Action Role Design and Observations in a Gestural Interface-based Collaborative Game

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Abstract

This paper explores the design of action roles for children playing an animal character-based collaborative game with gestural-sensitive tangible user interfaces. Based on trial runs with two inclusive groups of participants with mixed age and learning abilities, we report preliminary case study observations of the collaborative play behaviors solicited by the different interaction design patterns associated with the manner in which the action roles were distributed and coupled.

Keywords

TUI interaction, gestural interfaces, interaction design, collaborative play, collaborative design patterns

ACM Classification Keywords

H.5.3 Group and Organizational Interfaces: [Collaborative Computing]; K.3.1 Computer Uses in Education: [Collaborative Learning].

General Terms

Design

Introduction

Tangible user interfaces (TUI) have been widely adopted as the input modalities of choice for applications domains that features strong requirements for tangible manipulation, spatial interaction, embodied facilitation and expressive representation [7]. Evidence of this is can be seen in the commercial success of embodied gaming systems such as the Wii introduced by Nintendo back in 2006.

Despite the increasing ubiquity of TUI-based applications, not much has been understood about how they can be effectively used in promoting learning [9]. We are particularly interested in understanding how TUI-based interaction can be effectively employed for collaborative learning, especially among children in mixed-ability groups. The physicality, accessibility and collaborative (shared space) qualities of TUIs do open up interesting opportunities for designers of technology-supported collaborative learning applications. The challenge is how these affordances can be appropriately harness with appropriate interaction design patterns to produce the desired collaborative behaviors that facilitate learning and social skills development. This paper explores our design of a gesture interface-based collaborative game. We propose several collaborative design patterns based on the way each player's action role relates to another and present preliminary observations of some collaborative behaviors they appear to solicit. We report observations in two field trials involving participants with mixed age and learning abilities.

Related Work

Collaborative learning is defined as a situation whereby two or more persons interact actively, facilitate joint construction of shared knowledge, understanding and meaning [4]. Many works using technology-supported collaborative learning are grounded primarily on the constructivist approach of either Piaget's theory of equilibration where knowledge is constructed during collaborative problem solving among equal [11,15] or Vygotsky's view that scaffolding of knowledge can be provided by collaborating with a more skilled partner [10, 13]. The works of both Piaget and Vygostsky form the theoretical foundations for the design of our collaborative game. However, the collaboration model of Vygostsky was observed to be more suitable for the mixed-ability and mixed-aged groups featured in our case studies.

Using storytelling technologies, Benford et al. [2] focused on how children can be encouraged to collaborate. They suggest the possibility of longer term educational benefit when children discover the value of collaboration by themselves. On the other hand, Battocchi et al. [1] work on a collaborative tabletop jig-saw puzzle suggests that joint action by two persons that are enforced can help teach social skills such as shared attention, negotiation and imitative behavior to children with autism spectrum disorder. More research is definitely needed to understand which manner of collaboration is more suitable under what group demographics, social situations and desired interaction design objectives.

There are several researchers who have analyzed and summarized various useful cooperative game design patterns, albeit on more traditional computer and non-computer interfaces. Rocha et al. [12] identified six cooperative game design patterns, which include *complementarity* (different player's role complements each other), *synergies between ability* (characters can help another), *abilities that can only be used on another player*, *shared goals* (pattern that forces players to work together), *synergies between goals* (cooperate through synchronized goals) and *special rules* (rules to enforce cooperation within teams). El-Nasr et al. [5] extended the work of [12] and added another seven patterns identified from numerous commercial cooperative video games they evaluated. Zagal et al. [14] explored cooperative patterns within board games such as LORD OF THE RINGS and subsequently summarized various observations, design lessons and pitfalls that can be translated to collaborative computer games. Many of the patterns proposed are generalizable. Especially the six design patterns highlighted in [12], which has been in some ways incorporated into our collaborative game. Since the game discussed in this paper is a gestural interface-based collaborative game, we specifically focus on the design of the action roles that players play out with their team mates using their respective TUI.

The Collaborative Game

Panda and Pals (PAP) is a collaborative game played by six players with handheld motion-sensitive TUI in front of a large shared display (see Figure 1). Each player is assigned an animal character with a specific role and its associated action gestures. The task is to convey a large wooden plank into the sawing area and cut it in half before lifting the cut planks up to the top (see Figure 2). The challenge for the team is to complete this task in the shortest possible time before the allocated 6 minutes run out. This game teaches children how to cooperate with each other (social skills) and collectively reason about the cause and effect relationships of the different mechanisms required to move, saw and lift the planks (problem solving skills).

