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Autonomous Mobile Robotics

Introduction to Autonomy

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Topics

- Weeks in and Alex finally tells us why he bothers with robots at all
- Some Definitions
- What is Autonomy?
- What is Emergent Behavior
- An autonomy example with samples


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Network-Centric Applied Research Team (N-CART)
• Multidisciplinary R&D by
– Graduate, Undergraduate Students and Volunteers
– Collaborating Organizations
– Others
• Focus on Computational Public Safety (PS)
• Director: Alex Ferworn
– Computer Science Professor
– Canadian Army – 14 years
– OPP Auxiliary - 2 years
• Not a typical computer science lab
– "Dogs and Robots"
– Gary Herbert
» Governor - Utah
– "Best kept secret in Canada"
– John Hickenlooper
» Governor - Colorado
the application of computational resources, theory and practice in support of and improvement to PS processes.
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Canine Assisted Robot Deployment (CARD)

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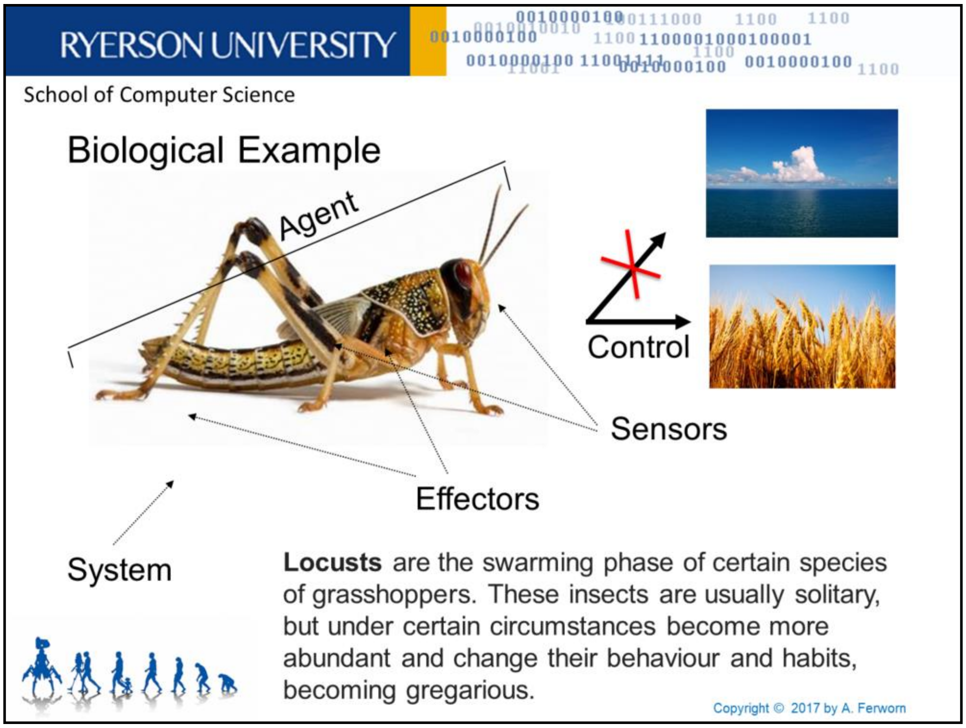
Definitions

- Sensing: Sampling the environment.
- Effecting: Making changes to the environment.
- System: A group of interacting items which form a unified whole.
- Agent: Any system which can be viewed as perceiving its environment through sensors and acting upon it through effectors.
- Control: The regulation of the behavior of a system to make it perform as desired.
- Autonomy: ?



The desert locust *Schistocerca gregaria* is a well known migrating insect, travelling long distances in swarms containing millions of individuals. During November 2004, such a locust swarm reached the northern coast of the Gulf of Aqaba, coming from the Sinai desert towards the southeast. Upon reaching the coast, they avoided flying over the water, and instead flew north along the coast. Only after passing the tip of the gulf did they turn east again. Experiments with tethered locusts showed that they avoided flying over a light-reflecting mirror, and when given a choice of a non-polarizing reflecting surface and a surface that reflected linearly polarized light, they preferred to fly over the former. Our results suggest that locusts can detect the polarized reflections of bodies of water and avoid crossing them; at least when flying at low altitudes, they can therefore avoid flying over these dangerous areas.

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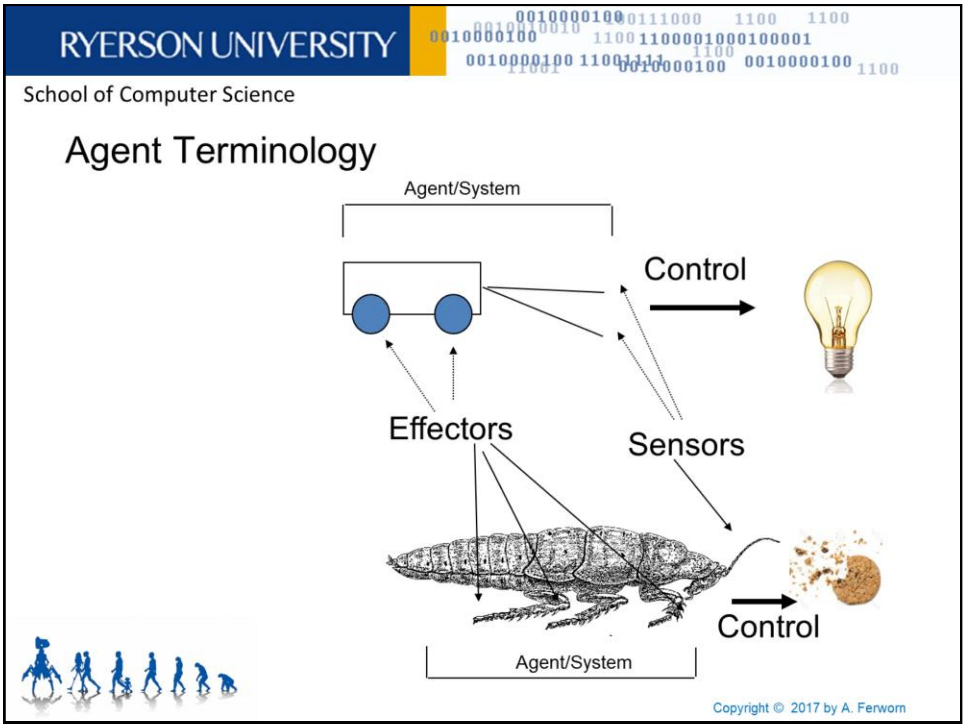
Why do locusts swarm?



