Preface

Advanced computational techniques for decision making on unmanned systems are starting to be factored into major policy directives such as the United States Department of Defence UAS Roadmap. Despite the expressed need for the elusive characteristic of "autonomy", there are no existing systems that are autonomous by any rigorous definition. Through the use of sophisticated algorithms, residing in every software subsystem (state estimation, navigation, control and so on) it is conceivable that a degree of true autonomy might emerge. The science required to achieve robust behavioural modules for autonomous systems is sampled in this book. There are a host of technologies that could be implemented on current operational systems. Many of the behaviours described are present in fielded systems albeit in an extremely primitive form. For example, waypoint navigation as opposed to path planning, so the prospects of upgrading current implementations are good if hurdles such as airworthiness can be overcome. We can confidently predict that within a few years the types of behaviour described herein will be commonplace on both large and small unmanned systems.

This research book includes a collection of chapters on the state of art in the area of intelligent machines. We believe that this research will provide a sound basis to make autonomous systems human-like.

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Editors

Intelligent Machines: An Introduction

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Abstract. In this chapter, an introduction to intelligent machine is presented. An explanation on intelligent behavior, and the difference between intelligent and repetitive natural or programmed behavior is provided. Some learning techniques in the field of Artificial Intelligence in constructing intelligent machines are then discussed. In addition, applications of intelligent machines to a number of areas including aerial navigation, ocean and space exploration, and humanoid robots are presented.

1 Introduction

"Intelligence" is an expression commonly used for humans and animals, and only until recently for machines. But what is intelligence? How can we say that this creature or machine is intelligent? Indeed, a lot of explanations and definitions for intelligence exist in the literature. Among them, a comprehensible excerpt from [1] with respect to intelligence is as follows.

> *"A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience"*

In general, it is believed that the main factors involved in "intelligence" are the capabilities of autonomously learning and adapting to the environment. So, unless the creature or machine learns from its environment, it may not be considered as intelligent. An interesting example is the behavior of the digger wasp, a *Sphex ichneumoneus* insect [2]. When the female wasp returns to its hole with food, she will first leave the food at the threshold and go inside the hole to check for intruders. If there is no intruder, she will take the food inside. However, if the food is moved, say a few inches, from the original position, she will put the food back on the threshold, go inside, and check for intruders again. The same procedure is repeated again and again if she found the food is displaced. This shows that the element of intelligence, i.e. ability to adapt to new circumstances, is missing in this behavior of the Sphex insect.

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When we talk about intelligent machines, the first thing that normally appears in our mind is robots. Indeed, robots have been invented to substitute humans in performing a lot of tasks involving repetitive and laborious functions, for examples pick-and-place operations in manufacturing plants. However, robots that are operated based on a programmed manner and in a fully controlled environment are not considered as intelligent machines. Such robots will easily fail when the application and/or the environment contain some uncertain condition. As an example, in applications that involve hazardous and uncertain environments such as handling of radioactive and explosive materials, exploration into space and ocean, robots that can react to changes in their surrounding are very much needed. As a result, robots have to be equipped with "intelligence" so that they can be more useful and usable when operating in uncertain environments.

To be considered as an intelligent machine, the machine has to be able to interact with its environment autonomously. Interacting with the environment involves both learning from it and adapting to its changes. This characteristic differentiates normal machines from intelligent ones. In other words, a normal machine has a specific programmed set of tasks in which it will execute accordingly. On the other hand, an intelligent machine has a goal to achieve, and it is equipped with a learning mechanism to help realize the desired goal [3].

The organization of this chapter is as follows. In section 2, some learning methodologies for intelligent machines are discussed. In section 3, applications of intelligent machines to a number of areas including unmanned aerial vehicles, robots for space and ocean exploration, humanoid robots are presented. A description of each chapter included in this book is presented in section 4, and a summary of this chapter is included in section 5.

2 Learning in Intelligent Machines

When tackling learning from the machine perspective, Artificial Intelligence (AI) has become one of the main fields of interest. The definition of AI can be considered from three viewpoints [4]: (i) computational psychology–mimicking and understanding human intelligence by the generation of a computer program that behaves in the same way; (ii) computational philosophy–formulating a model that is implementable in a computer for understanding intelligent behaviors at the human level; and (iii) machine intelligence–attempting to program a computer to carry out tasks, until recently, only people could do.

