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1ISRO19AI Artificial Intelligence for Space Applications

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FORMERLY EUROPIAN SPACE AGENCY LANGUAGE

Summary. The ambitious short-term and long-term goals set down by the various national space agencies call for radical advances in several of the main space engi- neering areas, the design of intelligent space agents certainly being one of them. In recent years, this has led to an increasing interest in artificial intelligence by the entire aerospace community. However, in the current state of the art, several open issues and showstoppers can be identified. In this chapter, we review applications of artificial intelligence in the field of space engineering and space technology and identify open research questions and challenges. In particular, the following topics are identified and discussed: distributed artificial intelligence, enhanced situation self-awareness, and decision support for spacecraft system design.

12.1 Introduction

In the second half of 2003, the European Space Agency (ESA) delivered a [illegible] will probably be constituted by a large number of heterogeneous

space agents (intended to be satellites, humans, robots, modules, sensors, and so

2000, 2004, and 2008).

12.2 Distributed Artificial Intelligence

At the end of the 1980s, the artificial intelligence community started wondering whether

intelligence resulting in a

distributed form throughout an agent started the study of intelligent systems made by
[illegible]
swarm intelligence and distributed computing.

12.2.1 Swarm Intelligence

[1] The so-called social component in the PSO algorithm requires at each step for each agent to know the best solution found so far by the entire swarm. Interagent communication is, in this case, direct and unlimited in range.

More recently, the idea of a number of satellites flying in formation has been used in [illegible] [McQ97] have taken the ap-

[2] At the time of writing, CLUSTER II is the only one operational.

proach of defining an artificial potential field to model the environment. The [illegible] swarm behaviors derived by introducing electrostatic interactions between

12.2.2 Distributed Computing

A second example of distributed artificial intelligence with specific applications to [illegible] other. This requirement is the main limitation to

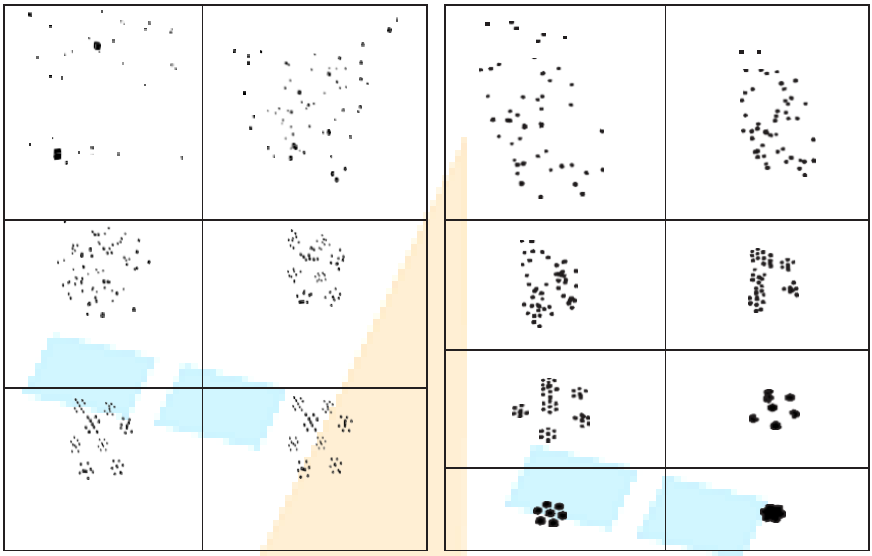

Fig. 12.1. Two examples of orbital swarms assembling a given structure (source: [IP07]).

the use of distributed computing. The forthcoming sections introduce, briefly, two examples of space applications suitable for distributed computations.

Analysis of Large Quantities of Data

The main purpose of most of the commercial satellites currently orbiting Earth is to provide [illegible] Satellites continuously [illegible] large amounts of [illegible] to [illegible] stations on the ground. [illegible] Depending on the [illegible] the data [illegible] Sometimes [illegible] the [illegible] Moreover, [illegible] Monte Carlo simulations of constellation architectures.

