A Robot in a Cage

Exploring Interactions between Animals and Robots.

Marc Böhlen
School of Art, The Robotics Institute, Carnegie Mellon University, Pittsburgh Pa
bohlen@cs.cmu.edu

Abstract

Typically, the animal world has been used conceptually by roboticists as a source of inspiration for finding new approaches to efficient locomotion, perception and intelligent control [Brooks91], [Hallam, Walker93], [Aloimonos97]. This paper explores the question of designing a robot to share a space with a simple animal. A series of experiments between a mobile robot and three chickens in a cage are described. Techniques are described to mechanically reduce chickens' anxiety towards moving machinery. A model of interaction between animals and machines is proposed. These insights are then placed into a wider context of robot design.

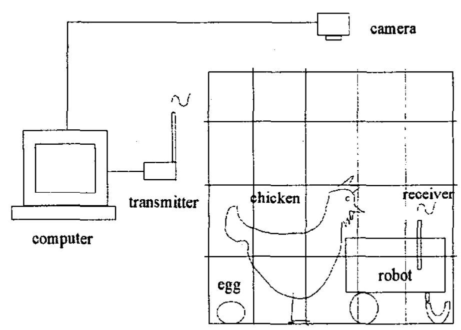
Introduction

While the interaction between human beings and machinery, in particular computers (HCI) has received much attention in the past, animal-machine interaction has not. The reasons are obvious. Why would one care? Furthermore, it is difficult to assess how animals perceive things in general, let alone machinery. While the question may be difficult to answer, there could be promising insights on both a theoretical and a practical level. On a theoretical level, one might want to know how simple animals perceive a non-animated object that can move autonomously. Simple animals understand motion as synonymous with life, and a moving but inanimate object constitutes a novel entity in their world. On a practical level, one might like to find design specifications that facilitate the introduction of mobile machinery into industrialized farms, for example.

Design Choices

Obviously, the ideas depicted above can not be answered in the abstract. In order to control the complexities of the problem, the following decisions were made. Chickens were chosen as experimental animals as they are neurologically comparatively simple [Rogers95], cheap and fairly easily maintained in a laboratory setting.[1] A mobile robot was chosen as a representative of machinery in general.

The implementation of the design choices proceeded as follows: Three Rhode Island Red chickens and a rugged, can-style (10 in. diameter), custom made mobile robot shared a 6x6ft calcium-sand cage during 60 days. Communication was maintained with the robot through radio modems. Feedback was maintained by a camera mounted directly above the cage. Figure 1 shows a diagram of the experimental setup.



Overview of Installation

Fig. 1

Figure 2 shows a flow diagram of the system components. The first step is the acquisition of an image by the camera. This information is fed into the image analysis module that discerns whether a found blob is a chicken or the robot. The arbitration module decides what the chickens are doing. The architecture module maps a robot action to the observed chicken action. The communication

[1] The project has been approved by Carnegie Mellon's Research Evaluation Committee with the identification number A3352-01.

module, finally, sends the appropriate instructions through the radio-modem to the robot.

