]; Praharaj, 2019 [29].

For Olsson et al. [5], computer systems can assume four roles in co-located collaboration: enabling, facilitating, inviting, and encouraging interaction. Enabling interaction refers to the role of a technological tool in enabling or allowing interaction to take place. Facilitating interaction refers to facilitating users' communication and coordination, relieving tension, and minimizing negative experiences, and generally helping to make the best of a social situation. Inviting interaction refers to providing additional information to users about their current social situation, so that they freely decide whether to act based on the additional information provided and social cues or not. And finally, encouraging interaction consists of motivating or persuading people to start interacting or maintain an ongoing interaction; For this, computational features must be used that stimulate people to take action, for example, technology could make an intervention when a person does not dare to say something to another person, or it could encourage two strangers to collaborate on something in which they seem to have a common interest.

In the literature, works have been found on how co-located collaboration has been supported and they have been classified according to the roles of technology proposed by Olsson et al. [5], as shown in Table 1. In the case of the role of enabling interaction, a wide range of examples of interactive systems such as TUIs have been found, and all these systems allow co-located interaction for learning activities, however, they do not fulfill the rest of the functions to support interaction.

Although the related works have made important contributions in supporting co-located collaboration, we believe that support for collaboration could be broader. The works where collaboration is invited through group awareness tools have helped to show users their current situation in the activity so that they decide how to act accordingly, however, our goal is that decisions about the collaboration does not fall only on students who sometimes do not know how to collaborate effectively, and instead users receive well-planned recommendations through interventions that suggest a change in their behavior, as a teacher would in a classroom.

2.3 Coaching Systems

The techniques that have been used to encourage collaboration have been through Tutoring Systems, Orchestration Tools or through Guide System interventions with personal agents such as a Coach [6]. Guiding systems perform all the phases in the collaboration management process and propose remedial actions to help the learners. The desired model of interaction and the system's assessment of the current state are typically hidden from the students. The system uses this information to make decisions about how to moderate the group's interaction [30].

In particular, the Coaching Systems observe the interaction of the users and provide them with suggestions, help and/or comments that help improve collaboration while they try to complete their activity [7]. Coaching mechanisms monitor group activity and make some interventions if it detects any anomalies in the collaboration.

Coaching is a technique in which the instructor observes students and provides hints, help and feedback while they try to complete a task. Since students often miss learning opportunities and get stuck on a certain level of proficiency, a coach can make students aware of further possibilities, provide unobtrusive assistance and create potential learning experiences that will improve individual's development. The coach's goal is to promote group-learning interactions and maintain balanced participation. The design of the coach was based on socio-cognitive and cognitive dissonance theories [7].

An example of a remote collaboration coaching system is COLLER which helps students collaborate while solving entity relationship modeling problems in a computer-mediated learning environment. This paper evaluates a new approach to supporting collaboration that identifies learning opportunities based on differences in problem solving and tracking engagement levels [7]. And an example of a coaching system in a collocated activity is described in the work of Praharaj, 2019 [28], in which they propose an automated feedback system in real time using audio signals to analyze the group and facilitate collaboration.

3. Method

To identify possible problems that could arise in a collocated collaborative activity and how it could be computationally supported, groups of students working in a co-located collaborative activity in a system with TUI were observed.

3.1 Participants

For the study it was necessary to recruit students from the User Interface Design Class. In total there were 16 students between 20 and 26 years old. Six groups were observed. Two groups with 2 students and four groups with 3 students.

All students had prior knowledge of web interface design. The students knew each other previously and worked on group projects prior to this study; however, the design activity for this observational study was previously unknown for all of them. All students signed a consent form to participate in the study and record their group interaction with a video camera.

Four observers also participated. They observed and recorded the interactions of the students during the activity. Two of the observers have knowledge and experience in collaborative systems design and software evaluation, and the other two have knowledge and experience in systems design. And in addition, an assistant participated, explaining the conditions and instructions of the study and attend to doubts and technical complications that the students had.

3.2 PaperTUI

The system used for this study was PaperTUI [31]. It is a paper-based system to design web interfaces (see Fig. 1). It has an interactive surface with a screen placed horizontally on a table and a video camera placed on top of the screen that is responsible for capturing user interactions.

