Dance Prototyping: Communicating Group Membership and Relational Attitudes via Multi-Robot Expressive Motion

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***Abstract*—Dancers are experts in expressive communication, communicating story, emotions, and attitudes via their motions. While there are many previous works illustrating the power of robot expressive motion in shaping effective human-robot interactions, fewer efforts have been made toward robot group expressive motions. Because of exponentially increasing relationships as you increase number of agents, it can be difficult to know where to begin. This work uses choreography and performance as a tool for designing and testing multi-robot group behaviors. In particular, we leverage the choreographic process, including concept design, rehearsal, and performance, to prototype, investigate, and demonstrate group membership between three robot jellyfish and two human dancers. This resulted in an 8-minute performance of three acts. In the first act, the robots and humans establish their motion styles with curious swimming humans and indifferent bobbing robots ("differentiation"). In the second act, relational dynamics are at the forefront with more active attempts by the robots to differentiate groups ("exclusion"). Finally, the third act shows all agents as members of a common group ("inclusion"). The goal was to gather implementation ideas for social concepts like inclusion and exclusion. We conclude with our proposed translation of these scenes into repeatable abstractions for multi-robot groups, including expressive formation, relational motion, and Laban Effort features.**

I. Introduction

In dance, the choreographic process allows choreographers to conceptualize and test many different movements on their dancers to see what work best. The dancers are co-contributors to this, using their own bodies to explore and create their desired expression. Sometimes the choreographer is a dancer in the scene as well, or they may view the scene from a distance, or on on video later, gaining the audience perspective. By the time a performance happens, the expertise developed in this process becomes baked into the final choreography and into the fluency of the relational movements between the performers.

In applying a choreographic process to multi-robot multi-human groups, we offer an example of how one might explore, test, and iterate over group expressive motions in a dance setting, a.k.a., *dance prototyping*. We build on exploratory research concepts like participatory design [7, 11], story boarding [3], and wizard of oz [10, 12], in that the approach is (1) inclusive, and (2) acts to prototype technology concepts and features. Both the people developing the robot motions and those dancing with the robots have a voice in deciding the final overall choreography, contributing to an identification of salient features for future technology development.

Robots are becoming more common in dance and stage performances, increasing the potential impact and accessibility of this method. For example, researchers have used robots on stage to explore social concepts [6, 2, 9] and collect data from the audiences [13, 5, 4]. Productions have also sought out robots for expressive purposes in large productions from Cirque de Soleil [14] to Blanca Li [8]) as well as local performances [da vinci days, swedish choreographer that visited]. While fewer examples exist for productions with robot groups, putting robots in performing arts contexts is no longer prohibitively expensive or attainable by highly trained individuals only.

The performance documented in this abstract and its companion video specifically considers how group motions can communicate group membership and relationships between groups. Integrating robots into performance art allows exploration of such concepts – in this case, inclusion and exclusion – in a less academic setting. The piece, titled "Mechahydrazoa

umbrellianus," is about two scientists who venture underwater to find a new species of jellyfish, eventually getting stung and becoming jellyfish themselves. As illustrated by these scenes, group membership can be used to to exclude or include, from illustrating boundaries at a construction site to engaging visitors into a museum display.

II. Choreographing Group Motions

The motion of the jellyfish depends on the state the dancers are in. A flowchart of the performance states can be seen in Figure 1. First in the "Differentiation" section the scientists and the robot jellyfish are separate. When the scientists touch the jellyfish they get stung and transform into jellyfish in the "Inclusion" section. After some group motion in the intergrated human-robot group, the robots move away and leave the scientists for the "Exclusion section."

A. Differentiation

First the dancers are divers and move separately with swimming motions. The jellyfish stay together in a group and spin slowly while moving up and down. The motions of the dancers are distinctly different from the motions of the jellyfish, which establishes initially that there is an in-group (jellyfish) and an out-group (dancers).

B. Inclusion

The jellyfish first turn towards the dancers, directing their focus on them. Then they begin to enclose in a circle around the dancers, showing they are being included in the group. The dancers then exit the circle and form a pattern with the jellyfish, doing similar up and down movements with their bodies. They also move back and forth on the stage with the jellyfish maintaining their group formation together. Next, the dancers obtains their own umbrellas and become full jellyfish. The jellyfish again dance with the dancer, this time taking their movement cues from the dancers by copying their movements.

C. Exclusion

After the integrated group motion, the jellyfish move to form a tight circle with each other. The circle formed is tight enough that there would not be space for the dancers to join, signalling that the dancers are excluded from the jellyfish group. They then move away and the dancers, which are again the out-group.

Overall, three different sections were choreographed: differentiation, inclusion, and exclusion. Differentiation explored how motion could distinguish an in-group and an out-group. Inclusion explored how group motion could be used to include someone in a group. Exclusion explored how group motion could then exclude someone from the group.

III. An Interdisciplinary Team of Engineers, Creatives, and Robot Jellyfish

The team, reflected in our author lists, consists of several multidisciplinary artists. The main choreographer (first author) has extensive ballet and dance training and is a PhD student in robotics. She met the two dancers (authors 2 and 3) at the Corvallis Ballet Academy, but they are also students in Biology and visual arts. The composer (author 4) is a professor in the music department, but advises students in the college of Electrical Engineering and Computer Science. Finally, the last author runs the CHARISMA Robotics Lab, with a tagline *where entertainment meets robotics*. Together this team created an otherworldly setting in which to explore robot group motions. We describe this setting below.