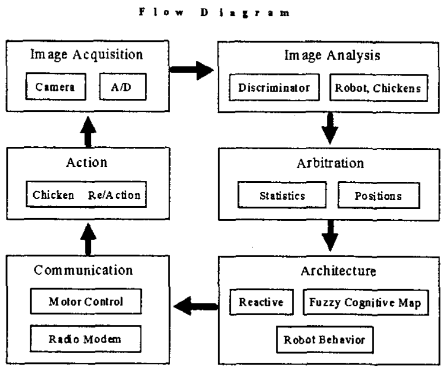


Fig. 2

Navigation

The goal of the navigation routines contained in the action and arbitration modules was to (1) be able to keep track of the robot's position at all times, (2) travel to any specified location in the cage, (3) travel a specified distance, (4) stop within a critical distance of the border of the cage, (5) be able to navigate on a slippery terrain, (e.g. full of chicken droppings), (6) avoid bumping into chickens, and (7) recover from a 'lost' state, should it occur. Direction and distance were calculated by maintaining state of the robot over two subsequent images, making use of the differences in x and y positions. With a lag of about 150ms between an issued command in the navigation module and the reaction of the robot, the machine was able to stop to within 1.5 inches of a specified position. One difficulty was given by the partially slippery terrain. Feed, water and chicken droppings created an adverse environment for the robot. Random spots of low friction (chicken droppings) in the cage made it impossible to use dead reckoning to navigate the robot. Instead a scheme was implemented by which the position of the robot was compared with the desired position at every instant and corrections were issued according to the progress the robot made in reaching the specified goal. Effectively, this is a servoing technique, using a captured image as feedback, and is referred to as *visual servoing*

Image Analysis

Each acquired image was subjected to a blob analysis[2]. In order to discriminate between chicken blobs and the robot blob, filters were applied to each image.

The robot filter contained min-max specifications of blob size (area), mean pixel value and aspect ratio. The chicken filter contained the parameters blob size and mean pixel value only. Aspect ratio could not be applied to the chickens as it varied with their activities. Size was problematic as fluffed-up, resting chickens appeared to be much larger that standing, feeding birds. If the first filter could not find three chickens, a second filter was called with widened parameter specs. Finding the chickens was a much more error prone task than finding the robot. As the animals were mostly in moderate motion, a 'lost' chicken was generally found in the subsequent image.

Arbitration

Once all the chickens could be reliably found, it was necessary to infer *significance* from the position coordinates of the chickens. While the positions of the chickens and the robot were recorded continuously, only a subset of this information was passed onto the architecture module. An important step in this design process was attributing different degrees of significance to different kinds of observation. The positions that passed through this filter were considered *significant positions*.

The first type of significant position was that of a *meaningful position*. For example, it was considered meaningful if the chickens were very close to the robot at any time. The complete set of meaningful positions is: (1) At Robot Home, (2) Close to Robot, (3) By Food Source[3].

To this set of information was added a set of *relational positions*. It included results that indicated whether (1) the chickens were separated out within the cage or (2) all in a group. The last set of positional information was that of *activity*. It

[2] The blob analysis consisted of (1) sharpening the image by convolution with a Sobel filter, (2) thresholding the result and (3) finding the areas of continuous values by growth regions.

[3] The robot home was defined as the origin of the coordinate system and the food source was located in quadrant III.

discerned whether the chickens were (1) feeding or (2) at rest.

Mapping

This sub-module (of the architecture module) was designed to map the observations made in the chicken world to that of the robot world.

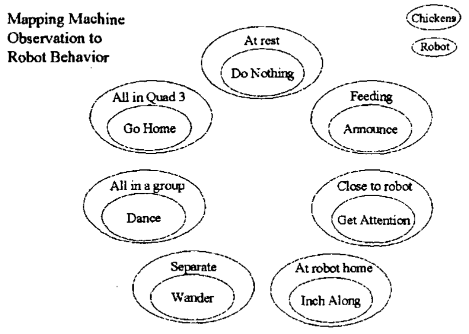


Fig. 3

The mapping concept is based on *mimicking* the chicken behaviors and on *reacting* to them. If, for example, the chickens were found to be at rest, the robot would rest as well. If, however, the chickens were found to be close to the robot, the machine would attempt to get the chickens attention. Figure 3 shows the complete set of correspondences between the chicken world and the robot actions.

Architecture

The architecture module governs the way the correspondences between the chicken world and the robot are activated. It has two modes of operation. One is a reactive system and the other is a fuzzy cognitive map. The reactive system is directly derived from the mapping described in the previous paragraph. It contains, additionally, procedures to prevent sustained activation of a single node and includes error recovery algorithms.

Figure 4 shows the FCM nodes of the robot actions. A circular transition from low activity actions (*Do Nothing*) to high activity actions (*Wander*) is enforced by strong connections along the nodes. Additionally, intermediately weighted connections, back to the rest state allow for a variety of node sequences. A single negative connection between the nodes *Dance* and *Go Home* adds complexity to higher activity levels.

