A Brief History of Robotics

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Acknowledgement

Following summary was written for introduction to my thesis, which in turn, found out to be more than enough, thus I present it as a separate work. I hope you enjoy it. I also wish to thank Burak Ata, for the best robot quote ever. I also wish to tip my hat to California.

> "*Hasta la vista, baby!*"
> -The terminator, in *Terminator 2: Judgment Day*, 1991.

1 Ancient Times

Life requires a controlled environment. Organisms deal with this problem in two ways, they either adapt to environment, or change environment to suit their needs. Simple organisms adapt by evolution, more complex organisms can learn and manipulate the environment. Manipulation of environment is probably the most powerful mechanism, since it is faster and it is potentially unlimited. By creating an ideal environment for themselves organisms can survive much better. For instance, birds build nests, beavers build dams and bees build hives. Although these constructs are impressive, mankind is the most capable species in manipulating environment for his needs. By this way there are people living on virtually every piece of land on earth. Civilization allowed comfortable lives in any climate with air-conditioners, sterilized water, farming and herding.

Although our reign over nature is quite strong, we still miss more comfort. Starting from the pictures in the caves, man has struggled to capture the essence of nature. Man made tools to extend their physical abilities. With steam power, these tools turned into machines. With machines we were able to surpass our physical abilities with orders of magnitude. Yet machines are still tools. They inherit inefficiencies of man. Even tough a bulldozer never gets tired, its driver does.

2 Clockworks

So if we can make tools with their own power, why can't we make tools that work by themselves. This was probably first occurred to clockwork machine designers. Their automatons were usually like clocks, they performed a predefined set of operations. Most of these machines were toys, expensive gifts for rich people of the time. These machines evolved into industrial robots and computer controlled tools in modern world. They are widely used in industry, and even in households. The main disadvantage of these automaton is the lack of flexibility. They are designed to work on specific conditions. They can not react to changes in environment, so the environment for these devices are carefully controlled.

Although clockwork machines and industrial robots can work by themselves, they lack one important ability: intelligence. Intelligence is defined as *"The capacity to acquire and apply knowledge and the faculty of thought and reason."*. These devices can not acquire knowledge. When the environment is kept constant, this is not a big problem. But the world we live in constantly changes: there's day and night, there are seasons, objects around us move, ... It is almost impossible to construct a device that does something useful under all these variance. But we have a huge number of examples for such devices, living beings. Living beings deal with this variance, gracefully. They are certainly not mindless automatons. Even tough limited, all creatures have some intelligence. They perceive environment and act accordingly.

Probably first example of a reactive automaton is *chahakobi ningyo*, the tea serving doll, built in 18th century Japan, by Hosokawa Hanzo. When a cup is put on the tray of this doll, it moves forward to "serve" the tea to the guest. When guest finishes the tea, he places the cup back on the tray, doll then bows, turns back and returns to the owner. Although quite simple, this automaton responds to the environment, perceives the cup and its state, in a crude manner. This automaton can serve different guests who drink in different speeds. So it requires a less restricted environment than an automaton that requires a fixed time to serve tea.

3 Age of Wonders

Increasing the perception and intelligence of the automatons, was of interest in 19th and 20th century. But the challenge is quickly discovered. We didn't really know about intelligence. People think in terms of themselves, thus earliest approaches was to model man for intelligence. This approach was making machines that think like humans. They were imagined to be servants of man, to ease our lives.

People imagined many constructs, that looks, perceives, thinks and acts like humans. Karel Capek, introduced the word robot in 1920, derived from the word *robota* for slave. His robots conquered humanity. Isaac Asimov, on the other hand, dreamed robots with ethical limits in their behavior, in 1950. They are designed to serve and protect humanity.

4 Recent History

Yet we are still very far from their vision. Early studies in artificial intelligence aimed to build intelligence by symbolic logic. In 1960's, it was believed that human like intelligence was only years away. When the actual implementations were attempted, the fault in this approach were seen. Frame problem or *"the challenge of representing the effects of action in logic without having to represent explicitly a large number of intuitively obvious non-effects"* limits the application of logic to robot control. Another problem with this approach was the noisy and unreliable nature of the sensors and environment. Robots did not have enough time to think and act.