If you've observed a cockroach, you'll notice that they always swing their antennae from side to side and up and down. This is them sensing the environment and deciding where the go next. When they touch an object, the flagellum can sense its chemical consistency, its temperature, and other such information, while the scape and pedicel determines its solidity and direction.

Each sensilla is connected to the nervous system, obviously. Each sensillum type goes to its own center in the brain, although some generalities can be identified: neurons from temperature, humidity, and smell sensillae go to the antennal lobe, while mechano-and chemosensory sensillae go further to the deutocerebrum and suboesophagal ganglion. The precise details are the subject of specific research.

Some of this research is funded from robotics and military sources, so there is interest from tech in emulating the sensory systems of insects. They are highly-efficient and modular, perfect for engineers to attempt to mimic.

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Cockroach Models are common

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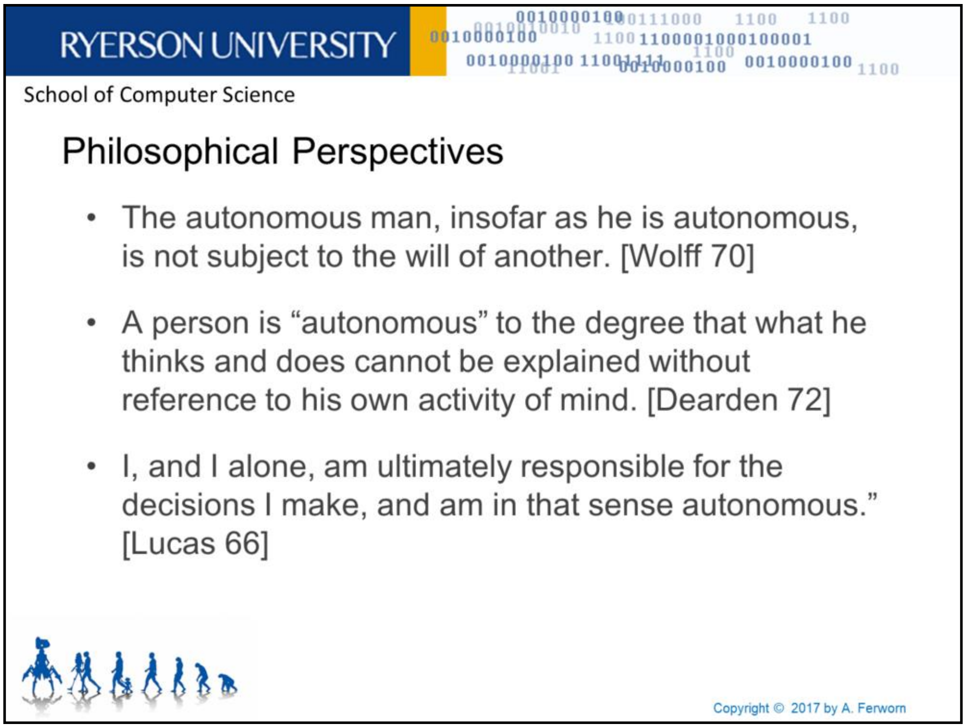
What is Autonomy?

- Philosophical Perspective
- Psychological Perspective

the study of the fundamental nature of knowledge, reality, and existence

the study of the human mind and its functions, especially those affecting behavior in a given context.



Autonomy is equated with dignity, integrity, individuality, independence, responsibility, and self-awareness. It is identified with critical reflection, freedom from obligation, absence of external influence, determination and execution of self interest. It is related to actions, to beliefs, to reasons for acting or not acting, to rules, to the will of other persons, to thoughts, and to principles. About the only features held constant from one interpretation to another is that autonomy is a feature of people, and that autonomy is a desirable quality to have [Dworkin 88].

One definition of autonomy is self-determination. The autonomous person is one who chooses for themselves what to think and what to do. They are self-governing in that their actions are a result of interests and values that they have decided upon. Also, these beliefs are arrived at independently, by means of critical reasoning. The autonomous individual is guided by their own notion of what is right, best, or at least possible. This has been termed the Autonomy of judgment or "thinking for oneself."

In reality we do not directly ascertain the validity of most of our beliefs. A good deal of our autonomy is derived from assessing the behaviour of others--we are taught. This requires that we have criteria by which to recognize an authority or when someone's testimony is dependable.

With the idea of dependence, we come to the matter of constraints or limitations on our autonomy. External constraints typically interfere with the exercise of autonomy, as with deception or censorship--being lied to or "kept in the dark" can severely limit autonomy. Internal restrictions are due to some condition suffered by the individual rather than outside interference. Typically, they will consist in deficiencies or "defects" in rationality. For example, stubbornness or stupidity might restrict autonomy in this way.

While autonomy of judgment is necessary for autonomous thinking and action, it is not sufficient. Because of either external or internal conditions a person may be incapable of acting or even choosing based on freely made decisions. Threats (external) or the possibility of embarrassment (internal) might restrict an action.

