Child-Robot Interaction: Perspectives and Challenges

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Abstract. Child-Robot Interaction (cHRI) is a promising point of entry into the rich challenge that social HRI is. Starting from three years of experiences gained in a cHRI research project, this paper offers a view on the opportunities offered by letting robots interact with children rather than with adults and having the interaction in real-world circumstances rather than lab settings. It identifies the main challenges which face the field of cHRI: the technical challenges, while tremendous, might be overcome by moving away from the classical perspective of seeing social cognition as residing inside an agent, to seeing social cognition as a continuous and self-correcting interaction between two agents.

1 Introduction

Within the field of Human-Robot Interaction (HRI) interaction between children and robots takes up a special place. Child-Robot Interaction (often abbreviated as cHRI) is different from interaction between adults and robots in that children have got a different, immature cognitive development. Children typically do not see a robot as a mechatronic device running a computer program, but attribute characteristics to the robot which are typically expected to be attributed to living systems. This has been observed in both adults and children [1] and that anthropomorphisation is already strong at the age of 3 [2], and possible at even younger ages. Furthermore, it would seem that children anthropomorphise more than adults do; or at least are more eager to maintain the illusion that the robot has life-like characteristics [3]. This is most probably amplified by that fact that children, and indeed a wide range of young animals, engage in play [4]. *Pretend play* and *anthropomorphisation* seem relevant to the ability of children to engage with robots and treat them as life-like agents. Pretend play and anthropomorphisation are not typically observed in great apes, and seem to have evolved uniquely in humans. It is believed that both have a neuropsychological basis, and that they are integral to the development of sociocognitive and linguistic skills, while at the same time being active during a short period in the

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pre-school and primary school years of a child, i.e. before between the ages of 3 and 11 [5]. This propensity for social play spills over into technology: toys and specifically robots are readily treated as being alive and having "beliefs, desires and intentions" [6].

While, as roboticists, we know little about the neurological and psychological underpinnings of what makes social human-robot interaction work (however, see [7]), this does not stop us from actively using the human propensity to interact with robots on a social level. Through prototyping and rigorous evaluations, the field has uncovered that certain design decisions (for example, using a humanoid form rather than a zoomorphic form) or behaviours (for example, providing timely reactive responses to the user's actions) work better than others. In the same way, we have discovered that human-robot interaction works particularly well with younger users [8].

Child-Robot Interaction might be fundamentally different from Adult-Robot Interaction: children are not just small adults. Their neurophysical, physical and mental development are ongoing, and this might create entirely different conditions for HRI to operate in. For example, children are still developing their language skills and while doing so they often make linguistic errors, but also seem to be oblivious for errors made by adults [9]. As such, certain linguistic errors produced by a robot might also go unnoticed .

This paper wishes to take stock of the current state-of-the-art in child-robot interaction by identifying opportunities for cHRI and the obstacles that are still in the way of deploying cHRI out of the lab and in the real world on a large scale. The authors are all involved in various aspects of cHRI, from designing perceptual systems to evaluating cHRI in the wild, and have more than three years experience in designing, creating and evaluating child-robot interaction. In the next section we not only identify challenges, but also offer suggestion as to how these can be overcome.

2 Opportunities

Next to the aforementioned propensity for children to readily engage with social robots, there are a number of factors which make the study of social cHRI particularly attractive.

2.1 Hunger for applications

As cHRI provides a relatively easy entry point into social HRI, there are a large number of applications where cHRI can have immediate and measurable impact. One is education: a robot can provide personalised, cheap and virtually tireless tutoring. Through the social rapport that a robot can build, tutoring has the potential of being very effective. The tutoring experiences that the robot offers are on a par with, and often exceed, the effectiveness of computer-based tutoring systems [10, 11]. This effect is likely due to the embodied nature of the interaction, which is not achieved when interacting with a screen-based device.

Fig. 1. A young cerebral stroke patient engaging in robot-led physiotherapy.

A robot can adapt its interaction and the level of its tutoring to the child's learning, using, for example, a Zone of Proximal Development approach (see Vygotsky [12]).

