Advanced Perception *(draft version)*

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Advanced Perception is an exploration of the unquestioned epistemological bias towards the eye and the integrative act of multi-modal perception. *Advanced Perception* is furthermore an experiment in creating a technology and an ethics by which to use it simultaneously. The piece is comprised of three parts: a performance of animal-machine cohabitation with an application of kind surveillance, a set of experiments pondering intricacies of the human visual system and a tasting of omelets prepared by a chef. The performance itself took place on April 10th 1999 from 7 to 9 PM at the Associated Artists of Pittsburgh gallery in downtown Pittsburgh. A hostess handed out a menu with a list of the events and a diagram of the installation.

This text is organized as follows: First, notes on the philosophical basis of vision technologies, then on computational vision, then on vision within power structures, on the tool set developed to test the idea of cohabitation, on the performance, and finally notes on definitions of the key terms: *Kind Surveillance, Good Taste, Animal-Machine Interaction, Cohabitation, Site Specific Robotics and Tethics.*

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There is a history of, and a discourse on, the art of seeing. Enlightenment philosophers relied heavily on references to the sun, daylight, twilight, clarity, insight and blindness, reflection, speculation and enlightenment as being suggestive of distinct positions and logical roles along the path of knowledge. This knowledge was believed to begin with the immediate vision of sense certainty and end with the absolute vision of speculative thought. The dominance of the theory of vision in the 17th century paralleled advances in the science of seeing: The microscope opened the realm of the miniature and the telescope that of the remote. Thinkers were also doers: Spinoza made his living as a lens maker.

Unlike earlier epochs, our present vision technologies have no declared philosophical basis. In this lack of a base, they take on the guise of the obvious and connect to enlightenment philosophy. One can argue that vision technology is entrenched in conceptually bankrupt ideas of visual innocence. The story of course is more complex. The recent history of vision is part of and linked to the history of computation. Spectacular advances in vision technology of the last three decades are based on an understanding of human vision as an information-processing task.

Computational Vision

The development of a computational approach to vision has an early focal point in David Marr. The discussion that follows is based on his landmark investigative work *Vision*[1].

Marr understands vision as comprised of two distinct parts: representation and information processing. Contrary to the simplicity of his program is the scope of his investigation. All aspects of the visual should, according to Marr, be explained by this approach. Marr's initial approach is an extension of the school of representational theory of mind. Earlier, psychologists of perception tried to formulate 'laws' of perception based on the work of Helmholtz and later the Gestalt school. In the 1960s, Julesz devised computer generated dot patterns that appear random when viewed monocularly but fuse when seen stereoscopically to give a percept of shapes and surfaces with a clear three-dimensional structure[2]. From this and similar experiments it became clear that the analysis of stereoscopic motion could be performed without additional (physical) information. Such results were seen as indicators that the study of perception could be subdivided into specialized parts and treated separately.

Parallel to these findings were the reductionist neurophysiological experiments of Barlow and others. These showed that the activity of a signal nerve cell and its response is a complete enough description for a functional understanding of the nervous system. There is, they believed, nothing else "looking at" or controlling this activity. Truth was believed to be neural. Initial enthusiasm toward these findings soon abated. Other, simpler scenarios than those of the real world were scrutinized in the hope that the results from the "toy world of white blocks" could be generalized to richer environments. With some notable exceptions[3], the results were

[1] [Marr82]
[2] The illusion is caused by the stereo disparity between matching elements in the images presented to each eye.
[3] Horn's work on shape from shading (1975).

disappointing. But one message was clear: There must exist a way to analyze the information processing tasks carried out during perception independent of the particular mechanisms and structures that implement them in our minds.

Marr and Poggio next formulated vision as a rigorous information-processing task. This made it possible to make explicit statements about what is being computed and to construct theories on optimality and functionality, with the adhoc element removed. The science of vision became a three-part practice: The study of representation, the study of description or algorithm and the study of hardware (neurons or computer) implementation (*machine vision*). Neuro-anatomy, psychophysics and computation theory contributed to a new understanding of the visual process[4]. The result was spectacular success in the development of vision technologies. The ability to infer shape from shading, shape from motion, to recognize texture and faces and to compute depth from stereo have given machine vision access to applications previously believed to be untouchable by automation.

