Enabling Embodied Interactions in Playful Environments for Animals

Abstract
The doctoral research presented in this paper focuses on the design and development of animal-centered interactive systems that enhance one of the most natural animal behaviors: play. The main goal of this research is to expand Animal Computer Interaction with the ability to learn from and adapt to the animals and humans' movements and gestures when interacting within a playful environment. This could provide more entertaining and complete activities to improve the animals’ wellbeing in several scenarios.

Author Keywords
Animal Computer Interaction; play; intelligent environment; multimodal interaction.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Play is one of the most natural and inherent behaviors among animals, and it is also a very important part of every animals’ life. It teaches them behaviors they need to acquire in their adult life. It also helps to keep their minds and bodies active, reduces stress and could be an indicator of well-being [7,12]. Research within Animal Computer Interaction [2] has shown interest in animals’ playful interactions with technology [1,10,11]. However, these interactions are mostly mediated by

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humans (either as players or as providers of the activity) and/or are focused on a specific artifact. But what happens when there are no humans around or when the animal starts to get used to the new device? With the aim of improving animals’ wellbeing, we propose the design and development of technological environments which could adapt and react to the animals’ playful interactions, or simulate humans’ playful behaviors with them, in order to create more engaging and dynamic playful activities [7]. However, animals cannot provide verbal feedback or configure themselves the system they are interacting with in order to adapt it to their preferences. As animals communicate mostly based on body language, it was decided to study their playful interactions based on their body movements, gestures or actions. For this purpose, this PhD research focuses on non-wearable tracking systems in order to account for the animals’ spontaneous behaviors and to allow for extracting information not only from the animal player but also from the rest of the environment, i.e. the context, or other participants such as human players. This knowledge would be used to adapt the features and reactions of the technological artifacts to what the animal users’ need/want.

Research Agenda
There are plenty of scenarios in which playful environments could play a role. Hence, this introduces a wide variety of factors affecting the design of the system and how it would learn and adapt: the animals’ species, its intuitive way of interacting with technology, preferred devices/interaction modalities, the place in which the system will be deployed (see side bar on this page), if there are several animals playing at the same time or if there are humans playing as well, and so on. We initially defined several features that can vary from one playful scenario to another and should be considered in the design of interactive playful activities [6,7]. We also outlined possible applications and benefits for the proposed research. This section will describe the research activities undertaken so far by the PhD student as well the studies planned for the following years before completion of the PhD degree.

Cats’ interest in technological stimuli (2014-2015)
Digital playful activities which include animals as participants should attract and maintain their attention, using suitable technological artifacts and adapting the activity to the animals’ preferences. To achieve this, the first step should be finding the best technological artifacts for a specific animal species in terms of engagement and interest, and study how animals interact with them. Being ACI a research field of recent appearance when this study took place, there was no research done in terms of animals’ preference for different technological stimuli. Moreover, there was no well-stablished methodology on how to conduct this kind of preference assessment with animals. Therefore, it was decided to conduct an observational study in which cats would be interacting freely with technological artifacts of different characteristics. The study was envisioned to cover the household context with pets, and cats were selected as the participant species [4].

Evaluation of a depth-based tracking system for cats (2015-2016)
Studying cats’ behavior during the first study allowed to envision different possibilities in which a system could be aware of a cat’s movements and behaviors to react accordingly and provide an engaging playful scenario. In order to allow for an open space of interaction and not limit the animals’ spontaneous reactions, a non-
A wearable tracking system for cats was developed [8,9]. This system works using a Microsoft Kinect sensor placed facing down from the ceiling. It makes use of the depth sensor to locate the cat, extracts features from its contour and recognizes different parts of its body (head, body and tail) as well as its posture. Recognizing the animals’ location, body parts and postures supposes the first milestone towards allowing an interactive system for animals to be aware of its context. With this information, the system could detect the cats’ posture and react accordingly. For example, it could detect when the cat is stalking a provided stimuli, e.g. a digital projection or a tangible robot, and make this element move towards the animal to trigger a chasing activity. An exhaustive evaluation of several machine learning algorithms for cats’ body parts and posture classification has also been conducted.

