Active Vision in Satellite Scene Analysis

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INTRODUCTION

In earth observation or planetary exploration it is necessary to have more and more autonomous systems, able to adapt to unpredictable situations.

This imposes the use, in artificial systems, of new concepts in cognition, based on the fact that perception should not be separated from recognition and decision making levels. This means that low level signal processing (perception level) should interact with symbolic and high level processing (decision level).

This paper is going to describe the new concept of *active vision*, implemented in Distributed Artificial Intelligence by Dassault Aviation following a "structuralist" principle. An application to spatial image interpretation is given, oriented toward flexible robotics.

TECHNOLOGICAL PRINCIPLES

In Cognitive Sciences, it is admitted that autonomous systems function following two main principles [12].

First Principle : Internal Organization

This means that an autonomous system has to be internally distributed and self-organized to catch the distributed knowledge of the outside environment. This principle determines the "structuralist" hypothesis.

Second Principle : External Interaction

This means that the system has to interact with its environment to actively adapt its own perception to unpredictable surrounding.

Those two principles are currently driving research in industry in complex system design, to establish a theory for adaptive cognitive distributed systems or multi-systems [9].

Knowledge Representation

In terms of knowledge representation, the classical assumption of the existence of a formal objective model *(cognitivist hypothesis)* becomes insufficient for autonomous system design. It is necessary, in the way this knowledge is processed by the autonomous system, to add a subjective link between the outside word and the system. This link is named an "eco-relation".

In other words, knowledge of an autonomous system cannot be defined only objectively, but has to be actively re-defined, on line, by the subject itself, in a phenomenological approach .*(constructivist hypothesis)* [8,11]. This is the foundation of active cognition, or active vision.

To implement active cognition principles, Dassault Aviation realizes fundamental studies in distributed systems, based on "structuralism" [2]. As it is proved that an adaptive autonomous system is structurally distributed (internal organization), the point is to study the relation between the connectivity of a large population of interactive internal components and the emergence of their collective adaptive behavior.

These scientific studies at Dassault Aviation are founded on Neurosciences [4] and non linear physics [1,10].

CURRENT REALIZATION : ACTIVE COGNITION MULTI-AGENT ARCHITECTURE

A "structural" generic multi-agent architecture is currently developed at Dassault Aviation. It is applied to different domains.

Architecture Main Characteristics

A Recursive Structural Organization (First Principle of Autonomy) The multi-agent architecture is recursively structured with a given organization composed of macro-structures and micro-structures (figure 1).

The macro-structures correspond to autonomous feedback loops which are groups of agents organized in a servo-control manner. Dedicated links between the agents structure the loops, interconnecting low level agents (subsymbolic signal processing) and high level decision and interpretation agents (symbolic processing).

The micro-structures are sub-agents wich correspond to the decomposition of the macro-structure agents. The structural links between macro and micro structures implement the semantic links between global and local perception, as it is known to be in the cerebral cortex [3].

The multi-agent architecture developed by Dassault Aviation differs from the other ones by a dedicated organization and a recursivity from macro to micro structures. This implements and controls the emergence phenomena in interactive micro-structures, and their collective behavior in a non linear dynamics.

Multi-Constructivist Agents (Second Principle of Autonomy). Each autonomous feedback loop is driven by a *distributed control* implemented in a "constructivist" agent attached to the loop. The "constructivist" agent has just enough knowledge so that one feedback loop can be autonomous for the function it processes.

The adaptation of the system to unpredictable environment is realized by a cooperative behaviour between the loops, via their "constructivist" agents. This cooperative processing realizes the necessary interaction between autonomous macro-structures and their environment.

First Results in Earth Observation Domain

A first prototype of structural multi-agent architecture has been realized. It is composed of four autonomous macro-structures. They are implemented on 4 SUN-workstations, each structural loop corresponding to one station. The 4 workstations constitute a cooperative multi-system.

Each loop implements a cognitive function as recognition, localization or scanning. The active recognition process has been realized in the recognition loop, where the sub-symbolic agent (agent LINE) is composed of image processing algorithms (Visilog software). The recognition agent (agent RECO) is a neural network (Perceptron membrane) [5] trained to recognize pieces of communication ways in an image (road, railways, rivers). The two agents, LINE and RECO, work cooperativelly together. For each new piece, e.g. a piece of road, the feedback recognition loop re-defines, on line and <u>subjectively</u>, the local pattern of a road, so that it can be eventually recognized by the neural network : <u>phenomenological approach</u>. This method has been proved efficient especially in the critical cases as, for example, road crossing points or road-railways junctions.