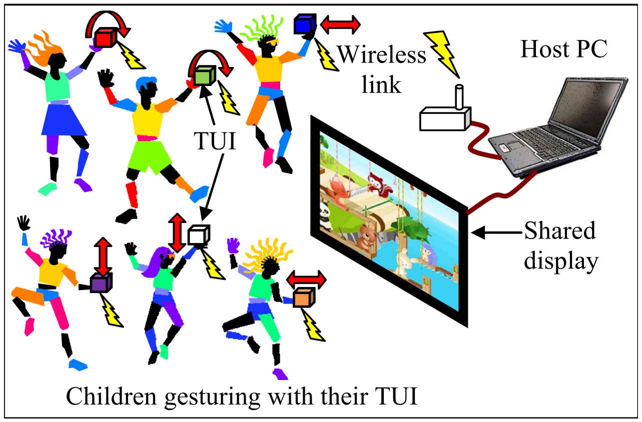

figure 1. Six children playing the Panda and Pal game using gesture-sensitive tangible user interfaces (TUI).

figure 2. A screenshot of the Panda and Pals collaborative game

Collaborative Game Design Objective

The design objective of this game is to create a collaborative learning environment that encourages active collaboration and social interaction among children, especially in an inclusive setting consisting of mixed-ability participants. We have employed various cooperative design patterns to achieve this goal. Johnson & Johnson [8] identified several essential components required to create an environment that is conducive to cooperative learning. They were summarized by Zea et al. [15] as follows:

- *Face-to-face promotive interaction*. Facilitate helpful verbal and gestural communication among players.

- *Social skills*. Facilitate opportunities for leadership, decision-making, conflict management, turn taking and trust-building.
- *Personal accountability*. Provide opportunities for each individual to contribute their best to the group goal.
- *Positive interdependence*. Facilitate cooperative behavior like helping the other player with his or her task.
- *Group processing*. Facilitate group-negotiated problem solving. Team members analyze with each other the best way to tackle the problem at hand.

Collaborative games can sometimes degenerate into situations where the most capable player dominates the game play. Zagal et al. [14] highlighted this pitfall in board games and suggested that different players be given different roles (*complementarity*) and abilities so that the best outcome depends on the coordination of all players (*shared goal*). This distribution of roles has been adopted in the PAP game but more importantly, we focused on the strategies employed in designing the various roles and the manner in which these roles relate to each other. Since PAP is a gestural input based game, the players fulfill their respective action roles by executing appropriate motion gestures. Trial runs with two different groups playing the PAP game were conducted. We present some preliminary observations of the collaborative play behaviors resulting from the different role designs and how they were observed to promote the various components of collaborative behaviors.

With a small sample of two field trials, our intention is to carry out a preliminary case study-based approach to evaluate if the proposed collaborative design patterns implemented in the PAP game do result in observable colloborative behavior (CB). Some possible methodologies include the quantitative approach using the Cooperative Performance Metrics of El-Nasr et al. [5] or a qualitative approach based on the Collaborative Learning Mechanism Framework proposed by Fleck et al. [6]. However, we decided to adopt the five observerable CB components proposed by Johnson and Johnson [8] to monitor how well we are able to meet the game design objective. These 5 components are well established and are commonly used by educational researchers in the field of computer-supported cooperative learning.

Sequentially-Dependant Roles

An effective strategy to generate face-to-face promotive interaction and positive interdependence is to ensure that different functional roles are distributed among the various players and the completion of one role function is needed before the next can begin. Figure 3 shows how the PAP collaborative game uses the sequential process of cutting a wooden plank to achieve this.

The pair controlling the conveyor needs to MOVE the uncut plank into the sawing position before the next pair can start the SAW plank action. After which, the last two LIFT the cut planks to the monkey at the top to complete one round of the task. Verbal interaction was particularly evident at the early stages of the game play as the sequential dependency of this process resulted in the pairs with downstream roles were engaged with the activities of those performing upstream roles as they waited eagerly to begin their own contributions. Once all the team members could perform their respective action task with reasonable competency and realized that they can efficiently overlap their respective tasks (much like a pipelined process), the level of communication reduced to mere handover acknowledgements such as "OK! Our turn" with those directly affecting one's activity