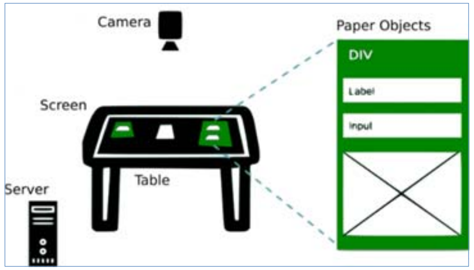

Fig. 1. PaperTUI outline (Source: [31])

Data entry in PaperTUI are paper tangible objects. These objects represent elements of a graphical web interface, such as images, video, text areas, maps, combo boxes, input fields, search fields, cancel or accept buttons, and some icons. The system must recognize the objects on the surface-screen and store the information in order to generate a HTML digital abstract web interface. Users receive feedback through video projection on the screen. Some of the feedback given to the user are projected circles below the recognized widgets and the HTML representation of the generated web interface.

PaperTUI was programmed in Python and uses Computer Vision libraries such as OpenCV and Tesseract. Its architecture is presented on Fig. 2, it is composed of a recognizer that detects objects through the detection of colors, images and text; and a generator model that creates an XML file that digitally represents the identified papers and then parses the XML to an HTML file that functions as a preview.

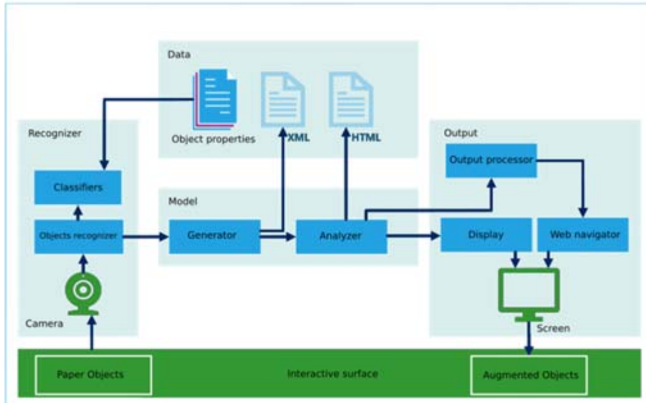

Fig. 2. PaperTUI architecture (Source: [31])

3.3 Process

Each group of people worked on a different session recorded with a video camera. In each session, the study objective was explained to the participants and they were given a consent form to record their interactions with a video camera. The task defined for the study was: "Design a user interface for a web page of a software development company". No subtasks were specified. The students had 5 minutes to do the task on PaperTUI. Participants stood around the PaperTUI table and had 15 minutes to design the interface. On one side of the table, the video camera was mounted to record all interactions for later analysis.

During the activity, an assistant participated to answer technical questions. Observers take note of all the interactions they identified. It should be noted that in the observational studies, the students worked without the definition of instructions that would regulate their social activity. They were simply asked to create a web page for a computer equipment sales company and the system was explained to them. Fig. 3 shows two groups executing the collaborative activity in PaperTUI. After the sessions, an observer played the videos, and analyzed the participant's interactions.

Fig. 3. Group of students interacting with PaperTUI

4. Results

It was observed 19 types of interactions: 1) Put object, 2) Take object, 3) Move object, 4) Point object, 5) Show object, 6) Look object, 7) Find object, 8) Look Workspace, 9) Take Workspace, 10) Have object e, 11) Leave object, 12) Conversation, 13) Diffusion, 14) Deictic references, 15) Transfer object, 16) Request Validation, 17) Show object, 18) Get Resource and 19) Reserve object.

The interactions that each participant executed in each group were counted. From this data, the dispersion of the number of interactions per group was determined. This was calculated from the standard deviation of the set of numbers of interactions executed by each participant. The type of interactions that were considered in the count were: Put object, Take object, Move object, Point object, Conversation, Diffusion, Transfer Object and Request Validation. Since these were the interactions that had the most repetitions.

Table. 2. Group Collaboration results

Group	**Interaction Dispersion**	**# Objects**	**Time (**minutes)
1	7.39	20	04:58
2	12.88	27	07:53
3	7.97	12	09:40
4	6.13	12	07:16
5	10.61	24	09:57
6	2.12	19	06:50

In addition, the collaboration of each group was analyzed considering the number of objects placed in the web prototype and the activity time. These data are shown in Table 2.

From the count of the interactions and the observation of the behavior of the groups, communication and cohesion problems were identified:

Communication problems. It was observed that the participants asked questions and requested approvals, but sometimes the other participants did not respond. There were also long episodes in which the participants did not speak to each other; even in some groups, despite having three participants, their number of conversations and diffusion interactions was low.