Machine Vision and Human Vision

Vision by machines differs fundamentally from vision of humans. For a computer, visual information must be transformed into a data set, a matrix of digital values[5]. As opposed to human vision, which can be selective while looking, a computer must (first) belabor a complete matrix, which may contain only a small section of interest. Most vision analysis tools consist of mathematical operations, for example convolution (filtering and sharpening) and thresholding (edge detection). Unlike human vision, machine vision must separate acquisition from cognition. New results from cognitive science suggest that in humans, cognition and understanding begin even before the signal is accessible in the brain. Our eyes are ‘hardwired’ to perceive certain stimuli more readily than others[6].

Machine vision is a general purpose, sequential model of the complex and interdependent elements of human vision. This approach is justified by the difficulty in finding a

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[4] The stringency of this approach masks a basic but debatable point of departure, that of assuming a form of (artificial) vision modeled after the human vision system.

[5] An analog video signal is converted to a digital signal, typically (for color images) 3 by 480 by 640 pixels. Dedicated hardware can achieve in excess of 30 frames/second conversion rates. This is fast enough to convincingly display continuous motion.

[6] This is also true for frogs that are particularly sensitive to ‘black dots’ (flies) passing through their field of vision. For more info see [Marr p12ff], [Lettvin59] and [Aloimonos97, p.6ff].

working alternative. Why, though, should a machine be designed to ‘see’ as a human? The rationale is that human vision is highly specialized and close to optimal. Why not learn from nature’s most successful example? Initially this approach was proven correct by the success with which mathematical operations seemed able to ‘mimic’ some the fundamental operations of the human visual process, such as detecting boundaries and edges. The Laplacian of the Gaussian[7] and its engineering approximation, the difference of two Gaussian filters can produce very similar results as the ganglion cells of the human retina.[8]

Solutions in machine vision are often application specific. While a human can seamlessly move from scanning text, viewing scenery and watching a moving object, vision algorithms for medicinal applications are not useful in navigational systems. The adhoc element of machine vision has been removed from the computational model (based on Marr), but the effectiveness of many machine vision solutions is often dependent on application specific parameters. The general-purpose machine eye does not yet exist.

Vision within Power Structures

The scientific vision community has invested little energy in formulating a philosophical or ethical framework for its endeavor. The problem of (artificial) vision is understood to be relevant because it is unsolved, difficult and promises great payoffs. This lack of conceptual, philosophical groundwork is typical of contemporary scientific practice. The rationale for the work is generally taken for granted. This void is an invitation for critiques of science. Historians of science such as Kuhn and Feyerabend have shown that each era has its own flavor of scientifically accredited truths and that these truths can, and often do, change over time. Our understanding and appreciation of (visual) perception has a history. The general discomfort with being observed is a historical consequence of the use of observation techniques. There is, so to speak, a particular flavor to surveillance.

[7] The Laplacian of the Gaussian is the second spatial derivative of a two-dimensional Gaussian (“Bell”) distribution.
[8] [Marr 82, p 62f.]

To Observe and to Discipline: Surveillance

There is pleasure in observation. Simply watching an object and paying attention to unassuming details is pleasurable. While there is no threat in a simple gaze, seeing others without being seen generates a knowledge gradient in favor of the seer. The non-consensual gaze can be manipulative as it can provide power over the unassuming observed person.

For Foucault, surveillance is a form of disciplinary control - a disciplinary gaze. In his attempt to write a history of the western idea of punishment,[9] Foucault describes surveillance as a perfect apparatus that makes it possible for " *a single gaze to see everything constantly*" [10].

The first effective tools of surveillance were architectural, crude, but efficient. A classic example of an architecture built not only to be seen but to also to see, is Bentham's Panopticum: An annular building whose central tower, pierced with windows that open to the courtyard. The periphec building is divided into cells, each of which extends the whole width of the building. Each end of the cells has a window. One allows the prisoner to be seen from the central tower and the other allows enough daylight to enter the cell to render the prisoner observable in backlighting. The Panopticum collapsed the three principles of the dungeon (enclosure, light deprivation and hiding) while maintaining the dungeon's principal goal: to contain and to control.

With non-architectural surveillance, the element of direct containment falls out of the equation, while the goal, control, remains unaltered. In a society with omnipresent control powers (police), the physical act of "capturing" an "identified" suspect becomes arbitrarily easy. Video technology has shifted the focus of the panoptic concept from containment to observation and identification. With improved observation techniques, a mere snapshot of a face can suffice for identification. The camera's gaze is no longer seen as innocent, but loaded with the potentiality of its (mis)use.