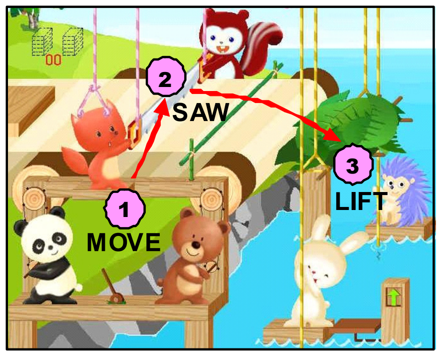

figure 3. The sequential dependency of various functional roles

Skipping a Step

A useful side-effect of employing sequentially-dependant roles is the ability to create interesting problematic scenarios when one functional role is accidentally skipped. This creates an opportunity for the team to learn gracious social skills such as accommodating someone's mistakes. The resolution of such unexpected situations, which usually affects multiple roles, also encourages the group to discuss and agree on a possible solution (group processing). For example, in one particular trial run, an uncut plank was unintentionally moved beyond the sawing zone and the conveyor belt cannot reverse its direction. One member of the team suggested rolling the uncut plank into the sea as a means of getting on with the game and the rest concurred and encouraged her to do so in order to progress to the next plank.

Coupled-Role Pairing

Vygotsky [13] suggested that the scaffolding of knowledge provided by collaborating with a more skilled partner is necessary to support learning. This is especially relevant in an inclusive setting with mixed learning abilities. We believe Vygotsky's model of collaboration can be most effectively implemented using coupled-role pairing, where a better player can be paired with a weaker player and when they work together, they can fulfill one of the functional roles within the collaborative game. This is a particularly important design principle for groups with mixed learning abilities, as is evident from our observations during field trials.

The PAP game contains several different coupled-role designs, which will be discussed in turn.

Synchronized Coupled Action

A synchronized coupled action role is defined as one that will only realize its intended function if both partners perform similar actions simultaneously. An example is the sawing action shown in Figure 4a. Both players have to perform to-and-fro motion gestures with their TUI in order to move the whip saw and cut the plank. Another example in the PAP game is the need for both bears to crank the shaft with circular motion gestures in order to move the plank on the conveyor belt (see Figure 4b). Having identical actions for both players has some inherent advantage. We observed that the scaffolding provided by the partner helps the weaker player learn passively or synchronize

figure 4a. Synchronized coupled action performed by the Fox and Squirrel to saw a plank together.

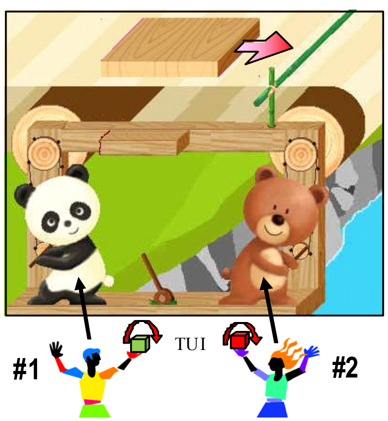

figure 4b. Synchronized coupled action performed by the Panda and Brown bears to move the plank by cranking the conveyor together.

timing through mere visual imitation. In one inclusive trial run (Group 1) involving players with mixed age and abilities, a player with Down syndrome was observed to be looking to his adult partner to decide when to begin performing his sawing action. He immediately followed suit when his partner began sawing.

In another trial (Group 2), because of the need to synchronize their actions for results, an older girl was observed to say, "OK! Now" to the younger partner as she understood that the lifted whip saw is no longer in the way and they can begin to crank the conveyor together to move the plank forward. In both situations, positive interdependence was exhibited, the former in an implicit non-verbal manner (i.e. "Do what I do") and the latter through more explicit verbal instructions (i.e. "Do what I say and when I say so").

In another instance during the trial run (Group 2), one of the boys emerged as a spontaneous leader, telling another pair of players what to do. It appears that he had quickly figured out the way the mechanisms worked. However, when it came to his turn to pull up the lifter, he did the up and down action but found the lifter unaffected because his partner was not doing the same synchronized action. He then touch his partner's TUI and said to him, "Go up and down, up and down." His partner immediately latched on and did the same action. Our observations suggest that the synchronized coupled action role design seems effective in facilitating face-to-face promotive interaction and positive interdependence.

Toggling Coupled Action

A toggling coupled action role is defined as one in which one player's action selects a function but the function can only be unselected by the partner's action. An example of a mechanism using the toggling action is the lever controlling the conveyer plank stopper (see Figure 5). The Panda bear moves right to push the lever. This raises the plank stopper but only the Brown bear can lower it by moving left to push the lever back towards Panda. At the start of one trial, the operation of this toggling lever created some interesting group processing among the pair responsible for operating this mechanism as they discussed whose lever activation was responsible for lifting the stopper.