Each loop works under the control of a "contructivist" agent. The total communication ways are recognized using the cooperation between several loops (or several workstations). Among those is a SCAN structure which follows, piece after piece, a complete communication way (figure 2). Dassault Aviation has developed a new theory in servo-control shape tracking based in advanced control theory [7]. The theory has introduced the new concept of "Shape Lyapunov Functions" to control the derivative of a shape observed by a moving camera [6]. These theoritical results are currently applied at Dassault Aviation in active vision for image interpretation. This process is considered as an active target tracking.

TOWARDS ACTIVE ROBOTICS

The structural multi-agent architecture is designed to simulate perception-based control multi-system as active vision system. Each macro-structure represents one autonomous system, which is by definition in interaction with its environment. Each macro-structure could be embedded in an active autonomous robot. This active robotics processing is simulated in satellite scene analysis on 2 macro-structures, the RECOGNITION and the SCAN structures, as already shown in figure 2. The SCAN structure works as a mobile robot.

The structural architecture implements also the multi-constructivist cooperative process between autonomous macro-structures. This could be used to implement and embed a cooperative work between active robots of a team in *collective robotics*. This active collective robotics principles could be applied to planetary exploration.

CONCLUSION

The *"structural" multi-agent architecture* is a first step toward flexible, modular, cooperative multi-system, built on autonomy principles. The *active vision* principle allows the system to adapt to unpredictable situations.

First experiments are at the moment performed in satellite image interpretation for ecological crisis management and military applications. Cognitive functions as recognition, localization, scanning, are implemented on autonomous macro-structures. Their cooperation is simulated on a network of four cooperative SUN workstations. The experiments could be extended toward active collective robotics, applied for exemple to earth observation or planetary exploration.

The recursive structural principles of the multi-agent architecture developed by Dassault Aviation could be generalized for the design of aerospatial multi-systems in which each system could embedded autonomous structure, all the structures cooperating together (application to aerospatial CIS, Communication and Information System).

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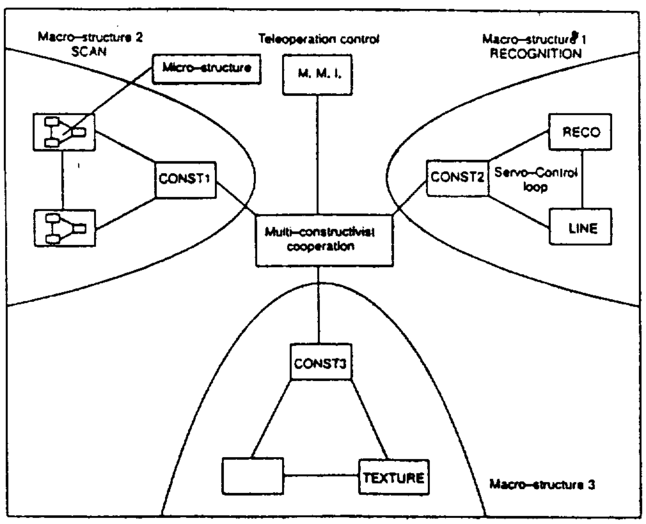

Fig. 1 : Recursive structural organization where each servo-control loop is an autonomous macro-structure driven by a constructivist agent, the loops cooperating together.

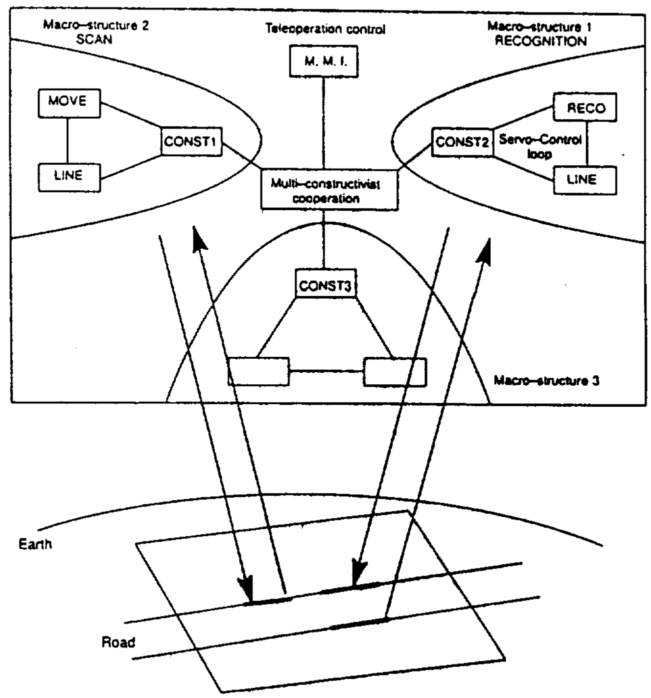

Fig. 2 : Functional cooperative processing between two autonomous macro-structures for active road tracking. The SCAN structure follows the track while the RECOGNITION structure adapts the shape of a road to the recognition process.