[9] [Foucault75]
[10] [Foucault75, p. 173]

The Rational for "Advanced Perception"

Along with other French critical theorists, Foucault saw bad times ahead for humanity given the uncontrolled advances of technology. 'Advanced Perception' takes a non-dogmatic stand towards technology. By integrating surveillance into a critique of surveillance, 'Advanced Perception' generates a meta-level discussion on human, animal and machine perception. The eclectic project is designed as follows:

Three chickens were kept in generously spaced captivity with a mobile robot and the eggs of the chickens were collected. On performance night a flashy chef, a *Cutter of Herbs* and a *Squeezer of Juices* prepared omelets from the eggs. Guests were invited to test and taste the work. Mr. Rudy Stanish,[11] master chef, prepared the products of this animal-machine cohabitation. The Squeezer of Juices, a professor of philosophy, incognito[12], had the task to seed discussion on perception with random guests on any level of detail. Two video monitors were deployed to opposite sides of the cage. One showed a documentary history of the interaction between the robot and chickens. The other showed a series of experiments on ambiguity of motion and our visual system's use of perceptual grouping.[13] In the back of the exhibit space were a series of documents and notes on work oddly related to the present installation.

Chickens in Experiments

Animals have been employed in art shows on numerous occasions. "[14]. Although chickens are generally considered to be dumb, dirty and good for nothing else than a cheap source of food, they have beaten humans at specially designed tic-tac-toe games[15]. Chickens are subjected to severe mechanization and experience the consequences of food industrialization from its ugliest perspective.

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[11] Rudy Stanish, age 86, has prepared omelets for Rene Magritte, John F. Kennedy, Paul Mellon and Bill Gates.
[12] Rick Grush, assistant Professor of Philosophy at the University of Pittsburgh.
[13] See http://www-bcs.mit.edu/people/yweiss/ellipse.html
In his thesis, Weiss shows that a single model can account for a wide number of percepts. This model is based on two assumptions: (1) a likelihood term that assumes that the image measurements may be noisy and (2) a prior term that favors *slow and smooth velocity fields*. He calculates the velocity field that maximizes the posterior probability and compares this prediction to the precept of human observers. Weiss finds that the Bayesian estimator usually predicts the psychophysical results.
[14] Recently (1996), Eduardo Kac used two turkeys in "Ornitorrinco ". See http://www.ekac.org/Uirapuru.html
[15] [Trillin99]

While the question of interaction between humans and machines has been recognized as a research topic, that of animal-machine interaction has not (yet). If 'Advanced Perception' attempts to formulate such an interaction, the goal is not increased efficiency. One premise of this experiment is that the design of machinery can be modified to accommodate anxieties that animals have towards machinery. For simple animals such as chickens, a moving object is a live object. To design a robot that 'lives' in their space and participates in their actions is equivalent to incorporating a low-level alternate life form into their world. How should such a machine behave? Can a mobile robot be perceived as non-threatening by a simple animal?

Chicken Visual Perception

Chickens are well adapted to their environment. Their visual system consists of pattern discrimination and color vision. With an isthmo-optic visual system, chickens are able to focus on moving stimuli, particularly erratic jittery motions[16], enabling them to rapidly detect living food. Their visual sensitivity is heightened in darker areas. An insect scurrying into a dark region for safety is clearly visible to chickens. Chickens have a ramped cornea that allows stimuli to be in focus frontally at short distance (while pecking at the ground) and at the same time at a long distance in the monocular lateral field. Hence, while the chicken is feeding its peripheral vision can detect the approach of predators from the side or behind. With their laterally placed eyes, chickens have in-focus panoramic vision of the ground at multiple distances. Chickens can accommodate each eye independently in the lateral field and to a lesser degree in the frontal field of vision[17]. Furthermore, they can move their eyes independently.

Chickens also have good audio perception and effective sensor fusion. While they are neurologically not complex creatures their sensory organs are more advanced than the most sophisticated robots to date.

[16] [Rogers95 p. 102ff]
[17] [Rogers95, p. 104]

Tool Set

In order to address these questions a custom-made hard- and software environment was created. The hardware consists of a 6x6 ft chicken pen with a calcium-sand floor, a ½ inch color single chip CCD camera, a framegrabber card, a set of radio modems and a small homemade mobile robot. (See figures 1 and 2.)