Another field where a robot can be effective is healthcare. Animal assisted therapy (AAT) is an often used method to improve the well-being of children during a stay in hospital. Unfortunately, AAT is expensive and not available to all young patients for hygiene reasons. However, robots provide an attractive alternative for this: Robot Assisted Therapy (RAT) is a fast growing sub-field of HRI. While robots can be used to just provide comfort and companionship, they can also take up a role in education and therapy. Robots have been shown to be effective for children diagnosed with diabetes [13, 8], but have also been successfully trialled for children suffering from trauma requiring extensive physiotherapy (see Figure 1). Other domains in which RAT holds promise is respiratory diseases, such as asthma or cystic fibrosis, or cancer. The benefit the robot offers comes in a variety of forms, at the most basic level the robot provides much-needed diversion, but it can also be used as a companion and educator, while at the same time offering the ill child an experience which offers much-needed social status.

In the same sphere, we wish to highlight the use of robots for Autistic Spectrum Disorders (ASD). Children with ASD often respond well to robots, for reasons not yet fully understood [14]. People with Autism Spectrum Disorder have good systemising skills along with a preference for predictable rule based systems [15], which might explain why they feel comfortable working with computers and robots. but possibly. For ASD therapy (and indeed other robot assisted therapy) the robot can offer automated diagnosis, progress monitoring, semi-automated running of therapeutic programmes, as well as serving as an intermediary interaction medium between a human therapist and the child.

Finally, the edutainment industry is keeping a close watch on developments in cHRI. Low-cost robots which capitalise on elements of cHRI have the potential of having significant economic impact. While developments here are more sensitive to fashions and correct retail timing, academic research into cHRI still has a currently underestimated role to play.

2.2 Next generation cognitive systems

The old views of cognitive systems being the product of solely the brain, or the brain interacting with the body, are giving way to a new view of cognition. In this new perspective cognition is no longer seen as just embodied, but is the product of interaction between two or more embodied brains (for some early musings see [16]). Indeed, social interaction is necessary for maturing cognition: without constant and extensive social interaction, the young child cannot grow into a socially and cognitively functioning adult. But this is only one side of the story: cognition does not happen in a social vacuum. Some of it does, such as object manipulation or locomotion, but most cognitive functions are social in nature: the manipulation of concepts and reasoning, language and multi-modal interaction all are inherently social.

cHRI provides an attractive point of entry into this new view of cognition (sometimes dubbed Cognition 3.0, 1.0 being the brain as seat of cognition, 2.0 being embodiment as focus of cognition). This view offers one very rich vein: the fact that cognitive interaction is the product of two agents, where it is not necessary for one agent to be fully cognitive. Instead social cognition is the product of high-resolution interaction between two or more agents, and when one agent provides impoverished interaction, gaps are often and readily filled by the cognition of the other agents. Take as illustrative example a conversation: spoken conversation does not follow the patterns seen in written conversation, instead spoken conversation is rife with hesitancies, disfluencies and interruptions. However, these do not negatively impact on the interaction or the intelligibility. The reason for this is that the conversation –and interaction in general– is the product of two agents, whose combined cognition caries the interaction forward.

This has tremendous potential for social HRI: the technical capabilities of robots fall far short of human cognitive capabilities. Nevertheless, given that social cognition is the product of two agents, any failures in the robot's cognition can potentially be covered by the human. This is never more obvious than in child-robot interaction. For example, the fact that a robot has no visual perception might go undetected for the entire duration of the interaction. Just the belief by the child that the robot can "see" is enough for the lacunas in the interaction (which are obvious to us engineers) to go undetected [17].

3 Challenges

Despite the positive notes in the previous section, there are a number of challenges which the field needs to address before cHRI can be considered a success.

3.1 Technical challenges

As with most AI systems, perception remains a bottleneck. This is certainly so in HRI and cHRI: users often expect the robot to have the same perceptual modalities as the user has, and it are these modalities that have proven to be very hard to realise artificially. Artificial visual perception, for example, has after 50 years of steady improvement only reached a fraction human capability. Functionality such as face detection, face recognition, object recognition, figure ground separation and human behaviour understanding have come a long way and are currently of a standard where they can be used in restricted scenarios [18]. However, open-ended interaction in real-world environments still is not possible. The same goes for Natural Language Understanding: while speech recognition has come in leaps and bounds, child speech recognition is still under-performing. This has a knock-on effect on Natural Language Understanding, forcing human-robot interaction scenarios which use language to either resort to restricted interactions or to revert to Wizard of Oz control.