Design, development and evaluation of an interactive system for the zoo (2016 - ongoing)

Animals of different species behave differently and also have different physiological characteristics. The ways in which the system could extract information from their behaviors would be different, and so would be the design of an artifact capable of providing this contextual information to the system. Moreover, animals’ playful or exploratory behavior of a system would also differ from one species to another. For these reasons, a new study with a different species in a different environmental context was defined. In this study, an interactive system for orangutans in a zoo environment would be designed. For this environment, the range of elements the animals could interact with is limited in order prioritize the animals’ safety. Therefore, no new elements nor technological artifacts could be placed inside the enclosure of the orangutans. In this study, a depth-based sensor has also been used but this time the sensor will track the orangutans’ hand movements of everyday non-technological objects [5]. As digital stimuli have already been studied as technological stimuli for these animals [13], sound-based enrichment would be studied in this case attending to keepers and researchers insights on orangutans curiosity towards these stimuli [3]. The developed system would allow to study which kind of behaviors and gestures orangutans would intuitively show to interact with the system. Besides, this system could also be used to evaluate orangutans’ preference towards different auditory stimuli.

Design, development and evaluation of a playful system based on tracking for humans and animals (2016-2017)

In order to include humans as participants within these interactive playful environments, an upcoming evaluation of an interactive system based on embodied interactions for humans is being designed. In this project, humans would be able to interact and manipulate technological elements in the environment based on their body movements and gestures, either tangible or digital elements as the ones used in the observational study with cats, or auditory stimuli as in the orangutans’ sound enrichment system. These embodied interactions would give more freedom to the human participant in order to interact with, e.g., their pet, or to explore and discover different ways of interacting with the system and the animal. As done with the animal participants, the instinctive and natural movements/gestures of the human users would be studied in order to adapt the system to include these natural or preferred ways of interaction.
Learning and adaptation of the system to human/animal postures and gestures (2017-2018)
Insights from the aforementioned studies would be used to develop a prototype of a system capable of learning from the body language of human and/or animal participants and react accordingly. There are several ways in which intelligent features could be incorporated into such a playful interactive system and the design of this study is still subject of discussion. On one hand, the system could learn and extract rules/patterns about the animals’ behaviors when interacting with a specific device. It could learn which features or stimuli of the provided device are more engaging to the animal based on its reaction. For example, which movements of the device trigger chasing behaviors from cats and in which situations, or which sounds produce more interactions or more usage time by the orangutans. This could make the system more engaging over time and adapted to different animal personalities. On the other hand, human gestures and interactions when using the system with animals could be learnt. In this case, the system could replicate those interactions later on without requiring a human to be present and create an engaging playful scenario just for the animal.

Discussion topics and challenges
The research framed in the last section presents several challenges and questions worth discussing in order to increase the quality of the PhD research:

- Experimental design: with the aim of following an animal-centered approach and account for natural and spontaneous interactions, experiments including animals have to be somehow semi-controlled. Therefore, there are difficulties when gathering conclusions from observational clues or subjective measures. Even when providing tracking systems as the one designed within this research, which rely on the animals’ body language, the interpretation of these postures is sometimes questioned as not sufficiently objective or animal-centered. How to draw conclusions from this kind of experimental set ups? How to find the balance between flexibility and reliability?

- Data: working with animals has the intrinsic challenge of unpredictability. ACI researchers sometimes even have to rapidly adapt the design during the experiment to account for unexpected behaviors/situations. Together with the aforementioned issue of semi-controlled experiments, these questions can lead to lack of sufficient data. This is especially challenging when we need to build an intelligent system capable of inferring rules/patterns, as it would need sufficient data for training and testing.

- Research methodology and terminology: due to the relatively recent appearance of ACI as a research discipline, it is sometimes challenging to coin the research within a specific methodology and terminology. These are well-established within the HCI community but usually cannot be extrapolated directly to ACI as animals cannot intervene in the design process as explicitly as a human would do. Such is the case of participatory design, and how to justify the participation of the animal in the design without verbally intervene or objectively assessing its contribution to the process. Should we therefore redefine these terms and formally define proper ACI methodologies? Should we instead try to broaden the applicability of certain terminologies to include what
could be considered an animal's participation in the design process?

- Intelligence: the intelligent features of the final prototype still need to be defined, balancing the required time to design and build the system and the ability to demonstrate the feasibility of learning and applying such intelligence. Are there any other interesting scenarios in which the use of learnt behavioral patterns could be applied?

**Conclusion**

The proposed PhD research aims to cover several contexts in which learning and adapting to the participants' playful interactions could improve animals' wellbeing. For this purpose, the research comprises studies of different animal species, contexts and interaction modalities, and also studies the contribution and participation of humans within the playful activity. This would allow to have an overview of the applications, limitations and requirements of these systems and how they should be designed, which could be drawn as a framework or design guidelines. Finally, a prototype of a system capable of learning and adapting the playful activity would be evaluated.

**Related Works**


