# Mobile robot, capable of social interaction
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## Final report

The aim of this project was to develop a mobile robot which is capable of social interaction, as well as expressing feelings and attachment behaviour using ethology-based patterns.
A future goal of the proposal is to lay the basis of etho-engineering, the new paradigm of product design. Mechanical engineers often try to find patterns in nature to be used in their mechanical constructions. Etho-engineering is different from this view since it considers the ethological function as pattern and not the mechanical construction itself. In the past few years, researchers at the Dept. of Ethology at ELTE University have developed an ethological model of attachment using behavioural patterns exhibited by dogs attached to their owners. We created a mathematical model describing the ethological model.

# Main results

**In accordance with our goals we demonstrated that MOGI ROBI (the first member of the etho-robot family) is equipped with movable mechanisms which enable the expression of emotions.** With ethologists we created an experiment for its validation in which the robot showed fear and happiness during interaction with participants, as well as guilt in another task. The robot was not allowed to topple an object that was hidden behind an occluder and the participants were asked to deduce whether the robot disobeyed the rule, based on the robot's behaviour. The 71 participants could recognize the emotions at a significant level and they also actively communicated with the robot.

*Experiment 1: Emotion Attribution in a Play Situation*
In the present observational study we investigated the effects of the emotionally expressive behaviours of a robot that were inspired by functionally analogous behaviours observed in dogs. By the means of both direct (behavioural observations) and indirect ('Robot Anthropomorphising Questionnaire') measures we wanted to study whether the non-human ways of emotion expression influenced human-robot interactions. We provided our companion robot with two kinds of emotional behaviour (joy and fear) designed on the basis of dogs' expressive behaviour (canine 'happy' and 'fearful' behaviour), and studied whether people recognized and attributed the appropriate emotion to the robot, and interacted with it accordingly.
We hypothesized that the dog-inspired expressive behaviour will be readable for humans and they will attribute the appropriate emotions to the robot. In addition, in line with the results of earlier studies we expected a lower emotion recognition rate in case of the 'fearful' emotional behaviour.
The experiment was conducted in a wizard-of-oz scenario (the participants interact with a computer system that they believe to be autonomous, but which is actually being operated by an unseen human being). For the testing we used two different-coloured balls with which MOGI Robi and the subject interacted. MOGI Robi's reaction toward the balls was one of two different kinds: preference vs. non-preference.
Preferred ball condition: When the subject took out the ball, the robot lifted its antenna and ear-like appendices, and wagged its antenna. When the subject threw/rolled the ball, the robot always approached it and brought it back to the subject.

Non-preferred ball condition: When the human took out the ball from the bag, the robot stopped moving the antenna, went closer to the ball, oriented its head towards it and suddenly lowered down its antenna and ear-like appendices, and backed. It tried to maintain as large distance from the ball as possible. When the human subject threw/rolled the ball toward the robot, it moved to the other side of the room.

*Experiment 2: Guilt Attribution Test*

Along these lines one can also assume that robots that show guilty behaviour when making mistakes would be perceived more life-like and believable as well, but it has never been examined so far if people can attribute guilt (a secondary emotion) to a robot.

In Experiment 2 we investigated whether participants tend to attribute guilty behaviour even to a non-living creature, a robot in some relevant context. The robot's behaviour was determined on the basis of the behavioural descriptions of dogs observed in similar situations. We investigated whether relying on the robot's greeting behaviour human participants could detect if the robot transgressed a predetermined rule. We hypothesized that the dog-inspired behaviour implemented in the robot will be effective in communicating guilt to the users, hence the participants will be able to detect if the robot transgressed the predetermined rule.

*Summary of results and discussion for Experiment 1 and 2*

Results of Experiment 1 showed that people readily attribute emotions to a social robot and interact with it in accordance with the expressed emotional behaviour. They played more (or exclusively) with the ball toward which MOGI Robi had previously expressed “happiness”. When we asked the subjects about an explanation of why they played more with that ball, they referred to inner states (emotion, cognition, and expressiveness) overwhelmingly. This tendency was even more explicit when we asked directly about what the difference was between MOGI Robi's reactions toward the two balls. These findings suggest that participants found the emotional behaviour of MOGI Robi quite convincing. When they had to name the emotions they experienced in MOGI Robi, the two most frequently reported emotions were the expected ones (“happiness” and “fear”). Subjects recognized “happiness” very well, especially in the forced-choice task (83.3%), but they were less successful in recognizing “fear” (47.9% in the forced-choice task), when approximately the same amount of people thought that the robot was indifferent or showed no emotion as those who said that it was fearful.

In the case of the present studies subjects reported to base their emotion-attribution mainly on MOGI Robi's expressive behaviour (body position and moving of the antenna and ear-like appendices) and its object-oriented behaviour (avoiding versus approaching the ball). This finding is in line with earlier findings on pet-owner relationships, which showed that specific features of pet animals, like expression of affection, responsiveness, or willingness to interact are especially important in forming a close relationship with their owner.

In Experiment 2 we have shown that people were able to recognize if the robot transgressed on the basis of its greeting behaviour, hence we can assume that people are able to attribute guilty behaviour to a robot. Although the robot's restricted capabilities did not allow displaying the sophisticated expression of emotional behaviours, which is shown by dogs, the manifestation of some specific behavioural features was enough to make human partners attribute the ‘guilty emotion’ to a non-humanoid robot.

