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Enhancing Trust and Confidence in Human Robot Interaction

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Abstract: We investigate human robot interaction under no-visibility conditions. A major pre-condition for successful human-robot cooperation in these circumstances is that the human trusts and has confidence in the robot. In order to enhance human trust and confidence we have to make design choices that impact on a number of ethical issues. We also look at the interaction between a visual impaired person and a guide dog for clues to enhance confidence. The interaction consists of mixed initiative and the guide dog does not have full navigation responsibilities. This model seems also appropriate for human-robot interaction and might in addition be a useful example regarding evaluating the ethical issues of human robot interaction.

Keywords: Human Robot Interaction, Trust and Confidence, Robot Guides, Guide Dogs.

1. Introduction

The REINS project aims to work towards the design of a robotic guide which will safely lead a human agent through an obstacle-laden environment; the environment is very noisy and there is no-visibility. Because of these conditions the guidance consists entirely of (low-bandwith) haptic feedback. In such situations human agents will be highly vulnerable and subject to unpredictable environmental stress. A major pre-condition for successful human-robot cooperation in these circumstances is that the human trusts and has confidence in the robot.

In order to enhance human trust and confidence we are introducing design choices that impact on a number of ethical issues. These issues include the 'degree' of guidance the robot is supposed to provide as well as the 'degree' of control the human can exert. We will argue that full autonomy of the robot will not be appreciated by a human subject; a human being by nature will try to read the situation and adapt the team (robot and human) behaviour to that reading. In order to do so, the human will need to be able to predict the robot's behaviour in the given context. Thus some sort of accountability is implicitly required from the robot and we have to opt for a 'mixed initiative' approach in which the human is able to direct the robot. Reduced autonomy for the robot also seems to imply limited responsibilities for the robot.

2. Background

Search and Rescue scenarios are often complicated by low or no visibility conditions, caused by smoke or dust. The lack of visual feedback hampers orientation and navigation and causes significant stress for human rescue workers. Robotic assistants provided with appropriate sensors seem to be an option. The Guardians project [1] pioneered a group of autonomous mobile robots assisting a human rescue worker operating within close range. A basic assumption of the Guardians project was that if the group of robots could overcome the navigation problems they would be welcome assistants to a human rescue worker. Trials were held with professional fire fighters of South Yorkshire Fire and Rescue. It became clear that the human subjects by no means were prepared to give up their procedural routine and the feel of security provided by these routines: they simply ignored instructions that contradicted their procedural routines. It was obvious, then, that the provision of robot assistance in fire fighting operations was no mere 'technical' matter but immediately raised complex emotional and ethical considerations that robot designers would have to address.

Building on these findings the Reins project is exploring in more depth the context of use for a robotic device in no-visibility conditions**.** We are investigating scenarios (under sensory-deprived conditions) in which a human and a semi-autonomous robot can develop cooperation and become a team while using a haptic interface. The key lesson from the Guardians project is that the human agent must be able to trust and have confidence in the robot guide since the robot co-worker is taking on responsibilities related to the well-being of the human agent. The ethical dimensions and implications of the project cannot, therefore, be ignored. In Wallach and Allen's [2] terms, our robot co-worker must be equipped with a '*functional morality*', given the degree of autonomy which the robot, as guide, will exercise in the experimental task setting.

3. Robotic Guides

Literature on experiences of human subjects with human-robot interaction in low-visibility is rather sparse. However, there are several works on robotic assistance to the visual impaired. Allan Melvin et al [3] developed a robot to replace a guide dog; however the paper does not extensively report trials with users. The GuideCane [4] is a cane like device running on unpowered wheels, it uses Ultra Sound to detect obstacles. The user has to push the GuideCane - it has no powered wheels- however it has a steering mechanism that can be operated by the user or operate autonomously. In autonomous mode, when detecting an obstacle the wheels are steering away to avoid the obstacle. The GuideCane has been tested with 10 subjects three of whom were blind and cane users, the other seven were sighted but blindfolded. Basic conclusion: '*walking with the GuideCane was very intuitive and required little conscious effort*', unfortunately nothing more is reported on the subjects' experience.

The robotic shopping trolley developed by Gharpure and Kulyukin [5,6] is aimed at the visual impaired. This trolley guides the (blind) shopper - who is holding the trolley handle - into the vicinity of the desired product and subsequently instructs the shopper on how to grab the product using voice instructions. The guidance is fully robot driven. Experiments with visually impaired subjects were performed in a supermarket. An interesting comment from the subjects was: '*Instead of just following the robot, doing nothing, I would like to know what products I am passing by*'. This seems to indicate that even in less stressful settings there is reluctance on the side of the human to cede control and a need to read the actual situation more directly.