It is well known that FCMs pose a number of problems to the designer [Kosko97]. First, one must devise appropriate connections and second find appropriate weights for them. The first

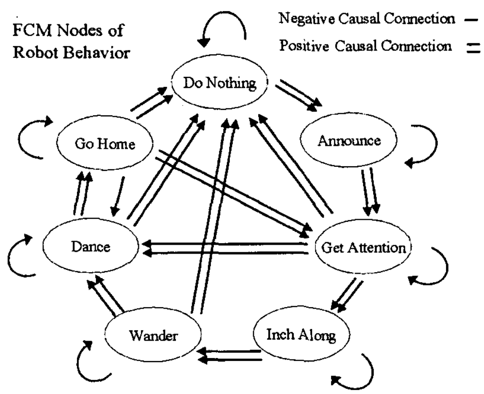


Fig. 4

point is a question of intention. For a clearly defined task such as an environment control scheme, the connections may be very clear. For an interaction scheme such as the one devised between the robot and the chickens it is not. The goal was the design of time-varying, interesting and non-threatening interactions between the robot and the chickens. All connections were chosen to enforce this goal.

The setting of the connecting weights is more problematic. It is presently accepted practice for simple FCMs to use a trail and error based approach of finding the node-connecting weights. This is the approach used for the present design of the Animal-Machine Interaction FCM.

Experiments in Animal-Machine Interaction

The first goal of the animal-robot experiments was to create an environment in which the chickens would share a space with the machine and feel comfortable enough to go about their activities without being threatened.

The chickens were put into the new cage for three days prior to any kind of exposure to the robot. After this initiating period, the aluminum top of the robot was placed into the cage. The chickens were mainly indifferent to it, but did peck at it intermittently. Only after the animals showed no sign of anxiety towards the top hat of the machine was the complete and mobile robot introduced into the cage.

The first day of interaction with the mobile robot was marked by anxiety on part of the chickens. Figure 5 shows the chickens huddling in a corner one hour after the robot moved towards

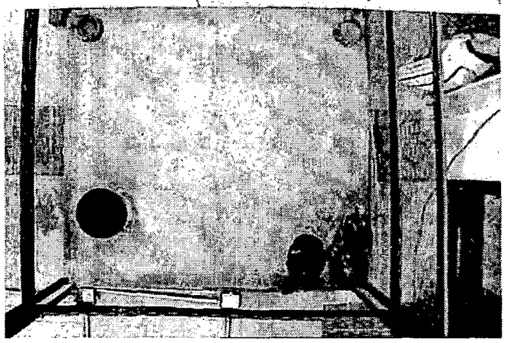


Fig. 5

them for the first time. The animals remained in the corner, afraid of an object that had moved even after it stopped moving. This is interesting as it confirmed that chickens are confused by the presence of a robotic machine. Apparently, they initially perceive an autonomously moving device as a danger of some sort. It is not clear if they believed the robot to be alive, whether they perceived it as an unknown animal or not. The robot was purposely designed *not* to resemble any kind of animal the chickens might have seen. The reaction was nonetheless clear. The chickens absolutely avoided the machine for an extended period.

On the second day, the chickens still maintained distance to the robot at all times, but were not uncomfortable to the point that they would not peck or search for food. This changed, however, once the robot began to move about. All movements on part of the robot made the animals nervous. They actively avoided the machine when it approached them. This behavior continued throughout the next day.

In order to attempt to reduce the anxiety of the chickens towards the robot a number of small experiments were performed. It was not quite clear what exactly the chickens were afraid of. In order to test whether the sound of the servo motors was the source of annoyance, the following experiment was performed: The robot was placed in the cage and the motors were powered with short pulses, at first to move the robot only a fraction of an inch, later with no apparent motion at all. The sound of the servos caught the animals attention immediately. They showed no fear towards the machine as it emitted sound but did not move. This was a surprising result. The next step, then, was to use this fact to reduce the anxiety towards the onset of motion. The servos were pulsed as before, and after a short pause the robot was commanded to move. Interestingly, the birds were not afraid of robot motion under this condition. It appeared that the initial sound of the servos caught their attention and that once they directed their attention to the sound source, the onset of motion itself was not perceived as threatening. The solution, thus, was to have the robot *announce* itself.