**Following the working plan of the proposal we built a new member for the etho-robot family called MOGI Ethon which is capable of social interactions with humans based on ethologically inspired patterns, and can perform porter functions.** We published multiple articles in connection with its technical details.

*We introduced an optical flow based odometry solution for indoor mobile robots.* The indoor localization of mobile robots is an important issue according to the increasing mobile robot market and the needs of the industrial, service and consumer electronics sectors. The robot odometry calculated from the robot kinematics accumulates the position error caused wheel slip, but an optical flow based measurement is independent from wheel slipping so both methods have different credibility which was considered during the sensor fusion and the development. The focus of the research was to design an embedded system with high accuracy on the possibly lowest price to serve the needs of the consumer electronics sector without the need of expensive camera and real-time embedded computer based high level robot localization solutions. The universal optical flow module can be implemented in any kind of indoor mobile robot to measure the position and the orientation of the robot during the motion even in case of a 3 DoF holonomic drive like kiwi drive. The application of omnidirectional wheels in mobile robotics requires high accurate position and orientation feedback methods contrary to the differential drives. The proposed method was implemented on MOGI Ethon.

**We built a new motion laboratory, suitable for the research of attachment behaviours in order to show the uniquely new result in robotics that a robot is capable of exhibiting authentic attachment behaviours toward humans.** The first results were published at the IFAC SYROCO 2015 Conference in a keynote speech. Due to this, etho-robotics was included as a new concept in the IFAC Research agenda: current and future roles, impact and grand challenges, which is published for scientists as a guidance in every 10-15 years.
Etho-robotics is a new emerging interdisciplinary field which aims to bring together engineers who are building and programming robots and biologists who are interested in behavioural discipline. Ethology is the biological science of investigating animal and human behaviour in the natural environment. Robotics is slowly reaching a stage where autonomous behaviour and interaction with other robots or humans becomes a reality. Having “behaving” robots means that ethologists are needed both for studying human-robot interaction but also for cooperating in the design and modelling of robot behaviour. Etho-robotics claims that inter- specific interaction should provide the basis of human and robot cooperation. Accordingly, the embodiment and behavioural skills of social robots should suit their specific niche in their function and cooperation with humans.
Etho-robotics advises that robots must not be built on any pre- concept of being either human or animal-like but both the embodiment and the behaviour should be derived from the functional demand.
This means that the engineers and the ethologists have to determine together

- the actual environment in which the robot “lives”,
- the performance which is expected from the robot,
- the optimal (and simplest) embodiment and behaviour skill which is needed for successful working, and
- complexity to minimum social behaviour if the robot is working in a human (anthropogenic) environment.

The etho- robotic approach also stresses the strong functional relationship between embodiment and behaviour.

*We developed a concept for path planning of mobile robots in household environments.* The proposed algorithm takes communicative means of locomotion into account in order to facilitate human-robot interaction. The well-known traditional artificial potential field method (APF) was extended by motion characteristics of household animals. The proposed algorithm includes velocity and orientation information and can be used in unknown, dynamic environments. The main contribution of this research is the definition of an online, local path planning method by adapting animal motion attributes in order to assist human-robot interaction. The algorithm was implemented in an embedded system and evaluated on MOGI ETHON, a holonomic drive mobile robot.

# SUMMARY

Robots will undoubtedly step outside of their classic roles in the industry into workplace environments and people's homes. The new environments require new solutions for challenges that industrial robots did not have to face. Service and assistive robots will have to perform their tasks according to their functions in a dynamically changing environment and they have to be able to interact with humans in a socially acceptable way. The function of social robots and the required social competences are in many aspects similar to what roles dogs fulfil in our lives. Dogs acquired specific social skills during domestication which assisted their integration into the human social environment. Human-dog interactions can serve as models for designing the behaviour of social robots, while ethological methods can be used to examine human-robot interactions and to get feedback on the performance of the robot or the implemented behavioural model. The goal of this research was to describe some of the research topics of social robotics in which etho-robotics can play an important role. The etho-robotics approach can be used to create behavioural models such as attachment, or behaviours that help the communication and interaction between human and robot, e.g. leading behaviour or social monitoring. Animal behaviour can also serve as a model for the path planning of social robots in various contexts. This research also developed a behaviour-based structure built from Fuzzy Rule Interpolation (FRI) models and FRI automaton for handling Human-Robot Interaction (HRI) placed on ethological model basis. The suggested structure is simple and could be implemented to be quick enough to fit the requirements of direct real-time HRI applications. It is an easily built and simply adaptable structure for many application areas as an application area in user adaptive emotional and information retrieval systems). The implementation of FRI reasoning methods in HRI applications simplifies the task of fuzzy rule base creation. The FRI rule base is not needed to be complete, so it is enough to concentrate on the main control actions, or even the rules can be added simply piece by piece.

**In today's aging societies remote diagnostics obtain an increasing role. However, the aging generation can have more difficulties with the acceptance of new, complicated technical devices. Robots, designed on the basis of the new paradigm could be more acceptable for their (elder) users since they would be rather like „somebody" than „something". We did the first steps in a long way to achieve a robot which (or who) can be a loved member of a family.**

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