4. Guide Dogs

Guiding and navigating a fire fighter or a visual impaired person are quite different tasks. Nevertheless, our study on a robotics guidance assistant can take advantage from experiences of the visual impaired and guide dogs. The current practice of fire-fighters is to rely solely on their own immediate haptic feedback for the purposes of navigating in hazardous conditions and we are aiming to introduce an additional - though artificial - agent to support navigation. Many visually impaired persons have developed highly effective navigational partnerships with specially trained guide dogs; refer to [7] concerning the training and use of guide dogs. Consequently we have devoted considerable time to the close study of these partnerships and, in particular, the mutually-oriented and jointly exercised communicational proficiencies required by human agent and canine helper. These communicational proficiencies are underpinned and sustained by a reciprocal behavioural confidence built on friendship and trust. Guide dogs are treated not as mere 'assistance' but as thinking and feeling beings – in short, as moral agents in their own right.

The guiding link between user and dog is called the *handle*, and the user is usually referred to as the *handler*. The handle is attached to a harness on the dog's back and shoulders. The dog is walking at the handler's side, 2/3 of the dog's body being ahead of the handler - the dog is half a pace ahead.

In terms of their guiding and navigational responsibilities, dogs are trained to work according to a strict protocol, within which they nevertheless exercise a considerable degree of autonomy: they will lead the handler at a comfortable pace in a (roughly) straight line, in the middle of the pavement. The handle is not used to push the dog, nor does the dog drag the handler along with it. The default condition is that dog and handler walk at the same pace: the handler feels the dog's movements and direction while the dog monitors the handler's walking and other aspects of behaviour as they proceed together.

Reflecting on a trial with a guide dog, a (sighted) colleague noted: '*I walked blindfolded with the dog along a busy walkway outside. Pretty soon I began to feel even the slight changes of speed and direction. The trainer who walked with me said that it is important to swing your hands so that the dog also gets some feedback on your active participation of* *walking.*'

The dog will slow down and negotiate minor obstacles on the pavement; the dog may take evasive action in advance if a slight deviation is required, which means that the handler will have avoided an obstacle without even knowing it. The dog continues the straight line until faced with a 'choice' of directions. At that point the handler will have to prime the dog as to the required direction. For instance, the dog will lead the handler to the kerb when there is a road to cross and await instructions. It is down to the judgement of the handler to initiate a crossing: the handler will have to command the dog forward. However, the dog will not move forward if it is aware of a hazard, so the handler will have to wait and then issue a further command etc.

This cooperative relationship between guide dog and handler is inspiring for the design of a human robot interface. Important point to notice is the division of labour between the handler and the dog. The guide dog is not instructed to take the handler to a destination - on the contrary, the handler is taking the dog to a destination. The team is depending on the handler's own spatial awareness and ability to read other clues and cues from the environment. The handler (not the dog) has to find the destination; which leaves the handler responsible for key *navigational* decisions (over final destination and exact route).

However, the dog is responsible for the safe passage between navigational decision points. This activity takes place in *locomotor space* as it is called in [4] and we call the task which the dog performs *locomotion guidance*. Locomotion guidance concerns moving from point to point in a nearly straight line without collisions; and it includes collision avoidance. Locomotion guidance by the dog and navigation decisions taken by the handler are complementary activities each performed by a 'specialised' agent, refer to Figure 1.

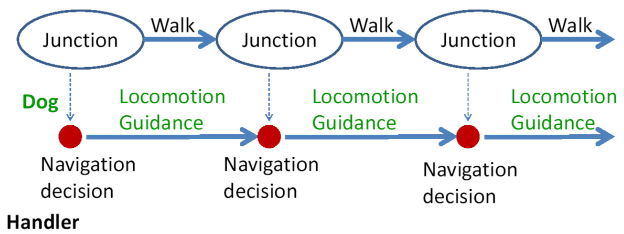

Figure 1, Handling a guide dog, task analysis.

Guide dogs feel quite comfortable in pedestrian zones. On the street people are on the move and quite aware of what is coming up ahead and tend to get out of the way. However, in a supermarket where lots of people with trolleys are traversing the aisles, most people are concentrating on food shopping and not on what is going on behind them. Nevertheless a dog can manage and stops if there is no way through without brushing the handler against any obstacle.

However, dogs are not at all good in dealing with motorised traffic. The team (dog and handler) may have to cross busy streets with moving vehicles, in which situation the team must have to rely on each other's limited abilities. In such situations the human agent must be able to **trust** the guide dog implicitly and the dog in turn must be **accountable** (we will discuss the concepts of trust and accountability below). This relationship of trust takes time to build up and develops through collaboration.