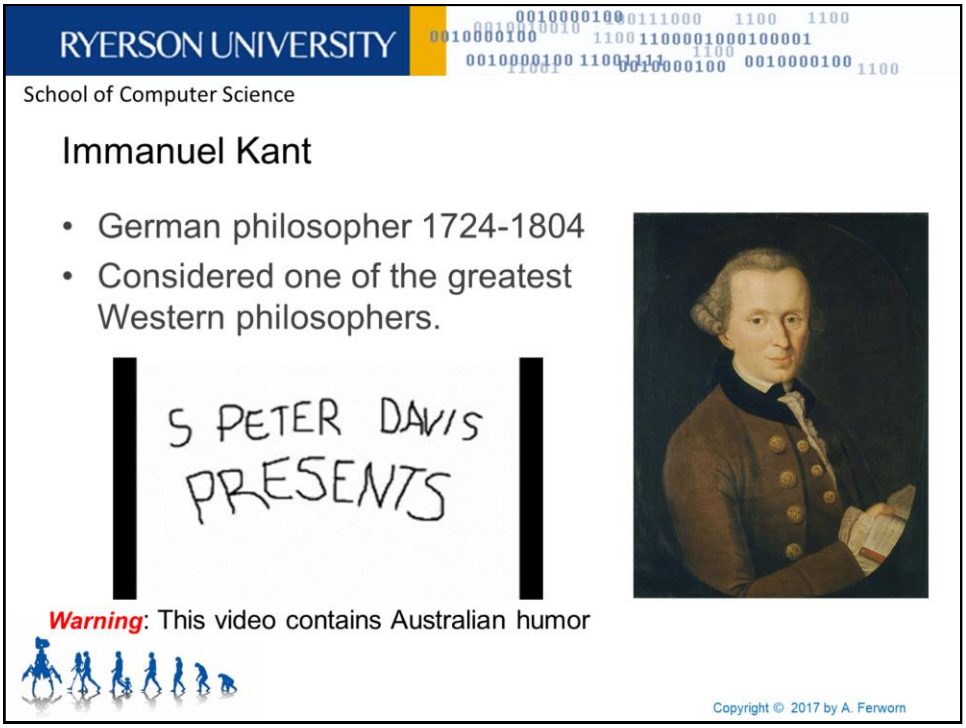
Efficacy of will indicates the ability to do what one wills. Deliberateness of will refers to the extent to which what it is that one wills is the fruit of deliberate choice. Efficacy of will might more colloquially be called autonomy of action, since it refers to our ability to act on our decisions or will.

It is easy to see how autonomy of action can be interfered with. Interference can range from physical limitation to coercion or exploitation. The latter limits the individual by, "attaching costs to certain forms of action that they would not otherwise carry."--For example the association of a certain action with pain (pain = wrong).

[Benn 76] example of the psychopath nicely illustrates how someone could have autonomy of judgment but lack of autonomy of action. Psychopaths cannot carry through projects requiring deferment of gratification. Only immediate consequences of action count as relevant considerations for decision-making.

The nature of one's will is relevant to the question of autonomy. Depending on why one wills what one does, or how the will is formed, it may be more or less autonomous. What one wills may be determined exclusively by the strength of one's desires and impulses. Such a person then acts in accordance with their strongest prompting. If you are both hungry and tired you will eat if the hunger is greater than the fatigue and vice versa. This sort of will consists of the most demanding, urgent force within the individual. Such a will is in some sense less one's own, hence less autonomous, than it might be.

There is a higher level at which our deliberations may proceed. We can assess and make decisions about who we are and what we wish to become. We can take up the question of what sort of person to be and what kind of life to lead. This sort of deliberation goes beyond the ordering of priorities.



German philosopher Immanuel Kant (1724-1804) is considered the most influential thinker of the Enlightenment era and one of the greatest Western philosophers of all times. His works, especially those on epistemology (theory of knowledge), aesthetics and ethics had a profound influence on later philosophers, including contemporary ones.

Besides establishing himself as one of the foremost Western philosophers, Kant also made an important contribution to science and is considered one of the most important figures in the development of modern science despite the fact that he was most interested in philosophy of science and knowledge that science produces. His main contribution to the rise modern science was its liberation from theology.

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The Autonomy of Reason

- Kant maintained that one ought to think autonomously
  - free of the dictates of external authority
- …one acts from duty in accordance with the universal moral law that the autonomous human being freely gives itself.
  - treat humanity as an end in itself rather than (merely) as means to other ends the individual might hold.
  - This necessitates practical self-reflection in which we universalize our reasons.

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Faith in the self-driving car

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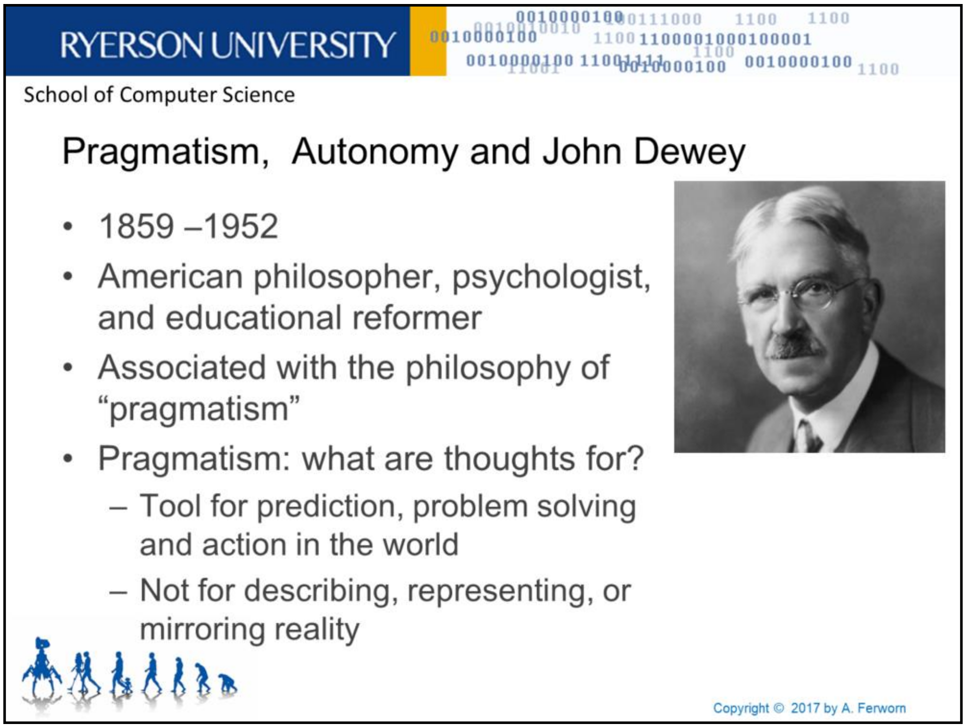
Why Kant's Ideas are Important for Self-Driving Cars