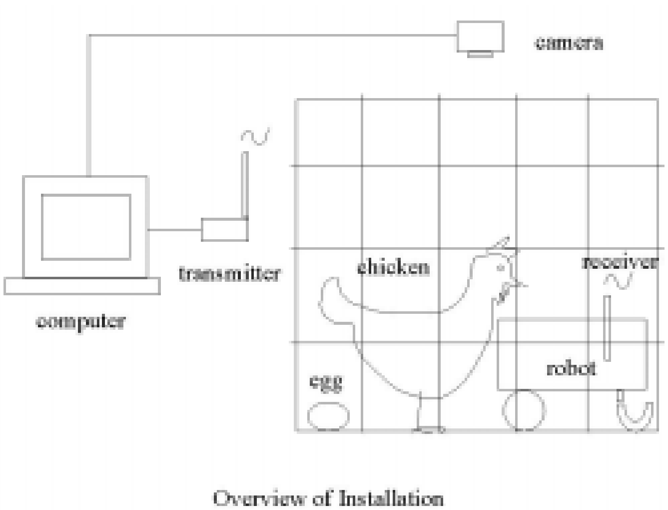


Fig 1.

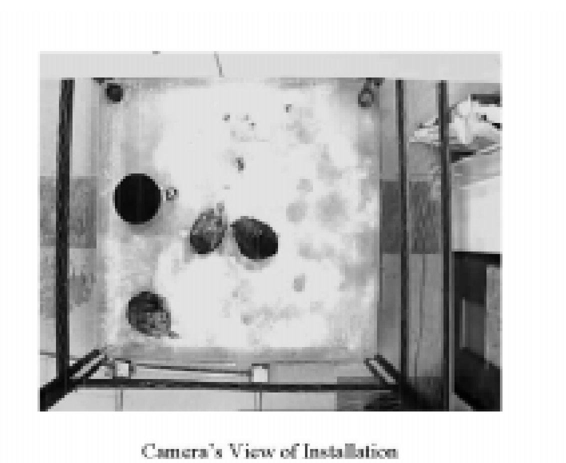


Fig. 2

The chicken dropping resistant, rugged mobile robot has two high torque servomotors for propulsion and direction and a caster designed to allow maneuvering on a dirty sand floor. It has a plexiglas frame, an aluminum shell and black felt top (Fig. 3) clearly discernable to the vision system positioned directly above the center of the cage.

Fig. 3

The software consists of four main elements:

- *Image acquisition and analysis module*
- *Information arbitration module*
- *Architecture module*
- *Communication and action modul*e

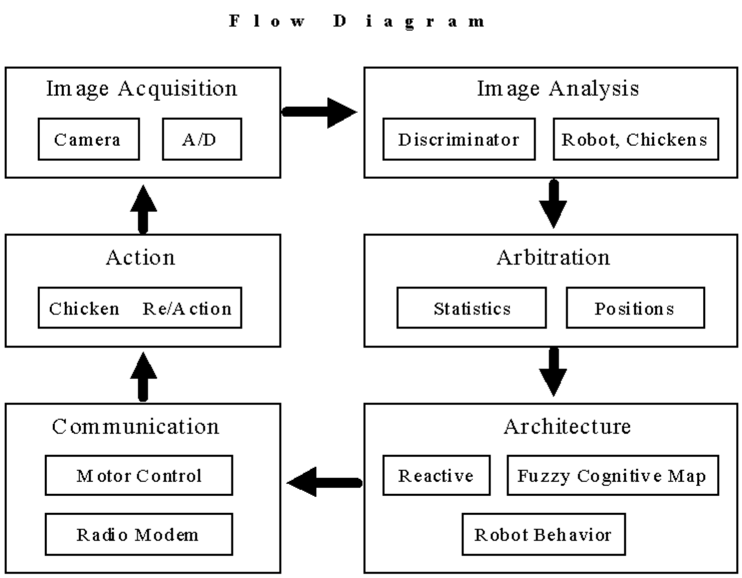


Fig. 4

The image analysis module sets a calibration and defines a region of visual interest before applying a set of blob analyses to find the robot and the chickens. Discriminating features are blob size, mean pixel value and aspect ratio (Fig. 5). This module returns calibrated centers of mass to the arbitration module.

