NRI: FND: Spatial Patterns of Behavior in HRI Under Environmental Spatial Constraints

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http://www.interactive-machines.com/projects/spatial

This project aims to advance autonomous reasoning about spatial patterns of group behavior during human-robot conversations. It provides the **empirical knowledge and methods** needed to incorporate spatial constraints into the way robots reason about human (and robot) spatial formations.

The Challenge

Robots need the ability to recognize social group conversations to effectively adapt their behavior to different social contexts in dynamic environments. One way of enabling them with this ability is by providing them with methods to identify spatial patterns of human behavior that typically emerge during social conversations (Fig. 1).

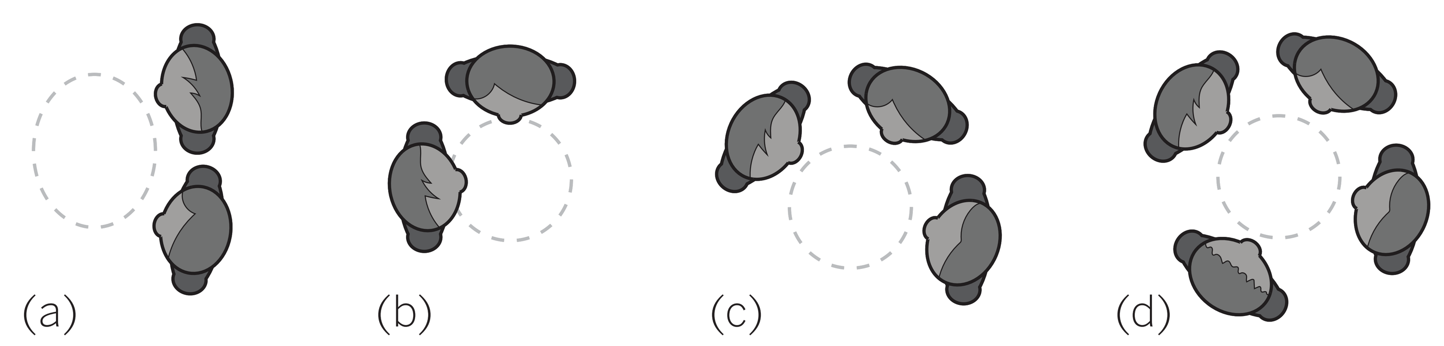

Fig. 1. Prototypical examples of conversational spatial arrangements. From left to right: side-by-side (a), L formation (b), and circular arrangements (c,d).

Prior work has shown that methods that reason about human spatial behavior are promising for automatic group detection; but these methods are often brittle because they build on simple mathematical models of spatial formations. These models do not consider the fact that **the configuration of the space where the interactions happen and the presence of other nearby people can affect human spatial patterns of behavior** [1]. For example, when people talk in an open space, they might distance themselves more than when they talk in a crowded elevator.

Approach

First, we are conducting a formative study with Kuri (Fig. 2) to better understand the effect of spatial constraints on group formations in HRI. Additionally, we are working on detecting spatial formations typical of conversations by combining model-based and data-driven learning methods. Afterwards, we will investigate mechanisms to enable robots to take part in group formations under environmental spatial constraints.

The project's first publication proposes a data-driven approach to detect conversational groups (Fig. 3, 4). This is a first step towards data-driven group detection models that reason about spatial constraints. The publication will appear at the 23rd ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW 2020) [2].

Education & Outreach

Several Yale students have already contributed to this project: Sydney Thompson (CS PhD student), Nathan Tsoi (CS PhD student), Chenyu You (BME PhD student), Joe Connolly (CS major) and Malak Khan (CS major). Research findings will be incorporated in courses taught by the PI, e.g., CPSC-429/529 Introduction to Human-Computer Interaction. Additionally, the PI will be presenting findings from this work in March 2020 at the 15th annual Human-Robot Interaction Pioneers Workshop. The workshop seeks to empower students early in their academic careers.

Impact

As robots enter consumer marketplaces, it is essential for them to be able to cope with the complexity of group interactions. Spatial reasoning is a foundational ability to facilitate group HRI in domains like service robotics, education and healthcare.

We will address three main questions to advance perception and decision-making for co-robots in group settings: (i) how do spatial constraints influence conversational group formations in HRI?; (ii) how can robots detect these formations under spatial constraints?; and (iii) how can they autonomously generate appropriate spatial behavior to sustain conversations in constrained environments?

Fig. 2. Kuri on a table (left) and on the floor (right) in the PI's laboratory. The robot will engage with groups of participants in our formative study. This study will serve to gather experimental data to understand how spatial constraints influence conversational formations in HRI.