Pragmatists contend that most philosophical topics—such as the nature of knowledge, language, concepts, meaning, belief, and science—are all best viewed in terms of their practical uses and successes. The philosophy of pragmatism emphasizes the practical application of ideas by acting on them to actually test them in human experiences. Pragmatism focuses on a changing universe rather than an unchanging one as the Idealists, Realists and Thomists had claimed.

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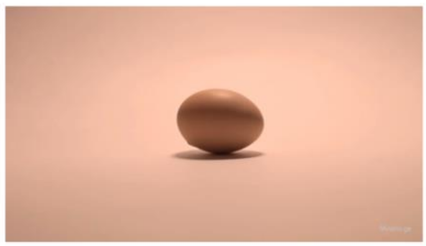
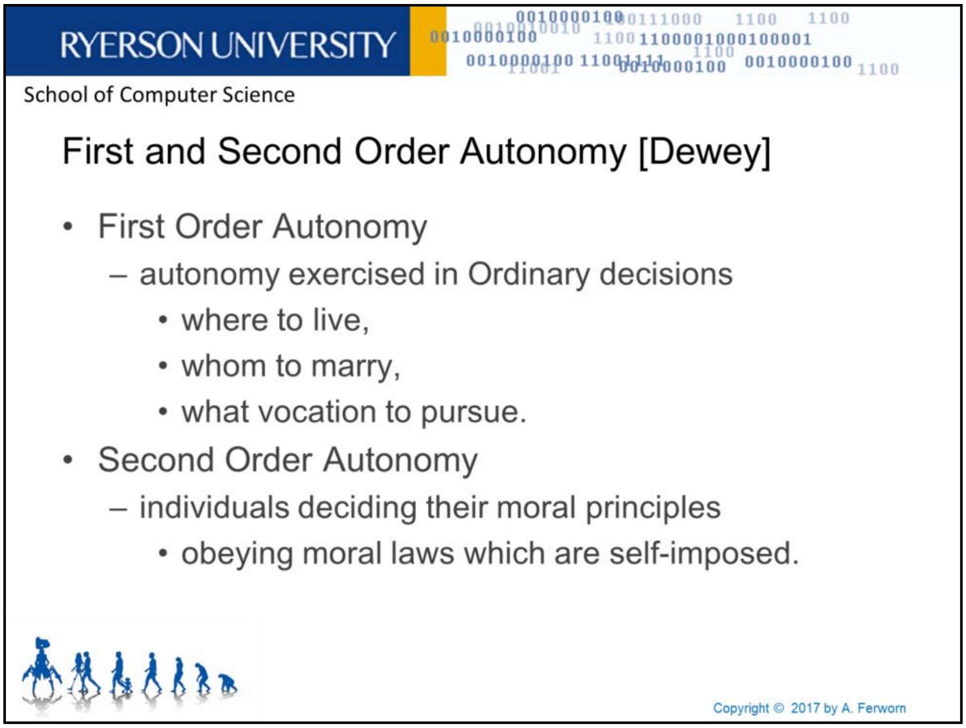
Psychological Perspective on the Nature of Autonomy

- The chick, which can peck accurately at food shortly after hatching, quickly develops its expertise in behavior because it stems from only a few original tendencies. Its immediate efficiency, however, is “like a railway ticket,...good for one route only.” Whereas, “A being who, in order to use his eyes, ears, hands and legs, has to experiment in making varied combinations of their reactions, achieves a control that is flexible and varied.”
  - John Dewey, Human Nature and Conduct, 1957