The arbitration module gets three sets of this information and calculates a number of statistics (such as the mean position of the group of chickens) to discern what the robot and the chickens are doing in the cage. It discerns whether the chickens are at rest, in a group or separate, wandering around, feeding or close to the robot (Fig. 6).

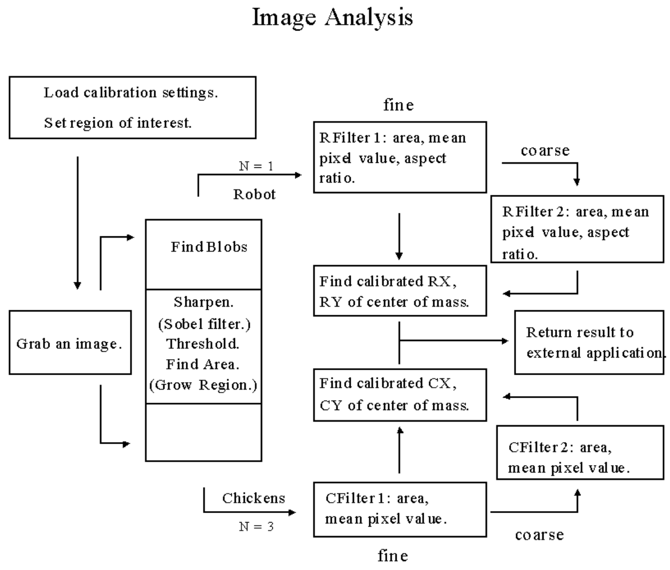
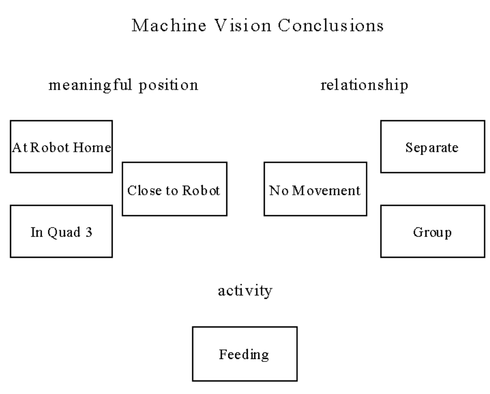


Fig. 5

The robot behaviors consist of a set of a set of seven named movement patterns. *Do-nothing* ensures the robot is quiet and at rest. *Announce* makes the robot audibly perceptible to the chickens. *Get attention* subtly alerts the chickens with a flashing set of red and green LEDs and small rhythmic movements. *Go home* makes the robot return to its defined home base in the lower left corner of the cage. *Dance* is a series of rhythmic and circular movements. *Inch along* is a linear motion mimicking the jerky walk of chickens and *Wander* is a random walk around the cage.



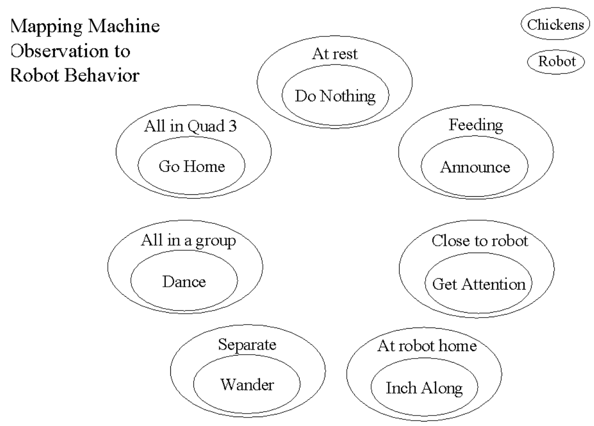


Fig. 6

Fig. 7

The architecture module defines the relationship between perceived chicken behaviors and intended robot movements. It has two modes. One mode is simply reactive, (Fig. 7) the other includes a fuzzy cognitive map to include previous actions of the robot and chickens in deciding the next movement (Fig 8). In both cases, there is a subjective choice as to which perceived chicken action should correspond or be linked to which robot activity. The action module sends these results via radio modem to the robot, which continuously executes them. Feedback is maintained by the vision system.