In general, the learning process in intelligent machines involves acquiring information about its environment, and deploying the information to establish knowledge about the environment, and, subsequently, generalizing the knowledge base so that it can handle uncertainty in the environment. A number of machine intelligence techniques have been developed to introduce learning in machines, e.g. imitation learning [5] and reinforcement learning [6]. For robot learning, researchers have proposed a multi-learning method that makes use of more than one learning techniques [3]. Besides, different aspects of research in robotics have been conducted, which include robot mobility and control [7], robot perception [8], as well as the use of soft computing techniques for intelligent robotic systems [9]. On the other hand, the divide and conquer principle is applied to the learning tasks [10]. Each algorithm is given a specific task to handle. The learning algorithms are chosen carefully after considering the characteristics of the specific task. Another potential solution to learning is intelligent agents. Agents collect data and learn about the surrounding environment, and adapt to it [11]. The learning process in agents also requires a self-organizing mechanism to control a society of autonomous agents [12]. It should be noted that the task of imparting learning into intelligent machines is not an easy one; however the learning capability is what makes a machine intelligent.

3 Application of Intelligent Machines

The applications of intelligent machines are widespread nowadays, extending, for example, from Mars rover invented by NASA to intelligent vacuum cleaners found in our homes. Some examples of intelligent machines are as follows.

3.1 Unmanned Aerial Vehicle (UAV)

There are some aerial missions and tasks that are not suitable for human pilots either because it is too dangerous like military operations, or it takes a long time in the air like mapping tasks. Yet, these tasks are important. UAVs have been invented to carry out such mission-critical tasks [13]. Typically, an UAV comprises onboard processing capabilities, vision, GPS (Global Positioning System) navigation, and wireless communication. One of the main functions of an UAV is to navigate in an uncontrolled environment, which also is often an unknown environment, safely, and, at the same time, to perform its required task [14]. What makes an UAV intelligent is the ability to fly to its target under varying conditions. As it is not possible to predict all possible navigation scenarios in one program, the UAV has to learn from its environment, and adapt to the changes as they occur in order to reach the destination.

An UAV used to collect data in the atmosphere between satellite and the ground base is created by National Oceanic and Atmospheric Administration (NOAA), USA. The UAV is able to fill the gap where land-based and satellite-based observations fall short, thus giving a view of the planet never seen before [15]. Another UAV, a version of the military MQ9 Predator B, is used by the Department of Homeland Security, USA to monitor remote and inaccessible regions of the border. The UAV is equipped with special cameras and other sensors, and is able to stay in the air for up to 30 hours [16].

Fig. 1. Flight test of the Avatar UAV
(copyright of Agent Oriented Software, used by permission)

On the other hand, a flight test of an agent-controlled UAV, the Avatar [17], has been successfully conducted in Australia, as shown in Figure 1. The Avatar is equipped with an intelligent agent-based control system, with the capability of real-time processing of flight and weather data, e.g. Avatar's position, air speed, ground speed, and drift, to assist the autopilot in determining the best route to fly.

3.2 Underwater Robot

Ocean exploration has attracted the attention of scientists for ages, as there are many parts of the oceans that are unknown to humans. Another purpose for exploring the oceans is because of commercial interests, e.g., communication cables, oil lines, and gas lines placed on the seabed. This has triggered researches into intelligent underwater robots for inspecting lines and cables faults, as well as for other scientific research purposes. Today, remotely operated vehicles (ROV) have been used as underwater robots, but controlling these vehicles requires high skills in an unknown environment [18]. An example of an underwater robot is shown in Figure 2. One of the applications of this robot is to inspect and repair underwater pipelines [19]. The robot is controlled from the surface with simple instructions, and it has to interact with uncertainty in the environment to complete a given task.

3.3 Space Vehicle

One of the ultimate applications of intelligent machines is in space exploration. In this domain, "Opportunity", as shown Figure 3, is one of the latest Mars rovers sent by NASA. Its mission is to explore Mars by maneuvering on the surface of Mars, and sending images and information back to Earth.

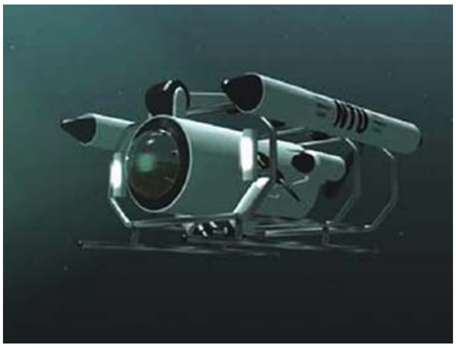


Fig. 2. The Underwater Robot
(copyright of Associate Professor Gerald Seet Gim Lee, Nanyang Technological University, Singapore, used by permission)