Later in the game play, this toggling action gave rise to an interesting situation that provided opportunity for the pair to demonstrate social skills such as trust building and tolerance. After Panda bear struggled for some time with her unfamiliar TUI motion gestures to push the lever (raise stopper), Brown bear accidentally pushed the lever back (lower stopper) and shrieked "Oh No!" Brown just undid the earlier efforts of her partner. Despite some disappointment, Panda lost no temper but just got on with the task of raising the lever again. The adult team member was observed to spontaneously demonstrate subtle conflict management skills and was heard saying, "Never mind, now we understand, we got it!" Brown also retorted sheepishly that she too figured out how the lever works and said, "OK, we got it!" In the subsequent focus group discussion, one of the participant commented that it felt upsetting when one moves the lever incorrectly and felt helpless that one cannot bring it back by oneself. This insight suggests that toggling coupled action can be effectively used to design game play situations that teach children about the need to trust and depend on others because there are occasions when one cannot be in complete control

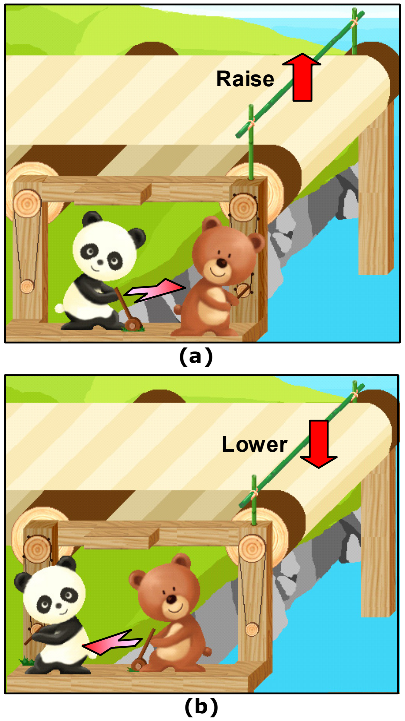

figure 5. Toggling coupled action performed by the two bears on the lever. (a) Panda can only raises and (b) Brown can only lower the stopper.

Pre-selective Synchronized Coupled Action

A pre-selective synchronized coupled action role is defined as one in which both players must first select the same mode or direction for the required function and only then will synchronized action allow the intended function to be realized. An example is the lifter mechanism shown in Figure 6. Both players must pre-select to move the lifter up by stepping on the toggling paddle till the arrow on the beam points upwards. Subsequent synchronized up-down actions by both players will move the lifter upwards. Similarly, to move the lifter down, both arrows must be selected to point downwards before synchronized TUI movement will bring the lifter down. With this coupled action design, constant awareness of the current mode is required in order to carry out the role efficiently. The opportunity to preselect the mode before synchronized action means that the player that is faster or more aware of the situation will often help or remind (positive interdependence) his slower partner. Such communication was observed particularly when the urgency and incentive to complete the game increased with the more successfully cut planks.

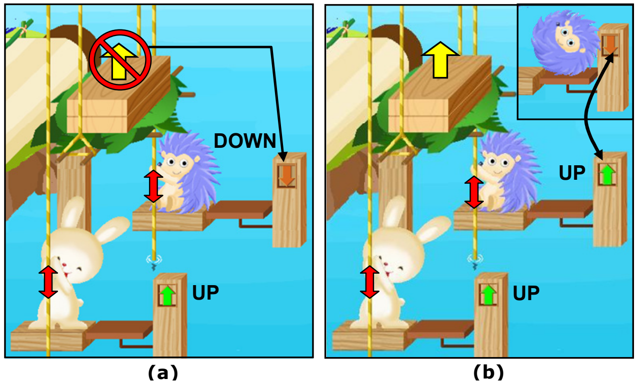

figure 6: Pre-selective coupled action performed by Rabbit and Porcupine. Synchronize up-down action in (a) does not lift planks because Porcupine has not pre-selected UP but in (b) lifter moves up because both have pre-selected correctly. Porcupine switches lifter mode by rolling over to the paddle.

During one trial run (Group 2), Rabbit was observed to have switched his lifter mode to UP in anticipation of the impending arrival of two cut planks. Porcupine was not so attentive and was looking at the number of remaining planks the group has to cut and said, "Two more to go!" Rabbit promptly reminded him to set his arrow to the UP direction by saying to his partner, "Now turn, turn, Porcupine." There were numerous occasions that Rabbit himself was unprepared with his arrow facing the wrong direction and required reminders from others. From our observations, the need to be aware of one's current mode does create many situations where the pair has to communicate and remind each other to get ready. Partners who do so would have demonstrated personal accountability as he or she wants the pair to perform their collective role as best as possible to meet the group's target.

figure 7. The field trial groups. (a) Group 1 – mixed age and learning ability. (b) Group 2 – Mixed-age typically developing children.