Once it was clear that one could counteract the innate fear of the chickens towards a moving machine, the *announce* solution was made the initial element of various kinds of robot motion. It preceded the *Inch Along* mode, the *Wander* mode and the *Go Home* mode. With this 'trick' it was possible to build a set of robot behaviors to which the chickens showed no anxiety.

Robot Behaviors

The robot behaviors consisted of a set of seven named movement patterns. (1) *Do Nothing* ensured the robot is quiet and at rest. (2) *Announce,* described in detail above, made the robot audibly perceptible to the chickens. (3) *Get Attention* subtly alerted the chickens with a flashing set of red and green LEDs and small rhythmic movements.
(4) *Inch Along* was a linear motion mimicking the jerky walk of chickens, and (5) *Wander* a random walk around the cage. (6) *Dance* was a series of rhythmic and circular movements invoked when the chickens approached the robot and remained very close to it. (7) *Go Home* made the robot return to its defined home base in the lower left corner of the cage.

The Reactive versus the FCM Mode

The rationale for choosing these two architectures is as follows. The reactive model is a simple and robust way of testing the chickens responses to various isolated robot actions. It allows the animals to have a direct effect on what the machine does. The advantage of the FCM architecture over the reactive architecture lies in the possibility of including previous interactions into the decision scheme of the next action. Given identical observations, an FCM based architecture can generate both more cohesive and more varied node excitations, depending on the chosen connections. The reactive model is a single-shoot solution. Each

observation leads to one and only one action, possibly repeating itself indefinitely over time.
In the reactive model a single action or motion is executed and the robot returns to the rest state resulting in a staccato behavior over time. In the FCM model, a smooth transition between actions is achieved. *Announce* can lead directly to *Get Attention* and then to a motion of higher intensity such as *Inch Along* without falling to low intensity *Do Nothing* in-between. Furthermore intermediate states of action can be activated without a corresponding observation. *Dance*, for example is not an input node in the FCM, but can be activated, over time, once enough energy flows into that node by virtue of the weighted connections.

AMI

Both the reactive architecture and the FCM enabled forms of interactions between the robot and the chickens. For convenience, these shall be termed *Animal-Machine Interactions* (AMI). AMI was enhanced by the intention to make the chickens comfortable in the presence of the robot. This was implemented on two levels. (1) As described above, the behavior primitives were designed to reduce the inherent anxiety the animals had towards a moving machine. (2) Additionally, the robot behaviors were enhanced to include 'politeness' towards the animals. The interaction model was one of *partial hierarchy*. This idea is best explained by examples.

When the robot approached a chicken it stopped and waited for the animal to move out of its path. If the chicken did not move within a few seconds, the robot would attempt to continue in its path, but stop again if the chicken had not moved. If the robot moved backwards, it did not care whether there was a chicken behind it. The animals realized this and moved out of the way of the reversing robot more readily than when the robot approached them frontally. Furthermore, the robot never placed itself for an extended time on top of the food source of the chickens. That particular location was 'out of bounds' for the robot. This was an attempt to effectively acknowledge a preferred territory of the chickens. With these enhancements, the previously neutral interactions acquired a flavor of *polite exchange* between the machine and the animals over time. For lack of a better term, this enhanced form of interaction shall be termed *Cohabitation*.

Cohabitation

After 5 days, the chickens became quite comfortable in the presence of the robot and cleaned their feathers while crouching right by the robot. Figure 6 shows a typical scenario towards the end of the adaptation period. If the robot maintained distance to the chickens, they effectively accepted its presence. Cohabitation was the result of successful AMI as described above. The chickens achieved this state after about 10 days of AMI.

Experimental Results

The experiments began on February 15 and ended on April 10, 1999. Comparative experiments were performed during four weeks. The Reactive model ran during this period for a total of approximately 80 hours and the FCM model for about 60 hours. The following qualitative conclusions are based on recorded video documentation acquired during this time.