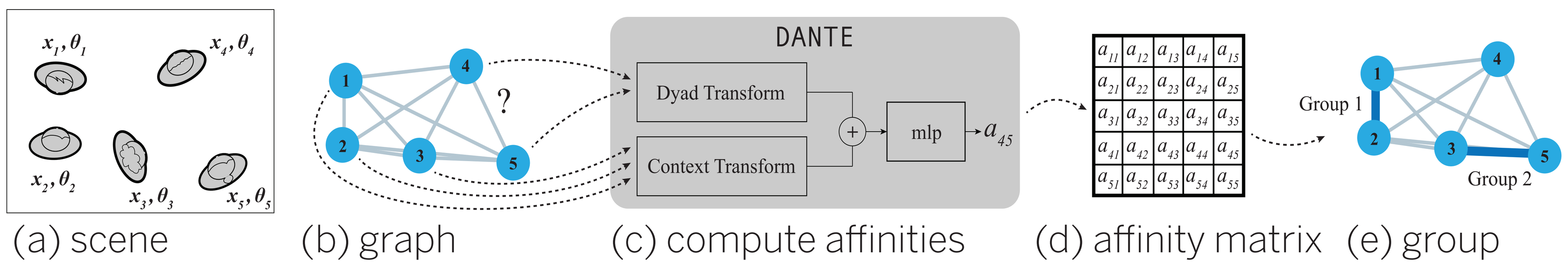

Fig. 3. Our data-driven approach for conversational group detection [2]. We will explore incorporating spatial constraints into our Deep Affinity Network (DANTE) for group detection.

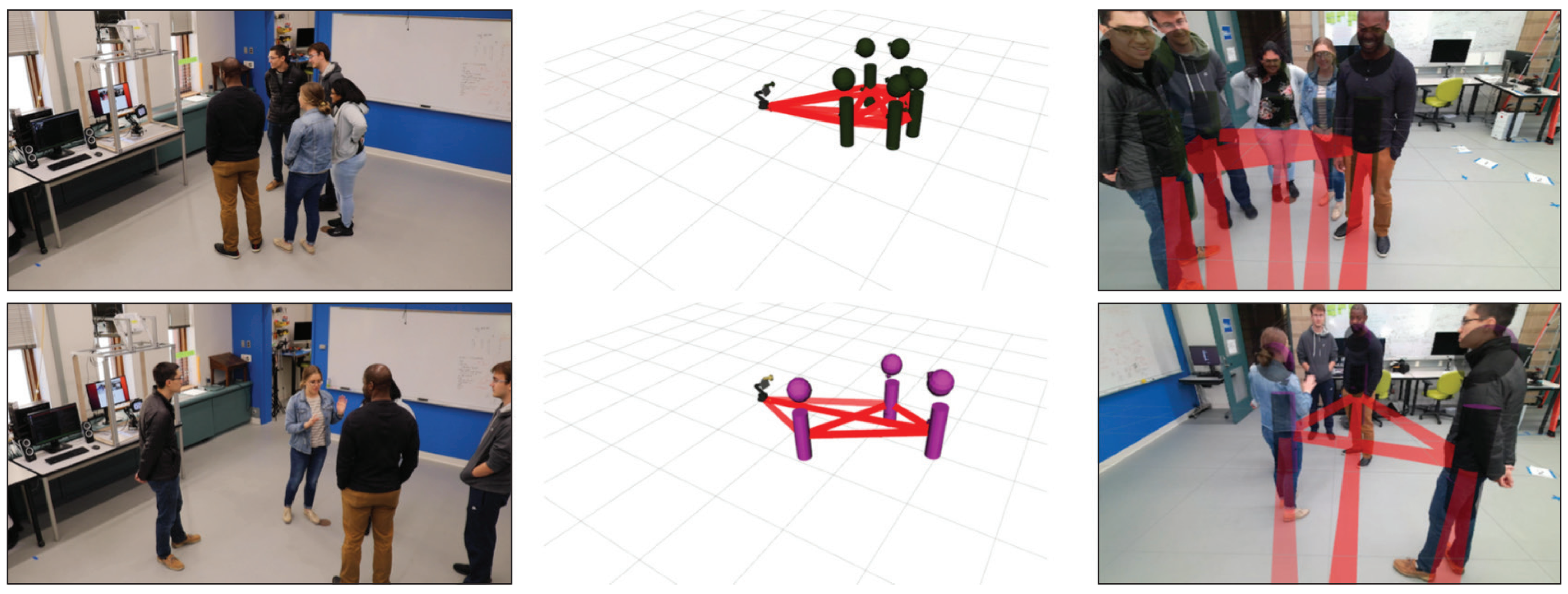

Fig. 4. Tests of our data-driven approach [2] on human-robot interaction scenarios. Groups of people interact with a social robot in the PI's laboratory (top) and among them (bottom). Agents with the same color in the middle image are predicted to be part of the same group.

Lowering Barriers of Entry and Measuring Progress

We will share the multi-modal data from our formative study as a new dataset of group-robot interactions. This dataset will serve to measure progress on group detection and lower barriers of entry to studying group HRI. We expect the data to be useful to researchers beyond HRI, e.g., in Social Signal Processing and Artificial Intelligence.

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References

[1] Kendon, A., Conducting Interaction: Patterns of Behavior in Focused Encounters. 1990, New York, NY, US: Cambridge University Press.
[2] M. Swofford, J. Peruzzi, N. Tsoi, S. Thompson, R. Martín-Martín, S. Savarese, M. Vázquez. Improving Social Awareness Through DANTE: Deep Affinity Network for Clustering Conversational Interactants. To appear in the journal Proceedings of the ACM: Human Computer Interaction (PACM HCI). https://sites.google.com/view/dante-group-detection

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