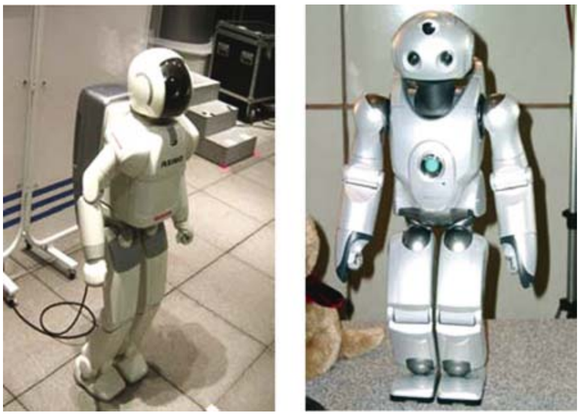
Fig. 3. The "*Opportunity*" Mars Rover
(public domain image, courtesy of NASA/JPL-Caltech)

3.4 Humanoid Robot

Humanoid robots are designed to imitate human movement, behavior, and activities. These robots can sense, actuate, plan, control, and execute activities. Among the successful humanoid robots include ASIMO [20] from Honda (Figure 4a), QRIO [21] from Sony (Figure 4b), and Actroid [22, 23] from Kokoro Co. and Advanced Media (Figure 5).

Each of these robots has its own salient features. ASIMO is a fast moving humanoid robot. It can walk to its goal while avoiding obstacles in its way. QRIO is the first affordable humanoid robot in the market for entertainment proposes. This robot can walk with children, dance with them by imitating their movements.

On the other hand, Actroid is an android that has its facial and body movements similar to real human movements. Actroid greets people in four languages (Chinese, English, Japanese, and Korean) and starts talking with



(a) ASIMO (b) QRIO

Fig. 4. Humanoid robots
(public domain images, courtesy of wikimedia commons)

(a) The Actroid robot (b) Face of Actroid

Fig. 5. Snapshots of the Actroid robot
(copyright of Aleksandar Lazinica, used by permission)

people when it hears "Hello". This office reception robot is also able to control its motions expressively within the context of a conversation, e.g., facial expressions, lip movements, and behaviour.

3.5 Other Attempts in Intelligent Machines

a. Unmanned Combat Air Vehicle (UCAV) project [24]: the objective of this project is to demonstrate the effectiveness of using UCAV to effectively and affordably prosecute twenty-first century lethal strike missions within the emerging global command and control architecture.

b. Micromechanical Flying Insect (MFI) project [25]: the objective of this project is to create an insect-like device that is capable of flying autonomously.
c. Medical micro-robot project [26]: this projects aims to create the world's smallest micro-robot as wide as human hair at about 250 micron. This micro-robot will be used to transmit images and deliver microscopic payloads to parts of the body outside the reach of existing catheter technology.

4 Chapters Included in this Book

This book includes nine chapters. Chapter one introduces intelligent machines and presents the chapters included in this book. Chapter two by Cummings et al. is on predicting operator capacity for supervisory control of UAVs. The authors have considered a cost-performance model in this study. Chapter three by Sujit et al. is on team, game and negotiation based intelligent autonomous UAV task allocation for a number of applications. The authors have also presented a scheme of searching in an unknown environment. Chapter four by Nikolas et al. is on path planning using evolutionary algorithms. The authors have used Radial Basis Function Neural Network in evolutionary environment in the design of their off-line path planner for UAV. Chapter five by Rathinam and Sengupta is on algorithms on routing problems related to UAVs. The authors have presented a class of routing problems and including review and recent developments.

Chapter six by Beard is on state estimation for micro air vehicles. The author has presented mathematical models for the sensors for multiple air vehicles. Chapter seven by Pongpunwattana and Rysdyk is on evolution-based dynamic path panning for autonomous vehicles. The algorithms take into account the uncertain information of the environment and dynamics of the system. Chapter eight by Prüter et al. is on evolutionary design of control architecture for soccer-playing robots. Artificial intelligence techniques are used to compensate the effect of slipping wheels, changing friction values, noise and so on. The final chapter by Gasper et al. is on robot perception through omnidirectional vision. The authors have examined how robots can use images which convey only 2D information to drive its actions in 3D space. The design of a navigation system considering sensor design, environmental representations, navigation control and user interaction is presented.

5 Summary

This chapter has presented an introduction to intelligent machines. A discussion on intelligence and the difference between intelligent and natural repetitive or programmed behaviors are given. The importance of an intelligent machine to learn from its changing environment and to adapt to the new circumstances is discussed. Although there are various machine intelligence techniques to impart learning to machines, it is yet to have a universal one for this purpose. Some applications of intelligent machines are highlighted, which include unmanned aerial vehicles, underwater robots, space vehicles, and humanoid robots, as well as other projects in realizing intelligent machines. It is anticipated that intelligent machines will ultimately play a role, in one way or another, in our daily activities, and make our life comfortable in future.

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