Cohesion problems. In some groups there was never a transfer of figures, this could mean that the team was not as integrated or that they worked alone. Likewise, in table 2 it can be seen that in most of the teams the dispersion of the number of interactions is high (group 1, 2, 3 and 5), this means that some students participated more than others.

5. Model for Group Coaching

Building a Coaching System to encourage co-located collaboration requires modeling the group it will support. The observational study that we executed also helped us to identify the elements of the group that the coaching system should consider to define the social interventions that can be launched to encourage collaboration.

5.1 Proposal of a model based on Group Cohesion

In order to support collaboration through interventions in Coach Systems, it is necessary to understand the group and its behavior. Each group is different, they have different sizes and forms, and researchers who have tried to define groups have focused on different fundamental properties of groups, such as similarity, interdependence, entitativity, social identity, leadership, among others [32, 33]. To understand groups from so many different perspectives is a challenge for those trying to analyze it.

Cohesion is a measure that allows to analyze the meaning of groups. Specifically, cohesion is the measure to which members of a group bond with each other in trying to achieve a goal [34]. Groups can have different levels of cohesiveness among members over time. Group cohesion influences the effectiveness of collaboration.

A Cohesive Group means that you have more frequent, less inhibited, and enhanced interactions [35]. To increase cohesion, a necessary element is to motivate people to participate [36]. A participation means the execution of an interaction. Modeling the group in terms of cohesion means representing the links between the members of the group. For us, these links are the interactions executed by members of the group. One way to represent these links is through a sociogram. Sociograms are diagrams that allow graphically explaining the position that each individual occupies within the group, as well as all the interrelationships established between the various individuals [37, 38].

The proposed group model considers the following facts. A Group is a set of Actors trying to achieve a specific goal through the execution of Interactions. An Actor is a member of the group, which can be a person or software agent that executes Interactions to handle or produce objects in a shared workspace. An Interaction represents a running action in the shared workspace. Several elements of MARs Model [39] were considering (e.g. Actor, Interaction, Object, etc.).

The representation of Cohesion of the Group is through a sociogram. In the diagram of a sociogram, the cycle point represents an Actor. When an Actor executes an Interaction, an arrow will be added on the line, and it represents the direction of the interaction (another Actor). The number on the line is used for indicating the number of Interactions that the Actor has executed. A simple graphical representation of this sociogram is shown in Fig. 4. That a group is cohesive means that the numbers of the Interactions executed by all the actors is balanced.

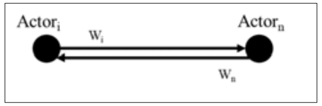

Fig. 4. Simple graphical representation of Group Cohesion Model

Formally, this sociogram can be represented as a weighted directed graph, where each vertex represents an Actor, and each edge represents the link between the actors that has been produced through Interactions. Each vertex has an associated weight based on the number of Interactions that the Actor has executed and that have linked it to the rest of the Actors.

This graph can be defined as an ordered trio

$$G\pm = (A, L, W)$$

where

$$A = \{a_1, \ldots, a_n\}$$

is a set of vertices that are the actors,

$$L = \{l_1, \ldots, l_n\}$$

is a set of edges that represent the link between two actors, and

$$W = \{w_1, \ldots, w_n\}.$$

W is a set of weights associated with each edge that represents the number of Interactions that each Actor executes. Likewise, W can also be represented as a weight assignment function $w: L \rightarrow \mathbb{R}$ so that for any vertex $l \in L$, its weight is $w(L) \rightarrow \mathbb{R}$. Since each weight is restricted to a subset of the natural numbers.

5.2 Instances of the proposed model

The 6 observed groups were modeled with the proposed group model. For this, in each group each actor, the link of each actor with the rest of the actors, and the weight of the link were modeled. The latter, calculated from the number of interactions that each actor executed towards another actor. The type of interactions that were considered in the count were: Put object, Take object, Move object, Point object, Conversation, Diffusion, Transfer Object and Request Validation. Since these were the interactions that had the most repetitions.

In the following subsections, the modeling of each observed group will be described.

5.2.1 Group One

The cohesion model of group one is presented in Fig. 5.

