Chapter 2 - Background

This chapter provides some of the background information needed to conduct this project. In particular, NASA, NASA's Goddard Space Flight Center, and basic concepts of swarm intelligence will be discussed. Material in this chapter will help in understanding the elements involved in this project.

2.1 The National Aeronautics and Space Administration

Lingering tensions in the decades immediately following World War II left the United States and Russian entangled in the Cold War. Initially a struggle over principles and loyalties, the Cold War soon expanded to include the two countries making great strides towards creating sophisticated military systems. The space race became a major area of competition as both countries recognized the military significance of a dominant presence in space.

The successful launch of Russia's Sputnik 1, the first artificial satellite, on October 4, 1957, caused many Americans to lose confidence in the effectiveness of the Unites States space program. Attempting the curb American feelings of technological disparity between the abilities of the Americans and the Russians as well as further national defense initiatives focused on a presence in space, the United States increased funding to aerospace endeavors while simultaneously promoting technical and scientific educational programs. The government also chartered new federal agencies to manage air and space research and development. The result of these initiatives was the launch of Explorer 1, America's challenger in the space race. To provide further impetus for progress, Congress and President Dwight D. Eisenhower arranged for the creation of a national organization to assume responsibility of all space exploration. On October 1, 1958, the country witnessed the birth of the National Aeronautics and Space Administration (NASA), created "to provide for research into the problems of flight within and outside the Earth's atmosphere, and for other purposes." NASA quickly enveloped the existing National Advisory Committee for Aeronautics and several other government agencies.

Shortly after it inception, NASA began a successful series of missions in space. Beginning with single astronaut space flights in the Mercury mission and soon followed by dual astronaut flights with the Project Gemini, NASA solidified its presence in space. The defining achievements for NASA in its early years were the Apollo missions. President John F. Kennedy announced on May 25, 1961, "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth." Eight years later, Kennedy's vision was realized when Neil Armstrong and Edwin Aldrin became the first humans to walk on the surface of the Moon on July 20, 1969. Following the Project Apollo, NASA began working towards establishing a sustained human presence in space. The Skylab program in 1973 and later the Apollo-Soyuz Project in 1975, a joint venture with the Russian space agency, proved that humans could work and function in space for continued periods of time. NASA's human space flights resumed in 1981 with the dawn of the Space Shuttle program. Today, NASA works with other countries to supports the International Space Station.

In addition to human space flights, NASA also focuses on space exploration and space applications using independent, unmanned spacecraft and satellites. The Echo, Telstar, Relay, and Syncom satellites launched during the 1960s and the Landsat program of the 1970s created a foundation for space exploration and observation. During the early 1970s, NASA's Pioneer 10 and Pioneer 11 traveled to Jupiter and Saturn to examine the composition of interplanetary space. In 1975, the Viking spacecrafts journeyed to Mars to search for signs of life. NASA sent additional spacecraft, Voyager 1 and Voyager 2, into the solar system in 1977 to explore the solar system as a whole. The Hubble Space Telescope, launched in 1990, gave NASA a highly sophisticated means of observing the vast expanse of space.

In the last 44 years, NASA has realized many significant scientific achievements. Throughout its history, the Administration has advanced the science of exploring space as well as provided innovative technology that has been applied in non-aerospace endeavors. Since its infancy, NASA has consistently provided the impetus for increased focus on space as the frontier of the future. [NASA 2000]

2.2 NASA Goddard Space Flight Center

NASA's Goddard Space Flight Center in located in Greenbelt, Maryland. The city of Greenbelt is considered a suburb of Washington, D.C. and is located in Prince George's County. It is the intersecting point of four major highways, is located only two miles from the New York / DC high speed metroliner station, and two major airports are less than thirty minutes away from the city.

The Goddard Space Flight Center was established in 1959 as NASA's first space flight center. The Center's mission states: "THE MISSION of the Goddard Space Flight Center is to expand knowledge of the Earth and its environment, the solar system and the universe through observations from space. To assure that our nation maintains leadership in this endeavor, we are committed to excellence in scientific investigation, in the development and operation of space systems and in the advancement of essential technologies."

The Center is headquartered in Greenbelt, Maryland. It occupies 1,270 acres of land and 32 buildings. "Goddard's Greenbelt campus has personnel and facilities to create, build, test, launch and operate various satellite projects in support of Earth science, space science and advanced technology programs." [NASA 2000]

Chapter 3 - Literature Review

The background chapter provided the basic information needed to conduct the project in the given environment. Material in this chapter is intended to aid in understanding the scope of the project. Various areas of artificial intelligence and their relevant applications are examined.

