Choosing How to Convey Robotic Intent: Method, Context and Platform Considerations

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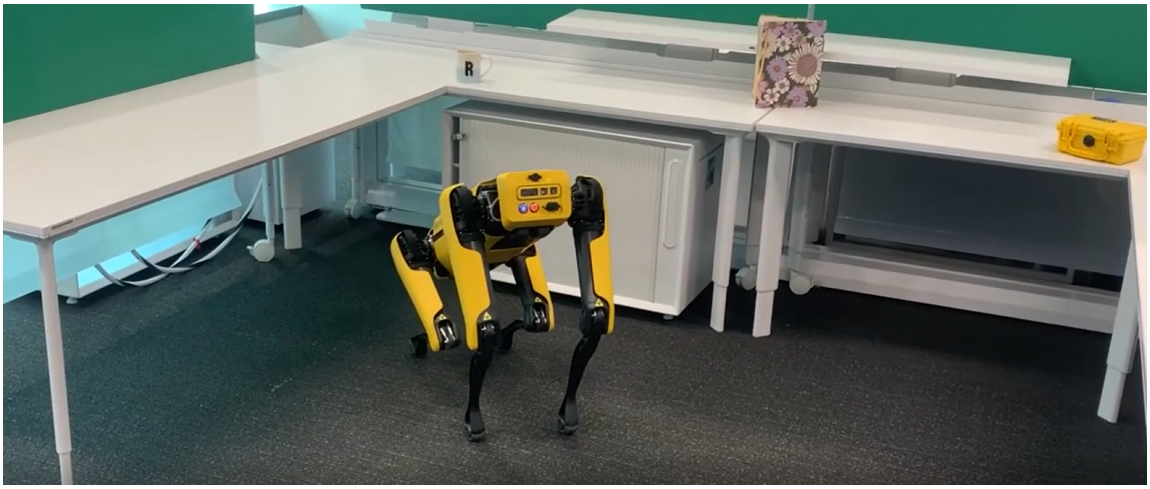

Fig. 1. Spot robot performing a gesture to indicate which object the human should look at.

The communication of a robot's intent or next planned action is vital for successful collaborative work between itself and its human co-workers. While many methods exist for signalling on robots it's important to consider the application context and platform abilities when designing any system. This paper considers the strengths and weaknesses of common signalling methods as well as how these may interact with the task context and capabilities of the intended robot platform.

CCS Concepts: • **Computer systems organization** → **Robotics**; • **Human-centered computing** → User centered design.

Additional Key Words and Phrases: human-robot collaboration, intention signalling

1 INTRODUCTION

In the field of human-robot collaboration, effective, bi-lateral communication is vital for continued progress into the future [16]. Choosing the form this communication should take is a difficult prospect and the task of comparing the efficacy of different signalling methods in a particular industrial application forms the basis of my doctoral thesis. I welcome any input or insight from workshop participants.

Humans feel most comfortable around robots when they are clearly aware of what is happening as well as what safety measures are in place for their benefit [18]. In the case of directly interactive tasks, this can be achieved by clear communication of the robot's next action/movement or intent to its human co-workers. In turn, operator comfort has affects on safety, due to the affects of stress on the likelihood of human error [13]; as well as the acceptance and effectiveness of any robotic or automation solutions. As such, clear and uncomplicated intent communication is an important step in the success of human-robot collaborative systems in industry and beyond.

Many different methods for signalling intent have been seen in this field before such as gesture, sound, lighting, augmented reality and screen displays [5]. Each of these have their own strengths and weaknesses as well as ideal

implementation conditions. Despite this variety there has been little investigation into direct comparisons between techniques on the same platform performing the same task [5]. This makes recommendations difficult for people attempting to design collaborative communication systems. No solution will ever be perfectly general, and signalling systems must be designed with both the context of the task and the existing properties of the robotic platform taken into account. A greater knowledge of the relative strengths and weaknesses of different signalling methods is needed to help designers make reasoned decisions about which methods to apply to their particular situation and robot platform.

2 SIGNALLING TYPES

When signalling intent, it's important to consider that there are many methods commonly used to achieve this end. This section outlines four methods that have been reported in literature; each has a variety of pros and cons that affect things such as their ease of use, ease of implementation and suitability for a particular setting or task.