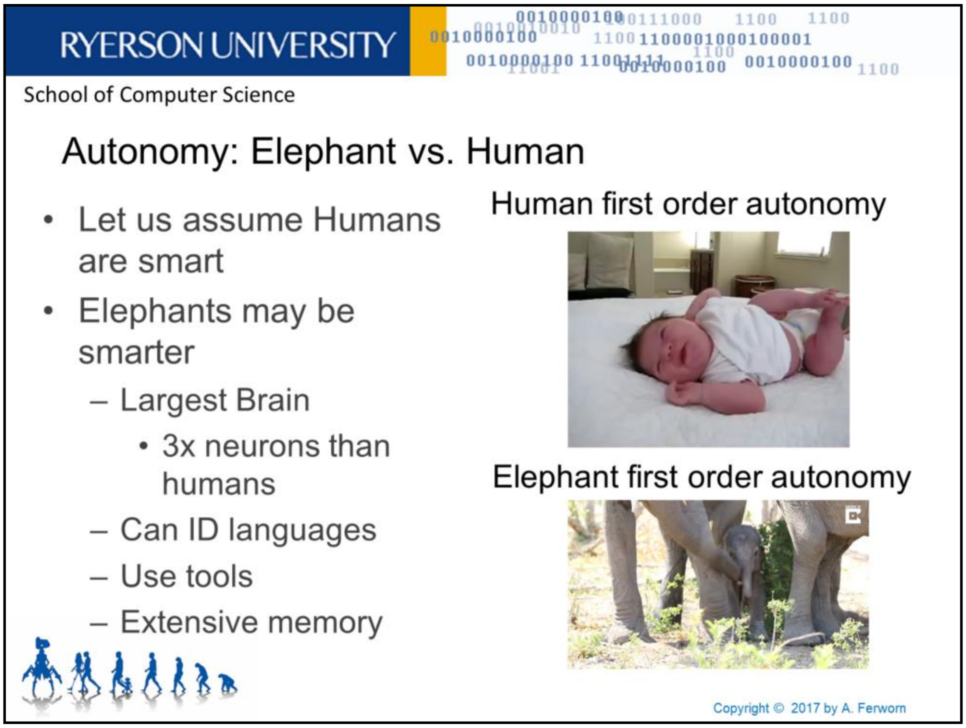




From Chapter 1 “Autonomy: Dimensions and Distinctions” in “Autonomy and Social Interaction” by Joseph H. Kupfer. State University of New York Press, 1990

First-order autonomy is autonomy exercised in the particular decisions which occupy us in the ordinary course of life: where to live, whom to marry, what vocation to pursue...These everyday decisions can be made more or less autonomously, depending, as we have seen, on our resources, abilities, and freedom from restrictions.

Autonomy may also be viewed as moral self-governance--the individual authoring his moral principles, obeying moral laws which are self-imposed. The autonomous individual does not simply conform to some conventional standard of conduct. Rather, they rationally ascertain for themselves what is desirable for any rational individual. This is autonomy not in the sense of being governed by contingent desires or ambitions, but governed by the rewards of a dispassionate, disinterested reason. This is what we will refer to as Second-Order Autonomy.

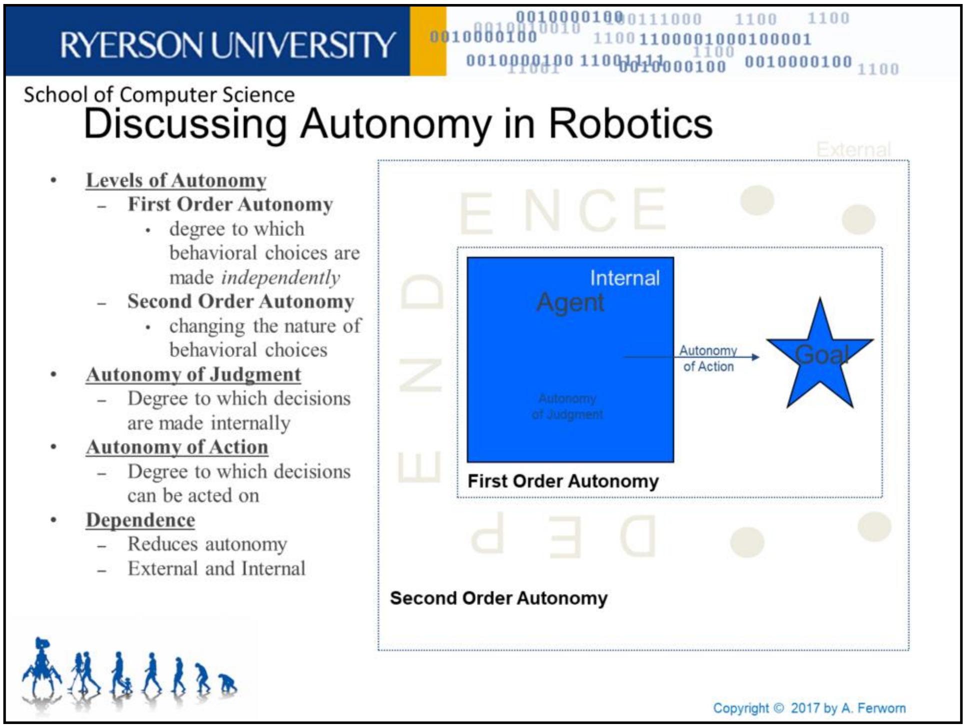


Most contemporary ethologists view the elephant as one of the world's most intelligent animals. With a mass of just over 5 kg (11 lb), an elephant's brain has more mass than that of any other land animal, and although the largest whales have body masses twenty times those of a typical elephant, a whale's brain is barely twice the mass of an elephant's brain. In addition, elephants have a total of 300 billion neurons.

Elephant brains are similar to humans' in terms of general connectivity and areas. The elephant cortex has as many neurons as a human brain, suggesting convergent evolution. Elephants manifest a wide variety of behaviors, including those associated with grief, learning, mimicry, play, altruism, use of tools, compassion, cooperation, self-awareness, memory, and communication.

Further, evidence suggests elephants may understand pointing: the ability to nonverbally communicate an object by extending a finger, or equivalent. It is thought they are equal with cetaceans and primates in this regard. Due to such claims of high intelligence and due to strong family ties of elephants, some researchers argue it is morally wrong for humans to cull them. The Ancient Greek philosopher, Aristotle, once said that the elephant was "the animal which surpasses all others in wit and mind”.