Another obstacle to autonomous cHRI (and HRI in general) is action selection: the problem of what to do next in response to current and past sensor input. Users have well-defined expectations of what the robot's response should be, but it has proven to be technically very challenging to select a correct response in open and unconstrained environments. Action selection mechanisms, and by extension cognitive architectures, are currently falling short when used in social interaction domains. New and radically different approaches will be needed to break through this barrier (see for example [19]).

However, as mentioned in the previous section, lacks in artificial processing and in generating appropriate responses, often go undetected by young users. This is a blessing for social robot builders and can be used to good effect. For example, the lack of visual perception can be disguised by still providing the robot with behaviours which make it appear as if it is seeing. Just the addition of two eyes to a robot head often suffices to "trick" the user into believing that the robot sees. Together with alternative technologies, such as RFID tags worn by the user for user identification and a laser range scanner for detection objects near the robot, this can be used to generate the illusion that the robot has visual perception.

3.2 Evaluation

Evaluating the effectiveness of cHRI has always been more problematic than with adults. While adults can be probed using questionnaires and self-reflection, children have the tendency to try to please the experimenter, rather than answer truthfully to survey questions. Likert scales always come back with extreme responses, and children often try to second guess the desirable response. As such alternative methods are required. A number of interaction metrics can be monitored: duration of interaction, proxemics, structure of utterances, biometrics, compliance with robot suggestions and instructions. However, these are often only circumstantial to the goal of cHRI. Often the interaction serves to offer consolation, or to educate a child or to encourage, and interaction metrics – while sometimes correlating with the goal of the interaction– cannot be trusted to inform us about the outcome of the interaction.

As an experimenter we need to measure if the desired outcome really is met. In some cases this is relatively straightforward: if the robot has a role in education, then a balanced pre and post test can be devised to measure what the contribution of the robot is to knowledge gain. However, other outcomes, such as the robot providing consolation, are much harder to objectively measure and might require very large sample sizes before returning significant results.

In conclusion, while other disciplines in robotics have relatively easy benchmarks to measure performance against, interaction with people introduces a level of noise which the field still has not fully addressed.

3.3 Expectations

When building social robots, it is important to set the right expectations. Not only in the young people interacting with the robot, but also in the parents, medical staff and teachers who use the robots. And it is the latter group which often proves problematic. In our efforts in creating social robot interaction, we have had to spend considerable effort talking to and demonstrating robots to adults in whose care children were. Children have preconceptions of what the robot can and cannot do, but are not noticeably troubled by unmet expectations. Adults, however, are different and as a robot builder you will need to invest considerable time and effort adjusting expectations. However, the investment will be very much worth it.

The authors found focus groups and regular meetings to be useful to identify a set of achievable goals for social robots in medical settings, which are both rewarding for us as researchers and for the medical staff we collaborate with. However, during this we learnt the hard way not to trust our own opinions. There is a temptation to think that, as an HRI expert, one knows what the user wants. This is seldom the case.

4 Conclusion

This paper did not contain a technical contribution, nor did it present results from evaluating technical systems or running user studies[4]. Most, perhaps all,

[4] However, the opinion and observations expressed in this paper are the result of 3 years and over 800 person months of experience in building and evaluating Child-Robot Interaction in the FP7 ALIZ-E project.

of the observations in the paper kick in open doors, but we feel the points made are worth making and worth communicating to our colleagues. In science and engineering too often we make mistakes and start redundant work which could have been avoided had we only engaged in a conversation about the challenges and potential solutions which others identified before us through hard graft.

We wish to reiterate that the interaction between children and robots is potentially very different from the interaction between adults and robots due to children's neurophysical and mental development being ongoing. At the same time, the view of cognition is being extended: we suggest that cognition is no longer the domain of the individual, but the product of a fine-grained interaction between agents, be they people or people and machines. This does not lead to new research questions, but also offers new opportunities for cHRI and HRI in general.

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