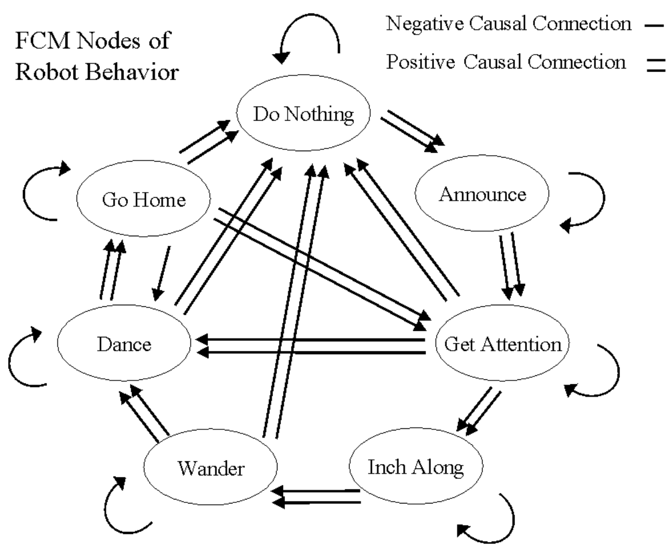


Fig. 8

Kind Surveillance

Kind surveillance is a kindly manipulative form of surveillance. This type of observation uses the same techniques of information acquisition as conventional surveillance, but does not impress a malicious hierarchy upon the observed. While there is no way to prevent a knowledge gradient when knowledge is acquired, the information is not used to impose constraints upon the observed. This is achieved by attempting to increase the comfort zone for the observed through the knowledge obtained. In the worst case scenario, kind surveillance is a neutral gaze and the gathered information is discarded. Kind surveillance is a case in point that the use of a technology alone makes it benevolent or malicious.

Good Taste

Taste as a subclass of aesthetics was introduced into the appreciation of art during enlightenment. From it was derived the idea of good taste as the by-product of an educated encounter with cultures differing from one's own. The avant-garde of the early 20th century attacked good taste, as it was connotated with little more than stale bourgeois self-assertion. Duchamp widened the debate by negating any kind of taste, good or bad, as being irrelevant. *Good Taste* here is understood as a genuine validation of perception. Could one taste a difference between the eggs of the chicken prior to robot cohabitation and after it? Factors such as condiments and the cooking skills of the chef are likely to overwhelm such differences. While the results of the experiment themselves remain second order effects, they indirectly reflect the overall quality of the eggs. The observing visitor was asked to ponder his/her perception of the interaction: Would tasting the eggs bring about an understanding of the visually understated complexity of the interaction between the animals and the robot? Could one generate *Good Taste* in a research goal? Would the invitation to use taste fold back onto 19th century good taste as nothing more than a social expectation, or could it unfold the imagination of the onlooker?

AMI

This first set of experiments was intended to open the territory of *Animal-Machine Interaction.* While robots have been successfully employed in industry, there has been no sophisticated attempt within robotics to deploy robots into sites where domesticated, industrialized animals live. Interaction here has no trendy cover. It is an exchange on the dirty side of industrialized captivity of animals. As with HCI, human computer interaction, AMI may some day become a recognized field of structured inquiry.

Cohabitation

Successful AMI can lead to 'comfortable' situations between animals and machinery. The term describing such an exchange is *Cohabitation*. The measure of success is exclusively the comfort of the animals. In this experiment, the comfort of the chickens could be gauged by their daily routines, their reactions towards the robot and their egg laying habits. The three chickens maintained an average of 12 to 15 eggs a week during the 8-week experiment (0.66 eggs per chicken per day). Cohabitation was a result of the robot assuming a non-threatening yet participatory role in the chickens' lives during the experiment.

Cohabitation can be engineered. The elements used here are a series on non-threatening robot movements. These movement primitives are made dependent upon the action of the chickens: If the chickens rested, so did the robot. If the chickens began to wander around so did the robot. Not all chicken activities were mimicked by the machine, however. If the chickens moved close to the robot, the machine 'defended' its space with a little robot dance. Choosing correspondences between chicken actions and robot movements was based on long observations of the chickens behavior in captivity. The choices were made to attempt to integrate the robot into the chicken world. They were decidedly subjective but proven effective for this task (see Results below). The method was to design non-threatening movement primitives, reactively map them to certain chicken behaviors and add historical dynamics through the fuzzy cognitive map, allowing previous events to be incorporated into the decision scheme for the subsequent robot behavior. Fuzzy cognitive maps are an approximation to set of *n* differential equations that allows relationships and dependencies between events, similar to a neural net, to be modeled[18]. While this feature overwhelmed the cognitive power of the chickens it opened the opportunity of extending these tests to neurologically more complex animals.