However, a few elephant researchers, and some ethologists, point to experimental and anecdotal evidence which appear to contradict the view that elephants are self-aware, can think, and possess a theory of mind.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Discussing Autonomy in Robotics
• Levels of Autonomy
– First Order Autonomy
• degree to which behavioral choices are made *independently*
– Second Order Autonomy
• changing the nature of behavioral choices
• Autonomy of Judgment
– Degree to which decisions are made internally
• Autonomy of Action
– Degree to which decisions can be acted on
• Dependence
– Reduces autonomy
– External and Internal
External
E N C E
D N E
D E P
Internal
Agent
Autonomy of Judgment
Autonomy of Action
Goal
First Order Autonomy
Second Order Autonomy
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Applying this to a Robot

- Sojourner
  - Aspects of first order autonomy, no second order
  - Heavy Internal dependence of preprogrammed behavior
  - Heavy external dependence of commands sent from Earth
  - Autonomy of Judgement limited to limited navigational tasks
  - Autonomy of Action limited by available power

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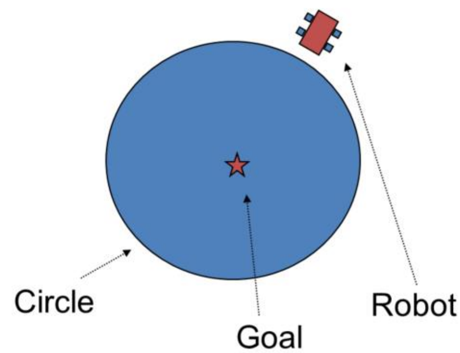
The Autonomy Problem Illustrated

- How would you build an autonomous robot that can move to the goal and push it out of the circle?



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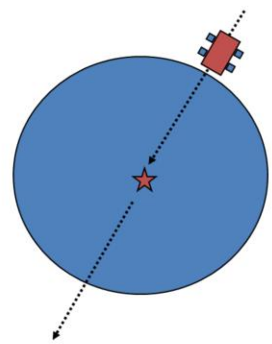
Possible Solution 1

- Point the robot at the goal and let it go in hopes of pushing the goal out of the circle.



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Discussion of Solution 1

- Very limited in terms or even first order autonomy
- dependence on various factors which limit the vehicle's success
  - friction
  - misalignment with target
  - no correction possible

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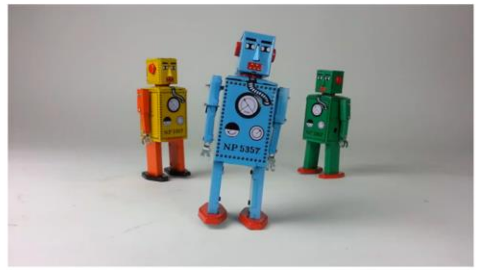
Examples

- Toy wind-up robot
- Moves in the direction it is pointed
- Very difficult to accomplish any kind of useful goal deliberately



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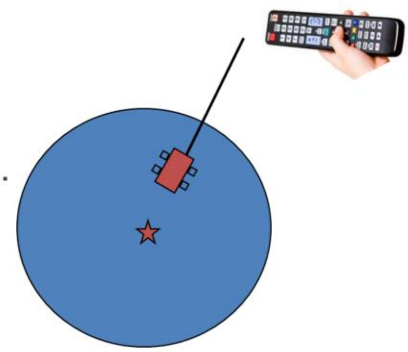
Possible Solution 2

- Hook the robot to a controller and manipulate the controller to steer the robot to accomplish the goal.



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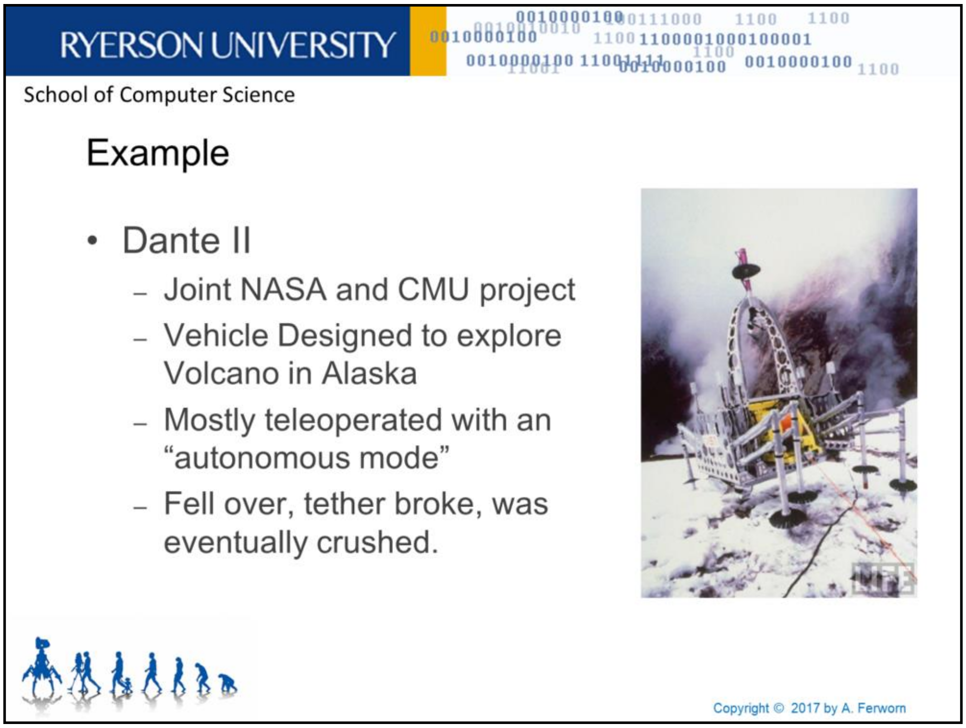
Discussion of Solution 2

- Hard to call it autonomous in any sense
- Just because it's tethered doesn't mean the task is easy!
  - sojourner was essentially tethered
- A robot might be tethered because it is not desirable or possible to put the controller on-board
  - size restriction, safety concerns, etc.



•The CMU Field Robotics Center (FRC) developed Dante II, a tethered walking robot, which explored the Mt. Spurr (Aleutian Range, Alaska) volcano in July

•1994. High-temperature, fumarole gas samples are prized by volcanic science, yet their sampling poses significant challenge. In 1993, eight volcanologists were killed in two separate events while sampling and monitoring volcanoes. The use of robotic explorers, such as Dante II, opens a new era in field techniques by enabling scientists to remotely conduct research and exploration.