The Field Trials

The observations reported in this paper we made through the analysis of video data captured during field trials with two groups of six participants each. These observations are also attached with the accompanying video submission. Group 1 is a mixed age and learning ability group consisting of one adult male, one teenage male with Down syndrome and four teenage girls (see Figure 7a). Group 2 consists of children between the ages of 5 to 10 years (see Figure 7b). Three were male and three were female. Both these groups consist of participants who are familiar with one another prior to playing the game and some of them members of the same family.

Prior to playing the Panda and Pal game, both groups were shown a short video tutorial regarding the function of their gestural interface. Each player in turn, was asked to practice performing their respective motion gesture before the tutorial would proceed to the next stage. A brief narrative regarding the background story to the game was given and the team was asked to work together to cut the five wooden planks. Group 1 played the game five times before they managed to complete the game objective within the allocated 6 minutes. After trail observations, the motion sensing algorithms were improved. Instead of the left or right motion gestures to move in the horizontal directions, a tilting gesture was used instead.

After these improvements, another field trial was held. Group 2 consisting of much younger children and were given an additional practice session with their TUIs after two rounds of game play. They were able to complete the game in the third attempt (with some background prompting from adult observers). After completing the game successfully, Group 1 was asked if they wanted to play the game again. All the boys said "Yes!", but all the girls said "No!" This is an interesting gender-biased observation that needs further investigation. Our general observations suggest that the use of gestural interfaces does not promote long durations of game play as physical fatigue quickly set in when performing the same motion gesture repeatedly. This was highlighted by the some participants in the focus group discussions. The physicality aspect of motion-based TUI interaction could be a possible reason for observed gender-biasness.

Conclusions

Despite the unsubstantiated virtue of unforced collaboration [3], we suspect that in mixed-ability group settings, where the intrinsic motivational model of each individual differs significantly, a thoughtful blend of both enforced and unforced collaboration may be needed to produce some form of social accountability structure that creates explicit purpose for individuals to begin engaging with one another. In other words, the intrinsic enjoyment of collaborative play in mixed-ability group (even more so in a group that is unfamiliar with each other) often needs to be "kick-started" by enforced collaborative activities. In our PAP collaborative game, many of the collaborative design strategies adopted at the one-to-one accountability level (between coupled partners) tend towards enforced collaboration. Design patterns such as synchronized coupled action would be an extreme example of this (i.e. "nothing moves unless we do it together"). On the other hand, the overall structure of the PAP game design (e.g. sequential-dependant roles) facilitated unforced collaboration at the group accountability level. Collaboration is encouraged when unfamiliar situations (e.g. skipping a step) arise or one particular pair is holding up progress in the sequentially-designed task flow because they are unable to work their mechanism correctly. Observations of a spontaneous leader in Group 2 demonstrating positive interdependence by giving instructional help and prompts to other action role pairs is an example of this unforced collaboration.

We also presented other variants of the coupled actions. The toggling coupled action design facilitates opportunities for building trust between the pair and the cognitively demanding pre-selective synchronize coupled action was effective in creating situations that facilitated communication between partners.

From the technological view point, motion gesture based interactive activities do have its challenges, as we encountered during our development of the PAP gaming system. The children had difficulty performing some of the action gestures because the gesture sensing algorithms were not robust enough to handle the infinite variations in the way a TUI device could be held and the manner in which circles and directions can be gestured in 3D space. In addition, the "immersion syndrome" [2], where every gesture, intended or unintended, is captured and interpreted is one persistent problem that prevents gestural interface-based game from being more enjoyable and spontaneous than they should be. However, having half the children in Group 2 say that they would like to play the PAP game again does give us some glimmer of hope for a promising future for collaborative games that use gestural interfaces. Much more research needs to be done to evaluate the efficacy and the consistency of the proposed variations in couple action design in soliciting collaborative behavior. These collaborative design patterns should be implemented in different ways to see if other aspects such as the type of motion gestures, the tasks and action mapping, the profile of paired players, etc may also have a bearing on the observable collaborative outcomes.

In summary, the main contribution of this paper is the proposal of TUI-based interaction design patterns that use coupled-role pairing to facilitate collaborative behavior, especially in inclusive group settings. Three different classes of paired action role designs were proposed and the observed collaborative play behavior each solicited during field trials with mixed aged and learning ability participants were reported.

Acknowledgements

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