Defending Advanced Perception

Animal experiments, for artistic inquiry, are refuted by Carnegie Mellon's Research Evaluation Specialists. *Advanced Perception* had to be declared a scientific experiment in order to access the necessary credibility. An interesting point in case displaying the entrenched idea that only

[18] [Kosko97, p. 403ff]

science should have the authority to address (socially) complex issues and that other fields of inquiry must remain subordinate to it.
After numerous iterations the proposal was accepted and given the ‘Animal Welfare Assurance’ identification number A3352-01. A copy of this document was on display at the gallery.

Experimental Results

Initially, the birds were very frightened by the machine. Figure 9 shows the chickens one hour after the robot had moved toward them for the first time. The birds huddled in a corner for an extended period. While they eventually accepted the presence of the machine in the cage (Fig. 10), the moving robot remained a threat for a number of days.

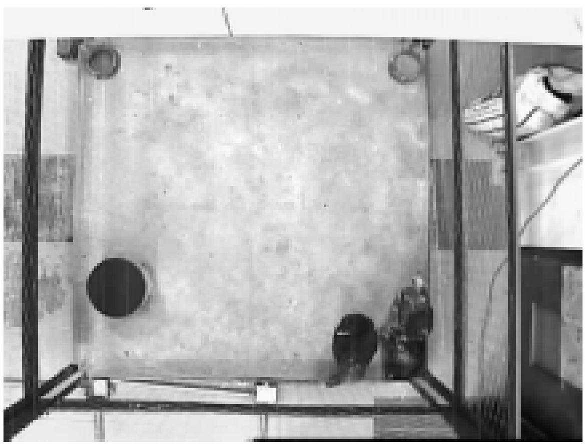


Fig. 9

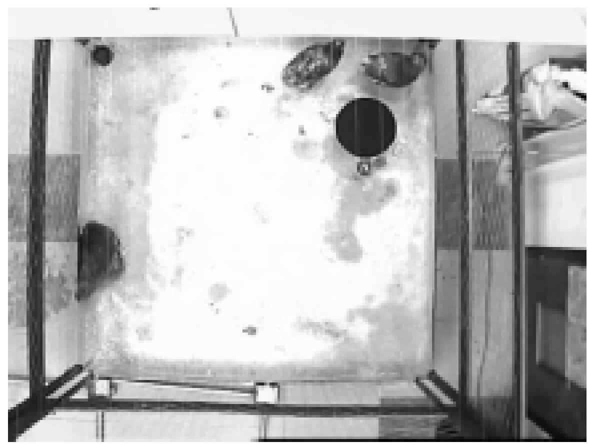


Fig. 10

Observing the animals’ reactions to the machine, it became clear that they were particularly frightened by the onset of movement. However, if the robot *Announced* its intent to move, waited, and then commenced movement, the animals showed almost no signs of fear. By signaling the servomotors to create a short audible sound, the robot alerted the animals prior to commencing movement. Once the chickens directed their gaze to the robot, the onset of motion itself was no longer perceived as a threat. Furthermore, slow speeds were perceived as less threatening than higher speeds. Additionally, the distance the robot maintained to the animals impacted their reactions to it.

After 5 days, the chickens became quite comfortable in the presence of the robot and cleaned their feathers while crouching right by the robot (Fig. 11).