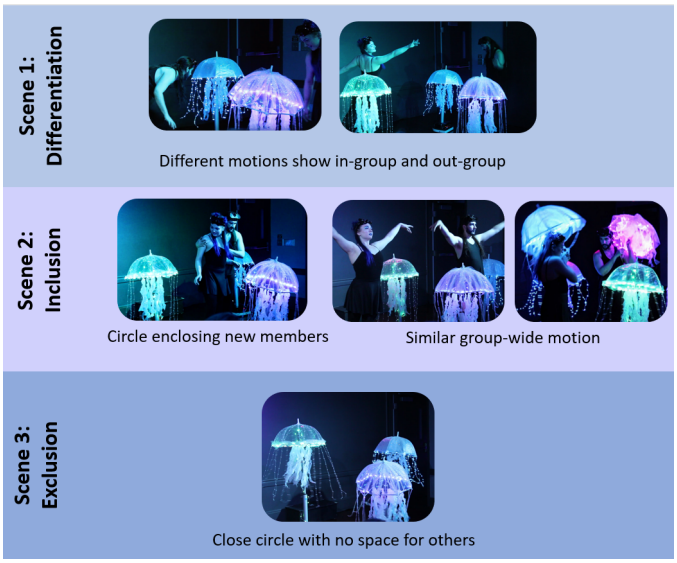

Fig. 1. Differentiation, Inclusion, and Exclusion are the three main scenes and scenarios explored with the dance prototyping method.

Music: The sonic environment in this piece is serene and otherworldly, using electronically generated music, recorders, keyboards, and percussion. The music has three different phases that pair with the dancer's transformations. When the dancer is a human diver, the music is slow and ambient with water sounds playing. This sets the scene as watching a diver explore unknown waters. When the dancer transforms into a human-jellyfish hybrid, the music becomes sharper, with sudden sounds to show that the calm exploration is over and something is changing. When the dancer becomes a full jellyfish, the music has a strong beat and a dance music feel, which reflects that the dancer is now able to join the jellyfish party and become one of them.

Lights: LED lights are used to create a light source within the jellyfish, and glitter is extensively used as decoration to refract the light in different ways. This creates changing light patterns with the jellyfish that mimic sunlight under water. The dancer is dressed in black, and the shadow they create also adds to the flickering light patterns. The dark space and stage lights in blues and purples also adds to the feeling of being underwater and somewhere unfamiliar.

Robots: The jellyfish use a Neato vacuum as their mobile base, with an acrylic piece attached to the top holding a linear actuator vertical on top of the Neato, first described in [1]. A linear actuator moves an umbrella up and down. The umbrella has LED lights, garbage bag strips, beads and sparkles to

both create an illuminated jellyfish top and help visualize the motion. All jellyfish have three degrees of freedom: x,y,theta in the ground plane, and up/down in the vertical. Using these motions, the jellyfish can move in ways that cause the tentacles to swirl and bounce around them, intended to mimic how a real jellyfish moves.

Value of Performance Context: For some people, suspending disbelief in a research setting may be difficult. However, in a performance setting, both the dancers and the audience are in a space where suspending disbelief is expected. Creating an immersive experience for the dancers and the audience helps in allowing them to suspend disbelief and allowing them to feel the experience is more real. The otherworldy landscape created by the robots, music, and lights is thought provoking and raises questions about how you would react to being in a group of robot jellyfish.

IV. Conclusion

While creating this piece, many different ways of showing inclusion and exclusion were tried, with those described above being the most expressive to the dancers and the choreographer. During the choreographic process and the performance, the jellyfish were controlled by the choreographer via a PS4 controller. However, after the performance, the some of the key inclusion and exclusion behaviors used in the choreography were implemented so the robots can do them autonomously. These behaviors are planned to be used in a user study exploring how multi-robot group motion affects a persons feelings of inclusion and exclusion in the robot group.

One interesting observation is that while we may typically associate inclusion with a positive feeling, such as a child joining a group to play on the playground, this is not always the case. It can be seen when the dancers are first being transformed that the inclusive movement of the jellyfish can come across as intimidating, unsettling, and trapping. While they eventually enjoy being jellyfish, the initial inclusion and start of the transformation is portrayed as uncomfortable and confusing.

One question this raises is if inclusion into a robot group will generally be uncomfortable for people at first, possibly due to the unfamiliarity of the situation or that robots can intimidate some people. It will be important to look at how we can minimize the initial discomfort of being included in a robot group and how to make people feel safe and not intimidated when around multi-robot groups.

Another interesting concept to explore is what it means to be "included" or "excluded" in a multi-robot group. As humans we understand what it means to be included or excluded from other groups of humans, but it is not fully clear how that will translate to robot-human groups. One way the robots can show inclusion of the humans is taking cues off them, as seen in the last section of the piece when the jellyfish begin to chose their motion based on the dancers. This method of showing inclusion may make the humans feel more part of the robot group, and not less separated. However, since humans and robots have such vastly different form factors, abilities, and levels of autonomy and consciousness, it may not be possible to fully make humans feel included in a robot-human group.

Future work will explore more ways of utilizing the choreographic process to inform the design of robots and their motions. The ideas of inclusion and exclusion found using dance prototyping will be transferred to a museum exhibit to run a large scale user study, as described in [1]. Future work will also include the use of different robot forms and other technologies in integrated performance art to gain insight on human-robot interaction. Additionally, this work has detailed the benefits of using the motion expertise of dancers and the choreographic process which can be utilized by any roboticists prototyping expressive motion.

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