
Author: Dr. Bogdan Raducanu

Problem Description:

This section is devoted to present the existing framework in robotics and to justify why a new one is needed. Within this broader vision, we also identify and propose a particular step to be achieved in order to bring us closer to the desired goal.

Classical Framework

Creating robots showing human-like intelligence is still a very big challenge for the scientific community. Despite of the efforts devoted in the past decades, only partial, limited success has been achieved. The question that arises naturally at this point is: what did we miss in our strategy that prevented us in reaching the desired goal? The traditional paradigm in robotics (which can be found on a large scale nowadays) is represented by manual development. Within this framework, the human designer is the one in charge to specify the task that must be performed by the robot, how it must be performed, its corresponding internal representation and the data structures associated to it. Being restricted from the very beginning by its creator, lacking the ability to ‘know’ or ‘understand’ what or why it is doing, the robot has no possibilities to ‘be’ something more than the purpose it was originally created for.

Emergent Framework

In order to overcome these strong limitations, a new paradigm has been recently emerged: cognitive developmental robotics. This is situated at a crossroad between robotic engineering and cognitive developmental sciences like psychology and neuroscience. Within this framework, opposite to its predecessor, the robot should be endowed with developmental abilities specific to humans: it should evolve from an ‘infancy’ stage to ‘maturity’. This paradigm implies a completely different approach for robot programming. It can not be task-specific anymore because the tasks the robot will perform are unknown in the design phase. Furthermore, it should be able to generate automatic representations of unknown knowledge or skills. However, the human designer is responsible for providing it some basic, ‘building blocks’ of knowledge (the kind of knowledge similar to what we carry in our genetic material) that contain critical specifications that will allow the robot to learn and evolve during its existence. In terms of theory of evolution, the ‘genetic’ information provided will resemble the phylogenetic process taking part in biological systems. Phylogeny refers to those adaptations and modifications in an organism structure that occurs at large time scales (across several generations). On the other hand, the development taking place in a system during its existence is referred as ontogenetic process. Ontogeny is driven by the phylogenetic factors, but it is also strongly influenced by the system’s surrounding environment. This aspect has been studied in detail by the psychologist Jean Piaget (Piaget, 1952), whose work represent a landmark in the theory of cognitive development.

In a similar manner, the cognitive development of a robot should happen through direct, continuous interaction (making use of its perceptual mechanisms) with the environment in which it will be situated. In consequence, the robot will create its own understanding about things and will build its own reality. The cognitive development is an open-ended, incremental and progressive process: a robot cannot learn complex skills successfully without first learning necessary simpler ones. A key element that plays a crucial role in the development of a robot is represented by an
intrinsically motivation system. This represents the ‘trigger’ of the interactions between the robot and its surroundings. Without it, the robot will be lacking of the desire to explore, to learn new things and to acquire new capabilities.

Social robotics represents a particular case of the cognitive developmental robotics paradigm presented above. Social robotics refer to a category of robots in which social interactions (through communication cues people normally use) plays a fundamental role. These robots should be able to learn particular skills as a result of their interaction with people and to learn to behave in a personalized manner. In consequence, they are not seen only as ‘service robots’, but as cognitive developmental systems that, hopefully, sometime could become part of our everyday life. There is psychological evidence supported by work of Vygotsky (Vygotsky, 1962) who claims that social interactions are essential for the development of individual intelligence.

Roadmap:

This section is devoted to the presentation of the steps to be taken in order to achieve the objective proposed: implementation of an intrinsic motivation system to support social interactions

General aspects regarding the motivational system

A way to implement an intrinsic motivation system might be to build a mechanism which could characterize a situation in terms of “novelty”, “surprise”, “complexity”. We have to find ways in which these concepts can be given an internal representation in the robot. This representation would allow the robot to possess a sense of ‘self’ that would be reflected in an inner state (for instance mood or emotions). The next step would consist in defining a ‘reward’ function. Since the intrinsic motivation system for a social robot gravitates around the interaction between the robots and people around, the reward function could be thought as measuring the impact it creates each time the robot interacts with a person. This reward function can be considered like an error between the desired outcome and current expectations. Then, motivation arises like an emergent property as a result of taking those actions which maximize the internal reward.