•At 6:45pm ADT, Dante had climbed to about 200 feet above the crater floor. While ascending on a steep cross-slope the terrain under the left legs of the robot collapsed, causing the robot to slide across the slope and roll onto it's left side. It appeared that the terrain, having been saturated with water from the ongoing snow melt, was not able to support the weight of the 1700-pound robot and simply gave way when weight was applied to the legs of the robot as it walked.

•...The most likely option will be to complete the extraction of the robot from the crater via helicopter sling-lift early next week.

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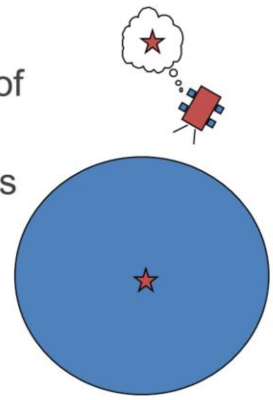
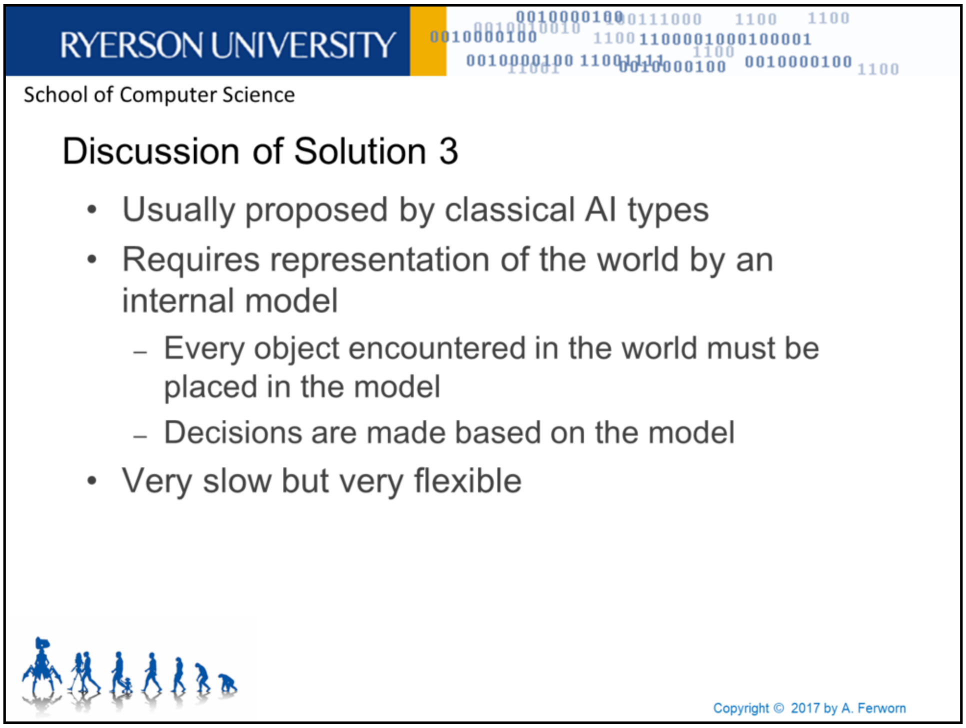
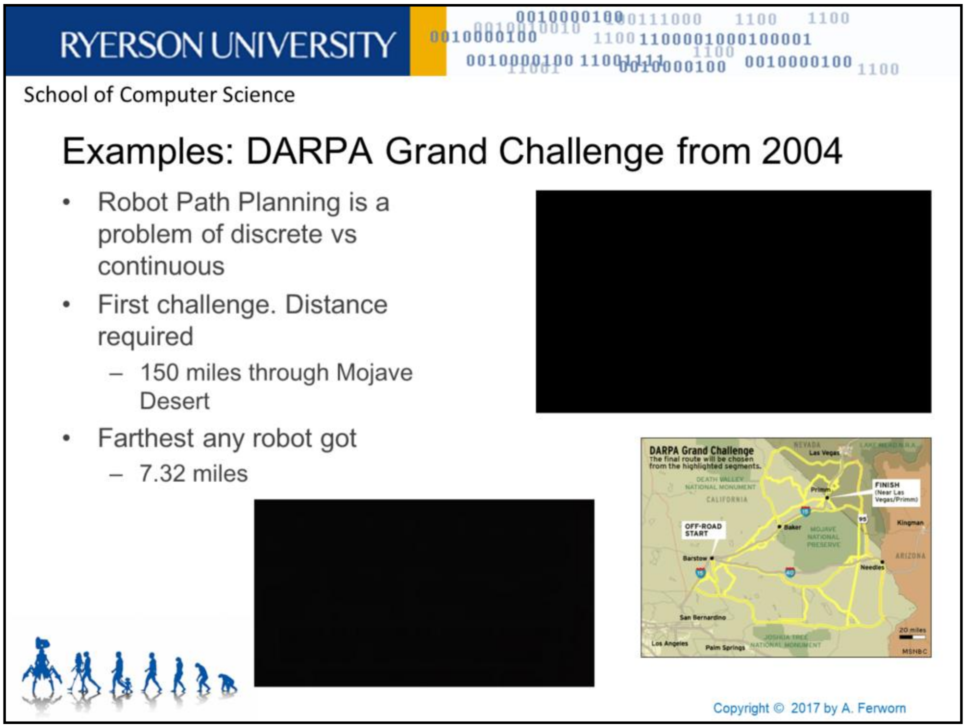
Possible Solution 3

- Create a robot which you “tell” to “push the goal out of the circle.
- The robot than goes and does that!





potential to go to second order autonomy



•The first competition of the DARPA Grand Challenge was held on March 13, 2004 in the Mojave Desert region of the United States, along a 150-mile (240 km) route that follows along the path of Interstate 15 from just before Barstow, California to just past the California–Nevada border in Primm. None of the robot vehicles finished the route. Carnegie Mellon University's Red Team and car Sandstorm (a converted Humvee) traveled the farthest distance, completing 11.78 km (7.32 mi) of the course before getting hung up on a rock after making a switchback turn. No winner was declared, and the cash prize was not given.