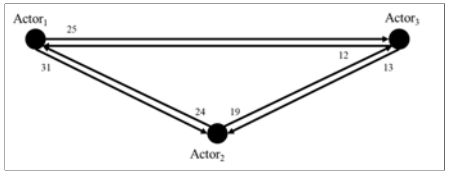

Fig. 5. Cohesion model within group one

The group one is a set of 3 student actors. The most active actor was $Actor_1$, who executed 31 interactions towards $Actor_2$ and 25 interactions towards $Actor_3$; followed by $Actor_2$, who executed 24 interactions towards $Actor_1$ and 19 interactions towards $Actor_3$; finally, $Actor_3$ executed 12

interactions towards $Actor_1$ and 13 interactions towards $Actor_2$. The left side view of the final prototype of group one is shown in Fig. 6. The number of objects placed for the prototype was 20, and the time of the activity was 04:58 minutes.

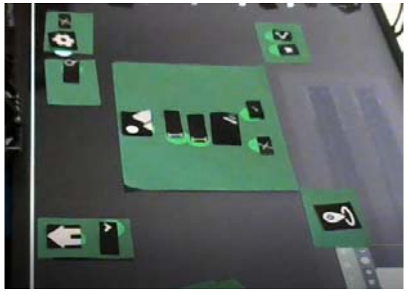

Fig. 6. Final prototype on PaperTUI of group one

5.2.2 Group Two

The cohesion model of group two is presented in Fig. 7.

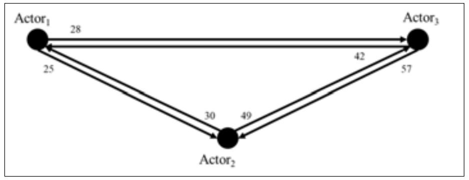

Fig. 7. Cohesion model within group two

The group two is a set of 3 student actors. The most active actor was $Actor_3$, who executed 42 interactions towards $Actor_1$ and 57 interactions towards $Actor_2$; followed by $Actor_2$, who executed 30 interactions towards $Actor_1$ and 49 interactions towards $Actor_3$; finally, $Actor_1$ executed 25 interactions towards $Actor_2$ and 28 interactions towards $Actor_3$. The left side view of the final prototype of group two is shown in Fig. 8. The number of objects placed for the prototype was 27, and the time of the activity was 07:53 minutes.

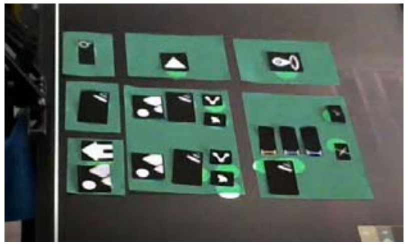

Fig. 8. Final prototype on PaperTUI of group two

5.2.3 Group Three

The cohesion model of group three is presented in Fig. 9.

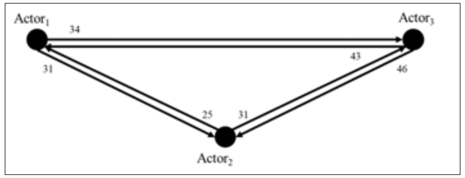

Fig. 9. Cohesion model within group three

The group three is a set of 3 student actors. The most active actor was Actor$_3$, who executed 43 interactions towards Actor$_1$ and 46 interactions towards Actor$_2$; followed by Actor$_1$, who executed 31 interactions towards Actor$_2$ and 34 interactions towards Actor$_3$; finally, Actor$_2$ executed 25 interactions towards Actor$_1$ and 31 interactions towards Actor$_3$. The left side view of the final prototype of group three is shown in Fig. 10. The number of objects placed for the prototype was 12, and the time of the activity was 09:40 minutes.

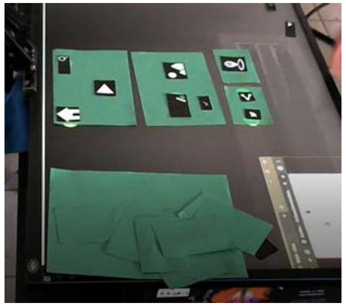

Fig. 10. Final prototype on PaperTUI of group three

5.2.4 Group Four

The cohesion model of group four is presented in Fig. 11.