3.1 Fuzzy Set Theory – A Brief Introduction

Lotfi A. Zadeh in the United States first introduced the theory of fuzzy sets in 1965. After Zadeh coined the term "fuzzy" and classified several distinctions of uncertainty, others furthered his research and began applying it all over the world. From this new understanding of uncertainty, or fuzzy information, it is attempted to make good and reliable decisions. These decisions are made through models that attempt to recover the information that is present in uncertain data. The models are of dynamic systems and it is essential to learn how to use these models and to learn how much faith can be placed on these them. [Kasabov 1996]

3.1.1 Fuzzy Arithmetic

Fuzzy arithmetic is a domain of fuzzy set theory. One way of grasping the concept of fuzziness is based on the interval of confidence. The interval of confidence is extended upon by considering the interval of confidence at several levels rather than at one unique level. Considering all the levels from 0 to 1 can further broaden this. The levels can then be used to provide a maximum of presumption at level 1 and a minimum of presumption at level 0. These presumption levels are suited to the concept of fuzzy numbers and the arithmetic applied to these numbers. [Kaufmann 1991]

3.1.2 Fuzzy Numbers

The construction of a fuzzy number can be explained quite simply. When constructing a fuzzy number the following three questions must be asked: "What is the smallest value given to this uncertain number? What is the highest? If only one value can be assigned to this number, what value should be chosen?" These three values are obviously different from each other, but allow the construction of a triangular fuzzy number. This number may be further developed later on with some refinements, leading to a convenient fuzzy number. [Kaufmann 1991]

3.1.3 Fuzzy Logic

The most unique property of fuzzy logic is that it deals with propositions that do not equate to TRUE or FALSE, as in propositional Boolean logic. These propositions, known as fuzzy propositions are composed of fuzzy variables and fuzzy values, which include all the values between two extreme values. The scientific name of fuzziness is multivalence, which means three or more possible values. This contrasts the accepted practice of separating everything into the categories of true or false, 1 or 0, which is termed bivalence or two-valuedness.

3.1.4 Fuzzy Systems

The essence of a fuzzy system defined by its three main components: (1) Fuzzy input and output, which are given by their fuzzy values (2) A set of fuzzy rules (3) A fuzzy inference mechanism. Fuzzy rules are used to deal with the fuzzy values. The fuzzy concepts are represented by a membership function, which determines the extent to which a value from a domain is included in the fuzzy concept. A reasoning method can be obtained by applying fuzzy inference based on fuzzy logic. This inference takes inputs, applies the rules and produces outputs. The outputs of the fuzzy system can be either fuzzy or exact. Fuzzy systems provide convenient and flexible methods at the sacrifice of depth and exactness. Although these systems may be said to lack "depth and exactness", in terms of what they represent they are often far more representative of the concept they represent than a single value. The term given to transforming the output membership function into a single crisp value is often referred to as defuzzification. The importance of fuzzy systems is that they are easy to construct, maintain and understand. Additionally, fuzzy systems are quite robust and inexpensive. [Kasabov 1996]

3.2 Distributed Systems

Distributed systems can be considered as the next "wave" of computing technology. A distributed system is usually a collection of independent computers linked together and to the user appears as one local system machine (Silberschatz & Galvin, 1999). This is in contrast to a network, where the user is aware that there are several machines, and their location, and functionality is not transparent. Distributed systems were mainly developed due to economic reasons (Tanenbaum, 1992). Early computers where typically large and expensive, thus, organizations would put all there money into a single mainframe computing system. The reasoning for this was based primarily on Grosch's law which, stated that the computing power of a CPU was proportional to the square of its price. Thus, by paying twice as much you could get four times the performance. Grosch's law was very representative of early computing technology.

However, with the advent of microprocessor technology Grosch's law no longer holds true (Tanenbaum, 1992). Today you can get a CPU chip that can execute more instructions per second than one of the largest mainframe systems of the 1980's for a fraction of the cost. Organizations have come to realize that they can purchase several cheap CPU's and put them together in a system instead of paying millions for one centralized system. Thus, distributed systems offer a much better price to performance ratio than large centralized systems.