Parallel to this mainstream research there were a few people experimenting on simple reactive robots. Walter Grey Walter, worked on autonomous robots with the ability of phototaxis, or moving toward light. These robots were controlled by very simple analogue circuitry, did not have any deliberation or planning but never the less they were mobile and autonomous.

Another milestone of the autonomous robots research is the subsumption architecture of Rodney Brooks[1]. With this study he proposed autonomous robots that model simple organisms, like insects. With this architecture simple and reactive behaviors can be combined to create a complex interaction with environment. His approach did not try to imitate the way humans solve problems but rather tries to solve problems from the viewpoint of a simple reactive organism. He proposed three key terms: *situatedness*, *embodiment* and *emergence*. Situatedness principle underlines the reality of robot, rather than being an abstract entity working with arbitrary symbols, embodiment on the other hand expresses the physical presence of robot, with its physical limitations. And at last the intelligence is defined as the observed behavior of the robot, that emerges or becomes visible, from the interactions of the robot with environment.

Using multiple robots to accomplish tasks are a natural extension of this view. Although seems trivial, it is generally very complicated to coordinate a group agents to perform tasks. One of the pioneers of this field is Maya Mataric[2]. She build an architecture to coordinate a group of robots in a distributed way. Her approach uses simple basic behaviors as building blocks to form group behavior. She's also one of the first to implement learning on a group of real robots.

5 Swarm Intelligence

Coordinating multiple robots is also addressed from a different point of view: swarm intelligence. In this methodology, simple agents were coordinating with minimal and possible no communication to perform tasks. This restriction is aimed to allow systems which are robust, fault tolerant and scalable. Swarm is a group of agents that work in coordination, like social insects, schools of fish and a flock of birds. Swarm intelligence further simplifies the agents in reactive and behavioral paradigms, and introduces hard limits on the distributed nature of the control.

Using swarm intelligence principles two novel optimization methods are proposed: Particle Swarm Optimization and Ant Colony Optimization. Both of these methods rely on a population of solutions similar to evolutionary methods. Particle swarm optimization, proposed by James Kennedy and Russel Eberhart in 1995[3], uses a group of particles that move in the search space according to perception of the objective function from close neighbors in the swarm. In this method, even though the individuals are quite simple and has no knowledge of the general picture, with social communication, the system can achieve high performance.

Ant colony optimization techniques was first introduced by Marco Dorigo in his doctoral thesis in 1992[4]. Ant colony optimization similarly uses a group of simple agents. But in this case the agents communicate through virtual pheromones, modeling the communication of ants. These pheromones that are laid by agents influence the behavior of other agents. This optimization technique shows the power of communication through environment, a method that can be quite scalable.

Use of simple agents with local communication and communication through environment is shown effective in this two optimization methods. Swarm robotics relies on these two abilities to solve multiple robotics tasks in a scalable way.

Although the idea of simple agents to accomplish complex tasks is interesting, it is rather difficult to construct individual behaviors that leads to desired group behavior. As indicated by Camazine *et. al*[5], in order to achieve swarm behavior, positive and negative feedback mechanisms must be provided. The success of the system lies in the balance of these driving forces.

Two main approaches were used in the literature for this purpose. First method is using optimization methods like evolutionary methods to generate control systems. Problems including aggregation[6], chain formation, task allocation and coordinated motion[7] is studied with this method. Stefano Nolfi and Dario Floreano provide many examples of such applications[8].

Second approach is to use carefully designed algorithms to control agents behavior. Using simple and usually probabilistic algorithms, feedback is implemented in the system. Problems including clustering[9], pattern formation[10] is studied with this method. Bah ceci *et. al*[11] gives a review of recent studies on pattern formation.

Hand designed algorithms are also useful in modeling[12]. By using simple individual behaviors, emergent behavior of the swarm can be predicted using much simpler macroscopic models. Macroscopic models allow deeper understanding of swarms, faster simulations and design of better individual behaviors.

APPENDIX

Here I present two of the failed attempts to use quotes for this study.

> First there was god and heaven. Then his wish, not forgotten. When he wished, there be light. With light came day and night. Each day heaven turned to earth. With his breath man came to birth.
>
> ... And then men built robots.

> *"It was the secrets of heaven and earth that I desired to learn"*
> -Victor Frankenstein

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