[IMN05]. In these types of applications no dependency is present between the different parts of the solution. Each part is evaluated independently from the others and the whole solution is the collection of all the parts. Therefore, the problem can be easily solved in a parallel way and by the different nodes. See the whole solution from the different parts learned by the

Distributed Solving of Global Optimization Problems

Distributing global optimization tasks over a large network of computers is

In the rather generic form

$$\min : f(x) \quad \text{subject to} : g(x) \leq 0$$

with $x \in R^n$. The problem dimension n depends on the type of trajectory

optimization problem has beenperformed by ESA

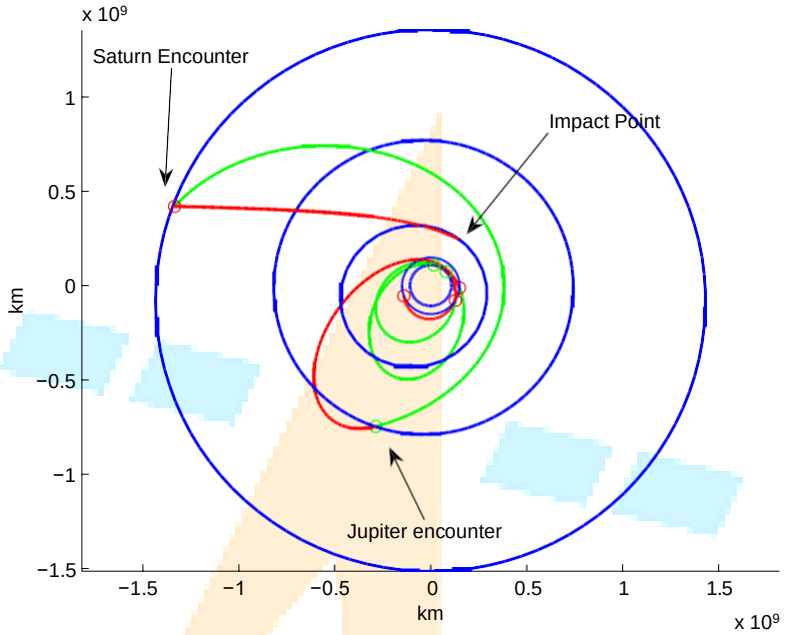

Fig. 12.2. An optimized Earth-Venus-Earth-Venus-Earth-Jupiter-Saturn-asteroid trajectory.

researchers, who solved a complicated MGA transfer distributing a differential

(subpopulations) extracted from a larger population stored in the server, demes

[3] There is actually no mathematical guarantee that the solution found is the global optimum, but the experiment improved previous solutions by approximately 10%.

which then takes care of the reinsertion of the drones. According to the results [illegible] whole trajectory optimization process without any expert supervision.

12.3 Enhanced Situation Self-Awareness

[illegible] system-level managers;

advanced onboard and ground based mission and maintenance planners and a host of technologies with the goal of real-time and life-cycle vehicle health information, [illegible] decision making.

12.3.1 Data-Driven Approaches

The application of data driven approaches to flight time series analysis is being [illegible] trend of the parameters by inferring association rules

from data by means of the a priori algorithm. Therefore, the fault occurrence data [illegible] similar events. Unexpected fault modes therefore cannot be detected by the algorithm.

12.3.2 Model-Based Approaches

Most of the model-based approaches for enhanced situation awareness that have [illegible] result

from a variation of the spacecraft geometry (e.g. from the deployment of antennas, solar panels, etc.) or from a change in the mission phase (e.g. from the nominal mode to the safe mode). The problem is approached using graph theory.

12.4 Decision Support for Spacecraft System Design

As the complexity of space systems increases, innovative approaches to system design are being explored. Space systems are the result of the integration of several subsystems, each of which is designed by a specialist. Typically, the design process is sequential and iterative. Each specialist would provide a sub-system design that would satisfy the requirements and constraints imposed by the mission and by the other subsystems. The design would then be passed on to the next specialist, who would add his subsystem to the overall design. The process would continue until the last specialist had added his subsystem to the design. Then the whole design would be passed back to the first specialist, who would begin another iteration, refining the design. This process would continue until the design converged to a satisfactory solution. Concurrent engineering is a design methodology that aims to capture the reasoning of the experts toward an optimal and robust design.

[4] A spacecraft is constituted by the following subsystems: attitude determination and control, telemetry tracking and command, command and data handling, power, thermal structures and mechanisms, and guidance and navigation [WL99].

[5] The term optimization is not used here in the strict mathematical sense but rather to indicate any procedure that aims to find a solution that is either optimal or suboptimal.

Therefore, the spacecraft design started to be viewed as the solution of an

without knowing the joint

[6] In the case of spacecraft design, the objective function is most of the time the cost, which is ultimately proportionally linked to be the spacecraft's total mass.

[7] For an extensive qualitative and quantitative overview of these uncertainties, the reader may consult [Thu05].

distribution of the uncertain variables or having sufficient amounts of data samples

design variables [RFD 07].