(1) It is possible to mechanically reduce the anxiety of a chicken towards a mobile robot. This can be achieved by the following means:

- Announce the intent to engage movement. Do this by either a small meaningless motion followed by a pause or simply an audible sound. Once the chickens direct their attention to the robot, the commencement of continuos motion is perceived as non-threatening.
- Never move faster than the average speed of the chickens. Speeds approaching their own speed of flight are perceived as highly threatening.
- Pause if the chickens approach the machine or if the machine moves too close to the animals.
- Avoid acceleration. All motion should be continuous.

Fig. 6

(2) It is possible to additionally enhance the interactions between the robot and the chickens by implementing a *partial, polite hierarchy* between the participants and choosing an appropriate architecture.

Interestingly, the FCM did not bring about richer interactions than the reactive module. Certainly, the FCM could be further refined to add depth and variation to the sequence of robot actions. Chickens have keen perceptional modalities but they do live up to their reputation of being simple animals. The FCM may have overextended their capacities. However, an increased complexity in their behaviors is observable in feed related activities. Had the robot had a feed dispenser and used it to 'reward' or tease the chickens on occasion, the chickens might have paid more attention to the details of the robot's behaviors.

The merit of the *announce* feature deserves a few comments. While it was clearly effective in reducing the amount of time required in making the chickens feel at ease in the presence of the moving machine, it was of little significance once the chickens accepted the robot in their world. At that point, even uninitiated movements were not perceived as threatening, provided they adhered to the other rules mentioned above. The chickens could simply get used to the robot over time. Unquestionable, however, is the fact that the *announce* feature reduced the time required to achieve this comfort zone.

After 40 days, a new chicken, from the same farm, was introduced into the cage. While it, too, initially showed anxiety towards the robot, the ease with which the other chickens interacted with the machine appears to have assisted the new bird in more readily accepting the presence of the robot.

Conclusions

The experiments in AMI described above show the following points.

(1) A mobile robot can be designed to accommodate the innate anxieties chickens have towards moving machinery *(announce-mode).*

(2) A necessary condition for achieving this goal is to observe and honor the particular habits of the animals, e.g. feeding preferences *(polite hierarchy).*

(3) Chickens will go about their regular habits with the robot in their vicinity if they perceive the robot as non-threatening *(non-threatening behaviors).*

Future Work: Site Specific Robotics

The experiments described above show a machine as a mostly reactive entity amongst simple animals. As opposed to a machine that is tolerated, it would be interesting to attempt to infiltrate the social structure of the chickens and, for example, control the pecking order amongst them. Additionally, schemes including learning and (temporal) planning could be included.

Finally, the experiments show the possibilities and constraints given by a *situated* robot [Brooks 90] in a *specific* location. The lesson is that the locus and particularities of a site of deployment of a robot are significant both for a good design and for interesting and intelligent interactions with the world. A similar concept holds in art theory, where *site specific sculpture* is understood as artwork that is particular to a place and a situation in which it is set. This work points to lessons that can be learned not from a simulated and not from an abstractly situated, but from a *site specifically located robot.*

Acknowledgements

This work was supported in part by the Art Department of Carnegie Mellon University, the Robotics Institute and the System's Group. Support from Matt Mason, Illah Nourbakhsh and Bryan Rogers made this project possible.

References

[Aloimonos97] Aloimonos, Y. Visual Navigation. From Biological Systems to Unmanned Ground Vehicles. Lawrence Erlbaum Associates, 1997.

[Brooks91]Brooks, Rodney A. "Intelligence Without Reason", MIT AI Lab Memo 1293, 1991.

[Brooks90]Brooks, R. A., "Elephants Don't Play Chess," Robotics and Autonomous Systems Vol. 6, 1990, pp. 3--15.

[Kosko97] Kosko, B. Fuzzy Engineering. Simon & Schuster, 1997.

[Hallam, Walker93] Ashley Walker, John Hallam and David Willshaw, "Bee-havior in a Mobile Robot: The Construction of a Self-Organized Cognitive Map and its use in Robot Navigation within a Complex, Natural Environment", IEEE International Conference on Neural Networks, San Francisco, 1993.

[Rogers95] Rogers, L. The Development of Brain and Behavior in the Chicken. Cab International, 1995.