5. Confidence

The term 'trust' is not easily defined; without going deep into the issue, the definition of ***Trusting Intention*** given by McKinght and Chervany [8] is helpful for our discussion: '*We define Trusting Intention as follows: the extent to which one party is willing to depend on the other party in a given situation with a feeling of relative security, even though negative consequences are possible. …. Trusting Intention is an intentional state: the person is ready to depend on the other in the situation. It is personal (originating in a person) and (one-way) directional: one person is willing to depend on the other.*' McKinght and Chervany [8] also define *Trusting Behavior* which goes a step further than Trusting Intention: '*Willingness to depend leads one to actually depend (behaviorally) on the other party. …… When one depends on another, one confers upon the other person a fiduciary obligation to act in one's behalf*'. However the second sentence indicates that this is more than what is needed in a robot -human relationship. Stormont [9] notes that unpredictability of an autonomous system is a cause of distrust. He notes: '*when working with humans, we usually can anticipate their actions in a wider range of circumstances … autonomous systems have a tendency to surprise even their creators.*'

Inspired by this we define ***Behavioural Confidence*** as follows: *the extent to which a person believes the current behaviour of another agent is a predictor of (near) future behaviour of the same agent*. It is our belief that confirmed behavioural confidence will result into a trusting intention and the human willing to depend on the robot.

As of the start of the project our presumptions on human robot interaction are the following.

1. **Cooperation develops in the interaction**:

we view human interaction and cooperation as a flexible, creative and dynamically adaptable process and we perceive human robot interaction as a communicational landscape emerging between the human being and the robot. Human robot cooperation develops while the team proceeds.

2. **Human Dominance**: we expect that the human being wants to remain the dominant and initiating partner, at least from his/her perspective.

3. **Situational Awareness**: we also expect that the human being, by nature, will try to ‘read’ the situation [10] and base decision making upon the ‘view’ obtained.

Situational awareness on the side of the human being is a prerequisite for behaviour confidence, the human being must be able observe current and predict (near) future behaviour of the robot in relation to the environment where it is acting. Behavioural confidence also implies a sort of **accountability** on the side of the robot. The robot is **accountable in the view** of the human handler, if in the occasion that the robot's behaviour deviates from the expectation the human is able to rationalise **why** the robot behaved differently.

6. Dogs and Robots

The cooperation between a guide dog and its handler is inspiring for the design of human robot interaction discourses and also seems to confirm our presumptions.

Human dominance: the division of labour between the handler and the dog - with the human making the navigation decisions and the dog providing locomotion guidance (refer to figure 1) - leaves the handler the dominant role of being responsible for the navigation. The dog's task is locomotion guidance, in executing this task the dog has to be reliable or in the terms introduced above: accountable in the view of the human handler. It is relevant to note in this context that not all dogs make good guide dogs, they are carefully selected; for instance dogs with a very dominant character are not suitable.

Cooperation develops: we note that the relationship between the dog and the handler has to be built while they are collaborating; a guide dog is not 'off-the-shelf' ready for use by everyone. Even if dog and handler are an experienced team they still meet difficulties for instance when trying to cross a busy street, and both the handler as well as the dog have to trust each other.

Situational awareness: we learnt from our trial with a guide dog, that the feedback through the handle from the dog to the handler (and vice versa) is very rich. The human obtains a feel of what the dog is doing, but the dog feels and adapts to the human's behaviour.

Accountability plays a key role as the handler will evaluate the dog's behaviour as a situational assessment of the current environment.

From the above we can extract some guidelines for designing a robotic guide. In order to enhance the human feel for dominance a fully autonomous operation mode for the robot seems not appropriate. Moreover, adopting the split between navigation and locomotion responsibilities seems to ease the requirements on the robots capabilities. The cooperation between the human and the robot has to develop, however this is only possible if the robot can provide rich feedback; feedback that is rich enough to create situational awareness for the human being. A focal point in the further research in the Reins project is to explore various types of handles: a stiff handle, a rope (rein) and a wireless connection. The advantage of the stiff handle is that quite some feedback comes for free, while for a rope or a wireless connection feedback has to be artificially generated.

A guide dog also receives feedback about its handler, and the dog adapts its behaviour to that of the handler. A second point of focus in the reins project is an attempt to estimate the confidence level of the handler. We hypothesise that the confidence level of a handler following a robot correlates to the force applied on the handle. For this we consider a person with impaired perception, who follows along a path guided by an agent with full perceptual capabilities. The impaired person has to trust the other agent with full perceptual capabilities to find his path.

The fact that interaction between a robot and a human being emerges and that a relationship has to be developed in a certain sense obscures the related ethical issues. Predictability and accountability are not just ethical issues; they are design requirements as well.

Dogs are intelligent, attached and understanding, qualifications we cannot attribute to present day robots. It is therefore interesting and a further aim to research ethical issues relating to the use of guide dogs and to explore whether these may apply in a human robot guidance relationship.

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