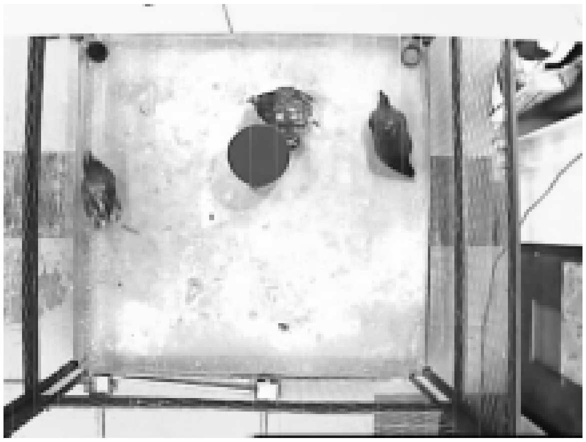


Fig. 11

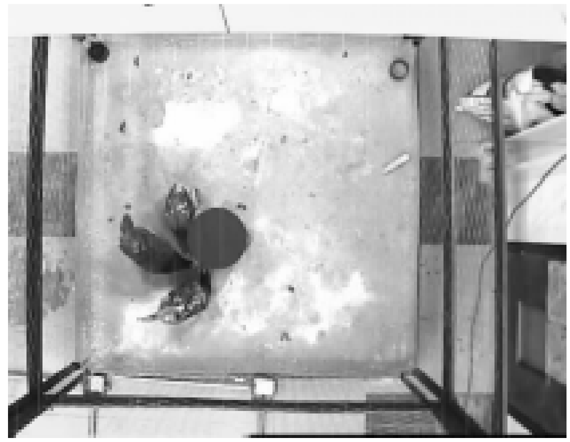


Fig. 12

Figure 12 shows the chicken devouring rice placed in the balancing caster as the robot inched slowly across the floor. They voraciously pecked at the rice when the robot stopped, and waited attentively while the robot was in motion. Fig. 13 shows a typical scenario after the adaptation period. If the robot maintained distance to the chickens, they effectively ignored its presence. One experiment (Fig .14) consisted of testing the color perception of the chickens. They were more attracted to a red LED than a green one and blink rates of around 500ms seemed to be effective in getting their attention.

Fig 13

Fig. 14

In order to achieve cohabitation it was imperative that the machine be perceived as non-threatening. Interestingly, its visual appearance was of less importance than its movements. The robot ‘looked’ like a generic can style robot, but its movements were designed to accommodate the animals. Listed below are the first three preliminary rules for designing the mechanics of a robot intended to cohabitate with *gallus gallus domesticus*.

- *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 to close to the animals.*
- *Avoid acceleration. All motion should be as continuous as possible.*

After 20 days, the chickens completely accepted the presence of the mobile robot in their cage. These rules are only a first entry point into a more elaborate form of cohabitation that could include nocturnal activities and cyclic planning of events, e.g. around egg laying and coveting. It would be interesting to test the results on a second set of birds[19]. In addition, it is not clear how these results could carry over to neurologically more complex animals.

Site Specific Robotics

Although the theoretical basis of Robotics is less tightly structured than in other fields of scientific inquiry, Robotics is a science, an experimental science. Nonetheless, it is quite common that an experiment in Robotics begins with a general theoretical premise and ends with a solution particular to a posed problem. Robotics is an *application specific* field of scientific engineering. *Field Robotics* is concerned with issues arising from deploying (mobile) robots not in sterile laboratories but in unstructured, natural and other terrain. Generally the site of deployment is considered a nuisance. *Dante II*, for example, a tethered walking robot, able to descend into the interior of a volcano in order to measure ambient atmospheric conditions, was designed to overcome the difficulties of the steep volcanic terrain[20]. The path into the interior of the volcano was considered an obstacle to the 'real' site of interest.

[19] The three chickens have been returned to the farm of their origin in Butler PA.
[20] See http://img.arc.nasa.gov/dante/dante.html

The term *Site Specific Robotics* is borrowed from art theory where *Site Specific Sculpture* or installation is understood as work that is particular to a place (and often a time) where it is set. Likewise, site specific robotics understands the terrain in which a robot is deployed to be as much a source of interest as the task the robot is designed to fulfill. Site specific robotics is an extension of the application-specific nature of solutions in robotics engineering. In the case of AMI the site specificity was enhanced: the robot dwelled in a cage with the chickens and really had no where to go and no particular goal to achieve. The deployment of a robot into a site of assumed un-interest is, likewise, a form of site specificity.

Tethics

Tethics is a term for developing a technology and a set of rules by which the technology should be used, simultaneously. Generally, technology professionals have little influence on the end use of the tools they create. Tethics assumes that technologies and ethics can be designed simultaneously. AMI is a simple "instantiation"[21] of *Tethics*. *AMI* shows that *Tethics* can be successful. Including non-technical constraints in the design of a technical system can lead to unexpected (scientific) results. Every scientific experiment uses *nolens-volens* a particular moral value set[22]. The approach in *Tethics* is to make this basis explicit and incorporate it into the design space of the experiment.

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