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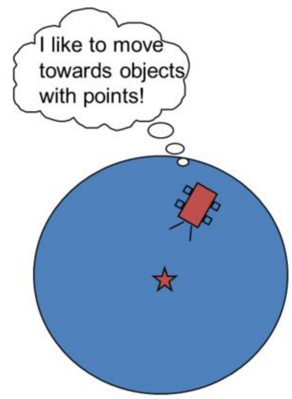
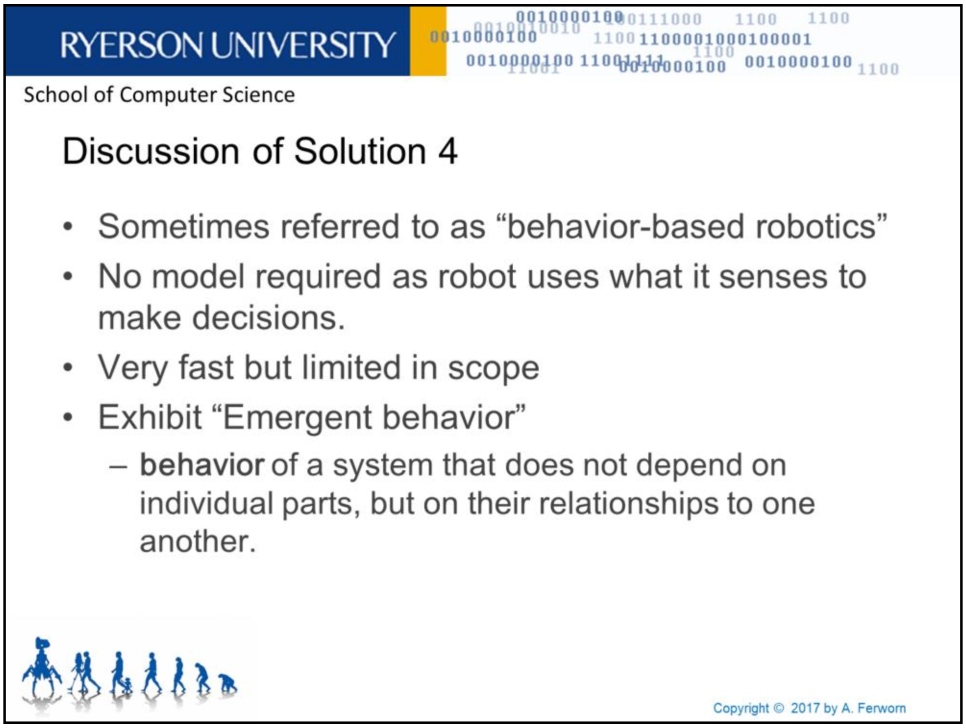
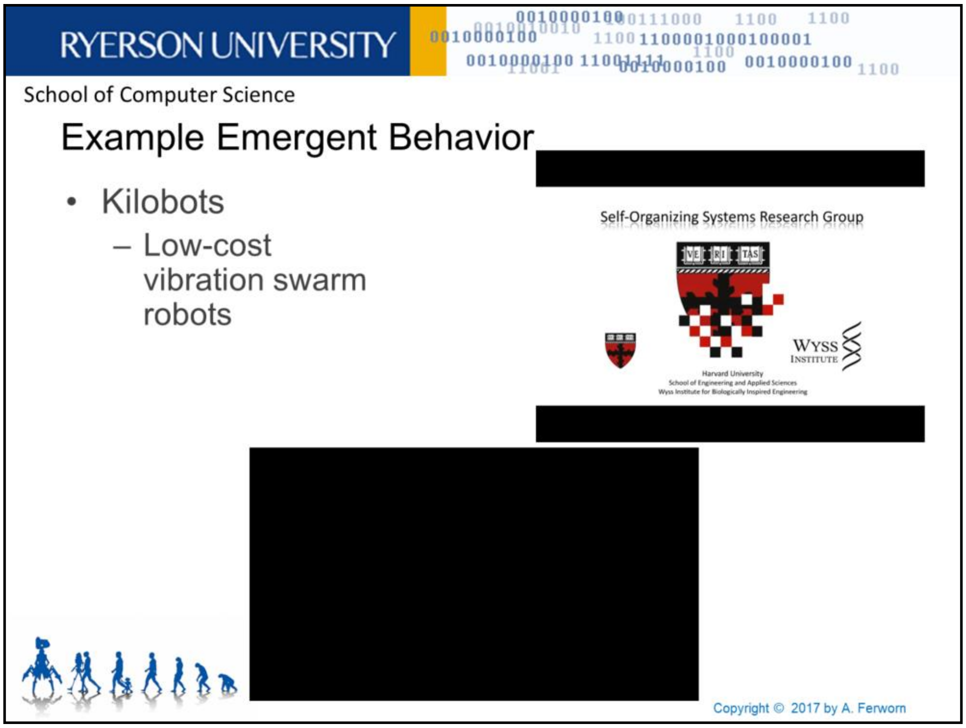
Possible Solution 4

- Instill a set of behaviours which allow the robot to use what it senses to make control decisions to allow it to reach the goal on its own.





Very limited ability to deal with second order autonomy issues but very successful at first order matters



2011. A **Kilobot** is a 3.3 cm tall low-cost swarm robot developed by Radhika Nagpal and Michael Rubenstein at Harvard University. They can act in groups, up to a thousand, to execute commands programmed by users that could not be executed by individual robots. A large issue with research on robot collectives is that the cost of individual units is too high, but the Kilobot's total cost of parts is under $15. In addition to the low cost, it still has applications such as collective transport, human-swarm interaction, and shape self-assembly. Kilobots self-organize through emergent behaviour.