Practical considerations

Humans’ perceptual modalities are not independent processes. Stimuli from one sensorial mechanism often influence the perception of stimuli in other modalities. Cues from the visual and auditory are processed simultaneously and their integration in the brain’s cerebral cortex forms our view of the world. In consequence, social robots are expected to develop similar cross-modal perceptual and integration mechanisms. The integration of the two modalities audio and visual can give the robot a better ‘understanding’ of what happens and to characterize the current context:
- In the visual domain, it could be attracted by faces (psychological research revealed humans use faces as main cue to assess person’s presence). Thus, perceiving a frontal face this could mean that the robot became the user’s focus of attention and so it could assume that the subsequent speech is addressed to it. Otherwise, the speech signal could be treated as an ‘ambiental noise’ and be ignored.
- In the audio domain, we are interested in studying prosodic aspects related with the speech, i.e. not to focus on the content of the signal, but on how the content is delivered. In other words, we are interested to study how non-verbal communication influences the robot behaviour. By the combination of the two perceptual modalities, the robot will construct associations between a particular face and its corresponding voice pattern.
Challenges:

On one hand, the robot has to organize its perceptual and behaviour systems not only to solicit interaction, but also to regulate these interactions in order to generate learning opportunities that will allow it to develop. On the other hand, it must figure a strategy how to evaluate its performance and to assess the progress made. These issues are discussed below in more detail:

- Learning process associated with the development

In a first case, learning should be online and unsupervised. The robot should start with an empty databases of people, and gradually construct new categories of persons as a result of the interactions it maintains. Unsupervised face recognition is a difficult problem in machine learning, since only partial success has been reported so far. We hope to achieve better results by exploiting the particularity of our framework. We would like to complement the unsupervised face recognition system by using spatio-temporal context to correlate pairs of face and voice sequences from the same individual to allow for multi-modal recognition. In a second case, the learning should be active. This refers a to a set of criteria that should be used in order to cope with the huge flow of audio/visual incoming information. More concrete, active learning is concerned to study things like: how to choose the next example in order to minimize the number of examples necessary to achieve a given level of performance in generalization? Or how to choose the next example so that the gain in information for the machine learner will be maximal?

- Evaluation methodology related with development

In classical machine learning, the evaluation of system’s performance was based on a measure related with the given human-defined task. However, the conventional principles and criteria, are not suitable anymore in our case, since the robot is task-independent. Although the user can still keep track of the evolution in robot’s development (progress is an observable property), what is most important now is to have defined an evaluation methodology which allows the robot to assess itself the degree of complexity achieved in its development. Thus, the ‘evaluation methodology’ is not anymore an absolute measure, but a relative one: the user and robot could have different ‘opinions’ regarding development.

Social impact:

This section tries to identify potential areas of applications which might benefit from developing social-oriented robots.

A major advantage of having cognitive developmental robotics is that they will become part of our everyday life. This will allow them to evolve and adapt in unstructured environment like homes, schools, medical clinics, etc. The relationship that will be created between persons and robots will be reciprocal in the following sense. On the one hand, the people will be able to communicate with us in their own terms, so it will be no need to possess technical abilities in order to operate them. On the other hand, the robot will not only adapt to the physical space, but it will also have to adopt the social context by learning people preferences. In consequence, the people will feel treated in a personalized way and this will make to minimize the distance between a human assistant and an artificial one. We identified two areas of applications for this technology:

- One key area would be the assistance for elderly people. Facing with the problem of a continuously growing aging population, countries like USA and Japan started social and psychological experiments in order to assess how this technology can help to improve the quality of life for old people. Preliminary results confirmed that social robotics are of great help in changing the mood or attitude in people who manifest symptoms of depression (Wada et al., 2005).
Another area would be the therapeutic treatment for autistic children. Psychological tests carried out in pediatric clinics revealed that children affected by autism have difficulties in relating with other people, but they show no fear when interacting with a robot (Yokoyama, 2002). One explanation is that they hesitate to look in the eyes of a person, but have no problem looking into a robot’s camera. Another way social robots can help children with autism is by showing a persuasive behaviour, in order to encourage them to socialize more each other. In this case, they act as mediators in human-human communication.

References:


