ARTIFICIAL DESIGN AND PLAN GENERATION BY LEARNING: A MODEL OF CONTROL- BASED COORDINATION

K. ALEXIOU, T. ZAMENOPOULOS
UCL, Bartlett School of Graduate Studies, Centre for Advanced Spatial Analysis (CASA), 1-19 Torrington Place, London WC1E 6BT, UK

INTRODUCTION

The generation of architectural and urban designs and plans is an intrinsically distributed task. It involves the coordination of multiple decisions supported by distributed knowledge sources (human experts and stakeholders or their domain models). In this presentation we introduce the idea of coordination as a tactic to search the decision space for a series of innovative plans and reach solutions that are potentially able to tune the diverse information resources and requirements.

We develop a formal model of coordination in design and planning problems, as a distributed learning control process over some basic design activities as proposed by Gero (2000): formulation, synthesis, analysis, evaluation and reformulation. The computational model performs two basic functions: first, learns from its environment input-output patterns of behaviour in on-line or off-line mode (based on neural network techniques) and second, utilizes this knowledge as a guideline to search for coordinated solutions (based on adaptive control methodology). We present some experiments and simulations of the model applied on a simple location and layout problem.

CONTROL- BASED COORDINATION IN DESIGN AND PLANNING

We consider that design and planning descriptions are built on distributed domain problems and partial proposals developed by agents (human or artificial). For instance, a trivial location and space layout problem may involve three groups of agents: one that defines the location and a suitable distribution of volumes, another that designs a potential spatial distribution of rooms and a third one that is involved in the structural engineering of the building. Each agent within a group is self-interested and represents a partial component of the overall description.

The design problem can then be considered as a coordination problem among the individual requirements and evaluations of agents that express domain-dependent problems; the decision space can be defined by the sum of the potential solutions that fulfil those diverse requirements. Each self-interested agent carries out two combined control-based activities: the first alludes to a synthesis-analysis-evaluation route expressed as a function among Structural Decisions S, Expected Behaviour B_e and Actual Behaviour $B_{s.}$ The second activity alludes to an evaluation-formulation-reformulation route expressed as a function of Actual Behaviour B_s, Expected Function F_e and Actual Function F_b (to some extent following Gero, 2000).

The objective of each agent is to find a suitable path of structures S that lead the behaviours B_s, to follow a reference (expected) behaviour B_e, despite uncertainties and despite exogenous disturbances Sd produced by other agents' decisions. The expected behaviour B_e is defined by a reference model, which is developed following a similar control process. The objective in that case is to find the appropriate behaviours B_e that lead the function F_b, to follow a reference (expected) function F_e, despite uncertainties and despite exogenous disturbances Bd (figure 1).

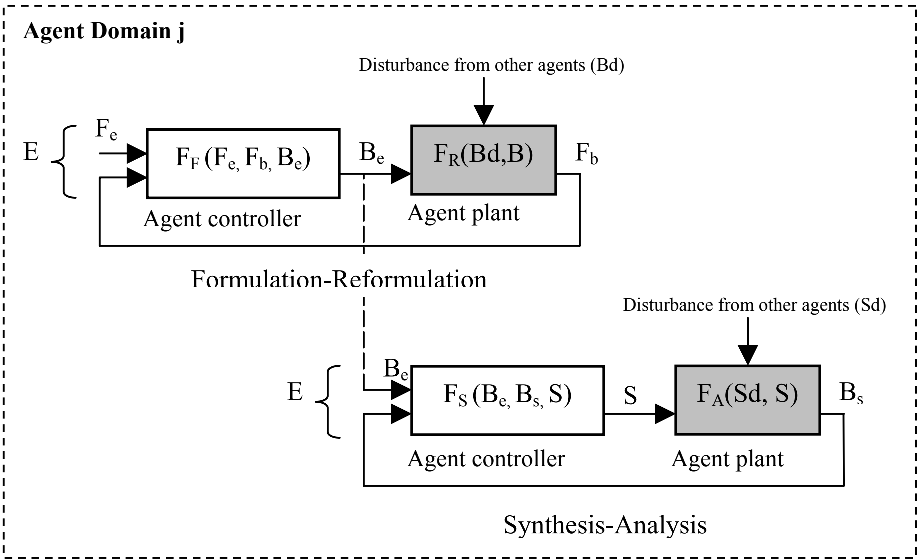

Figure 1 Plan and design generation as a control process. B= behaviour, F= function and S= structure, F_A=Analysis function, F_S=Synthesis function, F_F= Formulation function and F_R=Reformulation function. E= Evaluation

To sum up, what we call *synthesis* is the control process that aims to stabilise the state space (behaviour) of an agent according to a reference value for the behaviour (B_e); and *formulation* is the control process that aims to stabilise the state space (function) of an agent according to a reference value $F_{e.}$ The control signals St,…, St+n produced by this combined control process consist a set of evolving plans (proposals) for the design and planning problem in hand. The process of artificial generation of plans based on learning control is a process of self-adaptation of agents that leads to coordination of their distributed descriptions.

EXPERIMENT-SIMULATIONS

The model is developed and simulated in a MATLAB-SIMULINK (Mathworks, Inc) environment. We are experimenting with neural network based control architectures and more specifically with Adaptive Backthrough Control structures. These structures typically use two neural networks: the Controller and the Plant Model (figure 2). The plant model is trained to approximate the plant (agent) by learning on line or off-line input-output patterns of the agent behaviour. These patterns are used "backwards" as a guideline for the controller (Kecman, 2001).

The agent (plant) can be guided by human operators or artificial mechanisms, and represents design descriptions. We experiment with formal mathematical functions and/or fuzzy systems, to built formal descriptions of the plant, however we also consider the possibility of experimenting with architectures that incorporate human interaction and real time design.

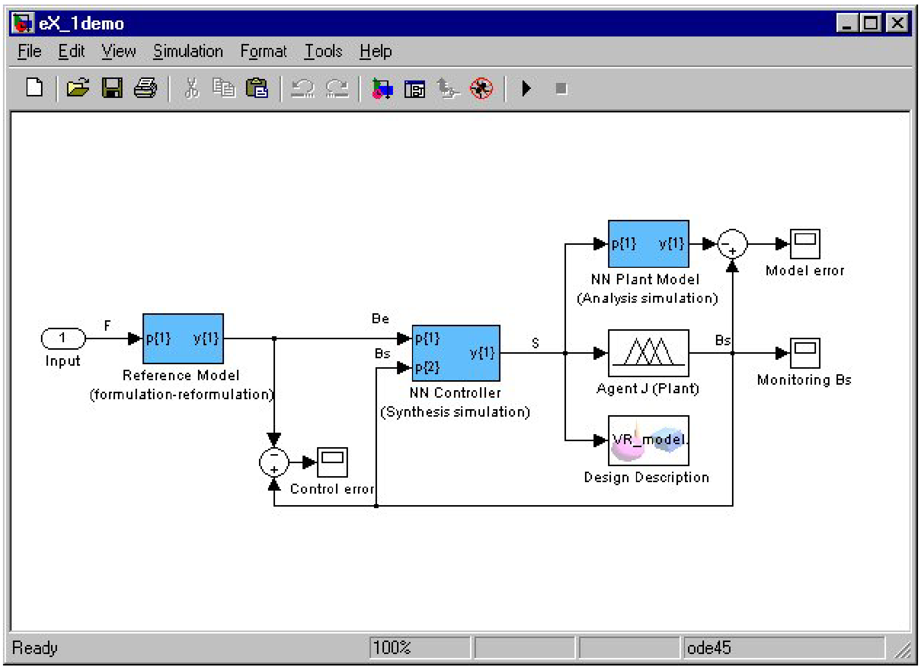

Figure 2 The control model.

For the case study we consider a simple design and planning problem, which involves decisions about the location and general spatial layout of a building. This problem involves three elementary classes of agents related to the intended group of functions: housing unit, shopping unit and open/semi-public space. In each case structural decisions involve decisions about the location, topology and geometry of the building. The behaviours are built on location analysis (land use suitability, accessibility), environmental measurements (noise), architectural criteria (accessibility, visibility, orientation) and economic measurements (cost-benefit evaluations).

The overall model is connected to the Virtual Reality Toolbox (Mathworks, Inc), which supports user interaction and facilitates visual simulation of the evolution of the design descriptions.

CITED REFERENCES

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Kecman, Vojislaw: *Learning and Soft Computing. Support Vector Machines, Neural Networks and Fuzzy Logic Models*, MIT Press, 2001.