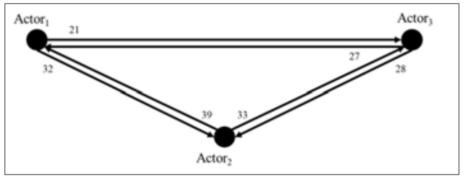

Fig. 11. Cohesion model within group four

Fig. 12. Final prototype on PaperTUI of group four

The group four is a set of 3 student actors. The most active actor was Actor$_2$, who executed 39 interactions towards Actor$_1$ and 33 interactions towards Actor$_3$; followed by Actor$_1$, who executed 32 interactions towards Actor$_2$ and 21 interactions towards Actor$_3$; finally, Actor$_3$ executed 27 interactions towards Actor$_1$ and 28 interactions towards Actor$_2$. The left side view of the final prototype of group four is shown in Fig. 12. The number of objects placed for the prototype was 12, and the time of the activity was 07:16 minutes.

5.2.5 Group Five

The cohesion model of group five is presented in Fig. 13.

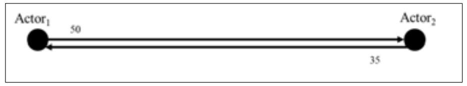

Fig. 13. Cohesion model within group five

The group five is a set of 2 student actors. The most active actor was Actor$_1$, who executed 50 interactions towards Actor$_2$; and Actor$_2$ executed 35 interactions towards Actor$_1$. The left side view of the final prototype of group five is shown in Fig. 14. The number of objects placed for the prototype was 24, and the time of the activity was 09:57 minutes.

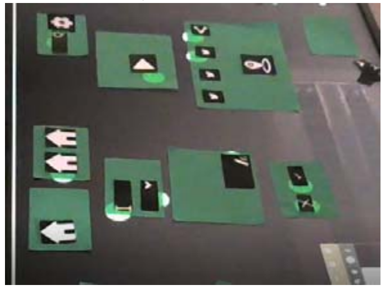

Fig. 14. Final prototype on PaperTUI of group five

5.2.6 Group Six

The cohesion model of group six is presented in Fig. 15.

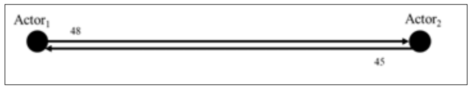

Fig. 15. Cohesion model within group six

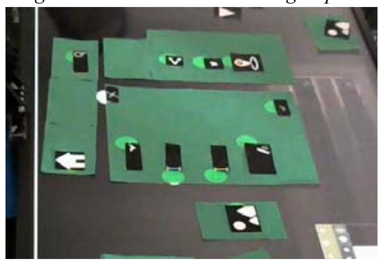

Fig. 16 Final prototype on PaperTUI of group six

The group six is a set of 2 student actors. The most active actor was $Actor_1$, who executed 48 interactions towards $Actor_2$; and $Actor_2$ executed 45 interactions towards $Actor_1$.

The left side view of the final prototype of group six is shown in Fig. 16. The number of objects placed for the prototype was 19, and the time of the activity was 06:50 minutes.

Table 2 shows the value of the instances of each group. Column 1 shows the group number, column 2 shows the number of actors, column 3 shows the number of links between the actors, and columns 4-9 show the value of the weight of each link.

Table 3. Group Cohesion model instance

Group	# Actors	# Links	Link weight					
			W_1	W_2	W_3	W_4	W_5	W_6
1	3	6	31	25	24	19	12	13
2	3	6	25	28	30	49	42	57
3	3	6	31	34	25	31	43	46
4	3	6	21	32	39	33	27	28
5	2	2	50	35	-	-	-	-

6. Conclusions and Future Work

We are interested in developing systems that support collaboration on co-located technologies. We executed an observational study to analyze the problems that might arise in groups collaborating on a co-located activity in a system with a Tangible User Interface. From this study, we identified some problems of communication and Group Cohesion.

Computational support for collocated collaboration can take various forms, in particular we commit to encouraging interaction between group members through a coaching system that implements social interventions. For this, it is necessary to model the group that the system will support and decide on the appropriate interventions to have an effective collaboration.

This paper proposed a model based on a sociogram to define the degree of cohesion of groups in a collaborative activity according to the number of interactions executed by each member of the group.

The goal is to have a Coaching System that automatically supports collaborative student learning as a teacher would regularly do in a classroom. For this, the system must identify the interactions of the students who carry out the activity, through the recognition of images by camera; then analyze interactions and take action to support collaboration. To analyze the interaction, the Coaching System would rely on the proposed group model, which helps determine the level of group cohesion. If the Coaching System identifies that the level of group cohesion is low, then it would launch a social intervention to remind the group to collaborate equally.

The design and implementation of this Coaching System is a future work. Likewise, carry out other observational studies with a larger number of groups and in other contexts.

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