3.3 Distributed Artificial Intelligence (DAI) and Multi-Agent Systems

Distributed Artificial Intelligence is focused on solving problems by utilizing both artificial intelligence techniques and multiple problem solvers (Martial, 1992). A minimum definition of a DAI system is that it must have at least two agents. The agents must have some degree of information and/or control autonomy and there must be some aspect of the agents that displays sophistication in an artificial sense. Distributed Artificial Intelligence is pursued because many Artificial Intelligence applications are inherently distributed (Weiss, 1999). For example, the ANTS project is spatially distributed. The satellites in the ANTS project will be spread out amongst the asteroid belt and will have to work together gathering, collecting, and interpreting data about it.

DAI systems work well when it comes to managing distribution of data, expertise, processing power and other resources compared to a single, centralized monolithic system (Martial, 1992). One advantage that DAI systems have is that they are faster at solving problems since they can make use of parallelism, which is the ability to simultaneous make use of more than one computer to solve a problem. DAI systems also have less communication traffic because they only need to transfer high level partial solutions to nearby nodes rather than raw data to centralized sites. In addition, DAI systems have more flexibility by having problem solvers with different abilities dynamically teamed up to solve a problem (Weiss, 1999). Splitting up a problem into parts and delegating those parts to specialized problems solvers allows for quicker results and greater reliability. Greater reliability is achieved by allowing a problem solver to take over the work of another problem solver that failed.

Another benefit of Distributed Artificial Intelligence systems is that they support the principles of modular design and implementation (Martial, 1992). A DAI design allows for the ability to structure a complex problem into relatively self-contained modules. This results in a system that is easier to build, debug, and maintain. Such a system is also more resilient to software and hardware failures.

Distributed Artificial Intelligence is divided into two subfields, distributed problem solving and multi agents systems (Martial, 1992). Distributed problem solving is a group of common collaborating agents that work in unison to solve a single task, like monitoring a network of sensors. In a pure distributed problem solving system a problem is divided into tasks, and special agents are designed to solve the tasks for the specific problem only. Thus, agents in a distributed problem solving system perform one specific job. Distributed problem solving can be looked at as a top down design for Distributed Artificial Intelligence since agents are designed to conform to the requirements specified at the top to solve a problem.

The other subfield of Distributed Artificial Intelligence, multi-agent systems, is a system where agents are autonomous (Martial, 1992). Multi-agent systems do not require restrictions to a single task like distributed problem solving systems do. The goal in a multi-agents system is to develop agents that can coordinate intelligent behavior among a collection of autonomous intelligent agents. Thus, the focus in a multi-agent system falls on how agents coordinate their knowledge, goals, skills, and plans together to solve problems.

Multi-agent environments exhibit three general characteristics. One is that multi-agent environments provide an infrastructure specifying communication and interaction protocols (Weiss, 1999). It is imperative in a multi-agent for different agents to be able to communicate with one another. In order for agents to communicate successfully, there must be standard from communication and interaction protocols that all agents use. Another characteristic of multi-agent environments is that they are typically open and have no centralized designers. In addition, any agent in a multi-agent system can have a special task to perform or be capable of performing several tasks. This is the main difference between multi-agent and distributed problem solving systems (Martial, 1992). In a distributed problem solving system agents work together to solve one single problem, in contrast to this agents in a multi-agents system may not only be working together towards a single goal, but also towards separate individual goals. A multi-agent system can thus be viewed as a bottom up designed Distributed Artificial intelligence system, since the agents are designed first, and the solution strategy for a given problem is specified later.

3.4 Agent Communication

Agents communicate with other agents in their system in order to better achieve their specific goals as well as the society/system in which they exist in (Weiss, 1999). Communication allows agents to coordinate their actions and behavior making the overall system more coherent. The better the coordination in a multi-agent system the more efficient it is. Coordination is negotiation among competitive or simply self-interested agents. In other words coordination is when agents to not share the same goals and are competing for resources. Systems with high coordination have to waste less time and energy dealing with issues such as contention, and deadlock. Cooperation is coordination among non-antagonistic agents (Weiss, 1999). Usually for cooperation to be successful, each agent must maintain a model of the other agents in the system, and also develop a model of future interactions.

Another important trait of multi-agents systems is coherence (Weiss, 1999). A problem that a lot of multi-agent systems face is achieving global coherence since there is usually not explicit global control. It is usually up to agents to figure out for themselves what goals they share with other agents in the system, determine common tasks, share information with one another, and avoid conflicts. In such systems it helps if there is some form of organization between the agents. For example, agents can be put in classes that play a specific role in the system. One class of agents could be responsible for gathering data, another class of agents could then be responsible for storing that data, and perhaps there could be another class of agents that issue commands to the other classes.