2.1 Lighting

Lighting sees a variety of applications both in and out of robotics and is a ubiquitous part of daily life. In general, it takes the form of either indicator lighting as we might see on a road vehicle [9] or more complex LED matrices which can form simple images to convey information similar to a traditional screen display [15]. The commonplace occurrence of lighting to indicate state or movement makes it easy for humans to interpret, however the amount of information it can convey can be limited and it is open to misinterpretation if people's existing associations are not matched during the design phase [12]. It is also important to note that not all robots can be modified to include external lights due to aesthetic or operating constraints.

2.2 Gesture and Gaze

Gesture and gaze involve the movement of all or part of the body to convey intent or communicate with a partner. Whilst reliant on some cultural knowledge or "emblematic" gestures, this method of communication displays consistency across cultures [10]. Its other main advantage is that it is not limited by noisy environments or situations in which the lighting does not remain consistent; the limitation on this assertion being that there must be enough light in the working environment for the robot to be seen clearly by the human. However, it is important to note a previous study comparing it directly with a lighting based signalling solution found gaze gestures to be less successful and resulting in a higher participant discomfort. Additionally, these methods can be hard to replicate on platforms without obvious lifelike features or broad posing capability.

In addition to intent, gesture and gaze are also widely examined in the context of communicating or eliciting emotions during conversations, this has been observed across both humanoid and zoomorphic robots [7, 11].

2.3 Sound

Speech is a ubiquitous part of how humans communicate intent to each other, however this does not guarantee successful implementation of this communication method on robots. Past studies have found that robots being either too loud or too quiet can impact the success of an interaction [5]. If a work environment is already loud and the robot is required to be louder, rather than improving the interaction it may actually contribute to operator discomfort [8].

Non-language sounds have also been used to communicate information to humans, such as with the robots Kismet and MiRo-E[2, 4]. Previous examples of this family of verbal communication generally focus on conveying emotions in casual interactions rather than collaborative industrial contexts.

2.4 Augmented Reality

Finally, augmented reality and ground projection are common methods for exploring the problem of conveying robot intent to humans. Ground projection often involves projecting some portion of the robot's upcoming path onto the ground in front of it and primitive versions are already in use on industrial forklifts [1]. Extending this, augmented reality has been used to project either the robot's path or its whole body through space several seconds ahead of time [14, 17]. Whilst very information dense, these methods all suffer from lighting issues and are only recommended in applications where the lighting is consistent [6].

3 SUITABILITY

As seen in the method outlines above, the benefits and drawbacks of each family of signalling solution are often associated with elements of the task or platform to be used. These factors bear consideration when designing any system for this purpose.

3.1 Application Context

Choosing which signalling method to implement is largely dependant on the conditions or context in which it needs to be used. In a quiet, brightly lit office it might make sense to communicate verbally or with augmented reality; whereas in a loud workshop the use of gesture may be ideal. Application context also includes accounting for the intended end user of the system and whether they have any particular skills or disability which may affect the viability of a particular signalling solution. As such, when evaluating which methods are most suitable or most appropriate, knowledge of this context is vital as it is unreasonable to work towards an 'overall' best or truly general solution.

3.2 Platform

Another important consideration when examining which method of intention signalling to utilise is the form and requirements of the platform itself. Some robots are considered "appearance-constrained", meaning that the look of the robot cannot be meaningfully altered without impacting its function [3]. Mirroring this concept, it is important to consider if there are features of the robot which can be naturally leveraged for one particular signalling method or another. If a robot already has lighting or speakers, re-purposing these will likely be more robust and natural looking than the addition of after-market hardware onto a platform that previously lacked these capabilities. Similarly, if the robot in question already bears resemblance to a living creature such as a human, or in the case of quadrupeds, a dog, it may be an ideal candidate for gestural intent communication due to these inbuilt associations.

4 CONCLUSION

Many methods already exist for signalling intent on a robot to a human, though there is a lack of comprehensive comparison between methods on similar tasks. When selecting methods to use or test it is important to consider not only the overall strengths and weaknesses of a particular method, but also their feasibility and performance in the particular context and on the particular platform where they'll be used.

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