Parameter Estimation for Adaptive Model-Based Reasoning about Environmental Dynamics

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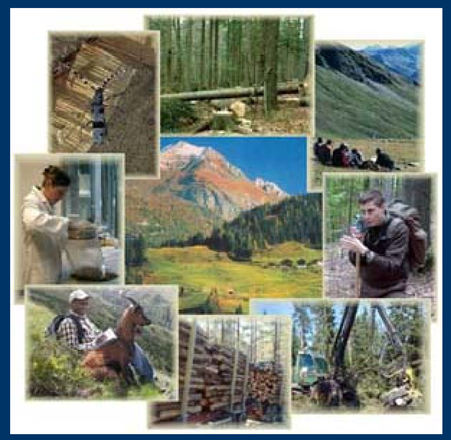
ABSTRACT

The environments in which agents are used often may be described by dynamical models, for example in the form of a set of differential equations. In this paper an agent model is proposed that can perform model-based reasoning about the environment, based on a numerical (dynamical system) model of the environment. Moreover, it does so in an adaptive manner by adjusting the parameter values in the environment model that represent believed environmental characteristics, thus adapting these beliefs to the real characteristics of the environment.



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INTRODUCTION

- One of the challenges for an agent is to be able to reason about the environmental dynamics in order to predict future states of the environment and to (avoid or) achieve the occurrence of certain (un)desired states in the future (Figure 2)
- A dynamical model usually involves two different types of concepts:
  - ✓ *state variables* representing *state aspects* of the environment
  - ✓ *parameters* representing *characteristics* of the environment
- The example environment for the agent considered here involves physical and biological elements.
- The example model for the environmental dynamics, used for the purpose of illustration deals with two species s1 and s2 which both depend on the factor moisture of the soil. Figure 1 shows a causal diagram for this example model.
- A differential equation form for the example environment model is as follows:

$$d\,s_1(t)/dt = \beta\ ^*s_1(t) * [c(t) - a_1{}^*s_1(t) - a_2{}^*s_2(t)]$$
$$d\,s_2(t)/dt = \gamma\ ^*s_2(t) * [c(t) - b_1{}^*s_1(t) - b_2{}^*s_2(t)]$$
$$d\,c(t)/dt = \omega^*(\eta\ m(t) - c(t))$$
$$d\,m(t)/dt = \Theta * (\lambda\ w - m(t))$$

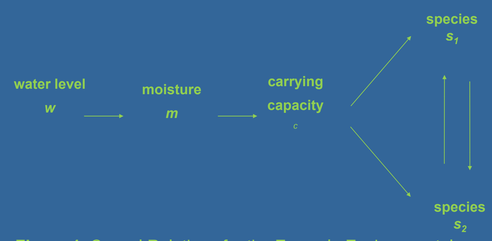

Figure 1. Casual Relations for the Example Environmental Model.

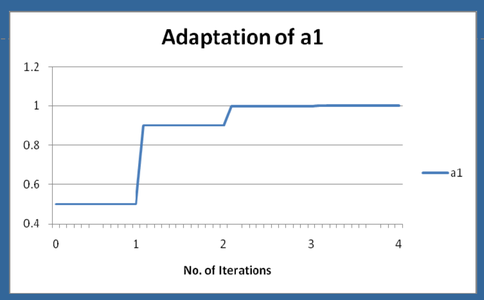

Chart 1. Adaptation process of a1

METHODS AND MATERIALS

- The agent
  - ✓Sets initial beliefs for parameters
  - ✓Predicts the environmental state for after say X years.
  - ✓Predicted and observed values of that state variable at time X are passed to the adaptation process.
  - ✓Tries to minimize the difference between predicted and desired values.
  - ✓This process of adaptation is kept on going until the difference is negligible, i.e., until the agent has an accurate set of beliefs about the environmental characteristics.

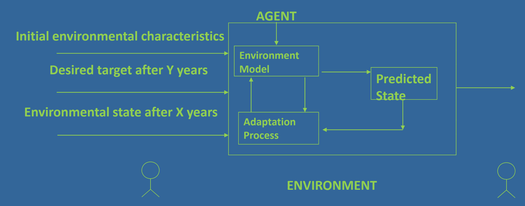

Figure 2. Model Based Agent Model.

- Differential equations for the sensitivities of values of the variables w.r.t. the parameter a1 are obtained by differentiating the original differential equations for a1:

$$(\partial s1/\partial a1)(t+\Delta t) = (\partial s1/\partial a1)(t) + \beta * [(\partial s1/\partial a1)(t) * \{c(t) - a1{*}s1(t) - a2{*}s2(t)\} + s1(t) * \{(\partial c/\partial a1)(t) - s1(t) - a1{*}(\partial s1/\partial a1)(t) - a2{*}(\partial s2/\partial a1)(t)\}] * \Delta t$$

$$(\partial s2/\partial a1)(t+\Delta t) = (\partial s2/\partial a1)(t) + \gamma * [(\partial s2/\partial a1)(t) * \{c(t) - b1{*}s1(t) - b2{*}s2(t)\} + s2(t) * \{(\partial c/\partial a1)(t) - b1 * (\partial s1/\partial a1)(t) - b2{*}(\partial s2/\partial a1)(t)\}] * \Delta t$$

$$(\partial c/\partial a1)(t+\Delta t) = (\partial c/\partial a1)(t) + (\eta * (\partial m/\partial a1)(t) - (\partial c/\partial a1)(t)) * \omega * \Delta t$$

$$(\partial m/\partial a1)(t+\Delta t) = \partial m/\partial a1)(t) + (-(\partial m/\partial a1)(t)) * \Theta * \Delta t$$

- Simulation result for a1 are shown in Chart 1 & 2
- Similarly other parameters including a2, b1, b2, β, γ are also estimated in same way and there collective results are shown in Chart 3.

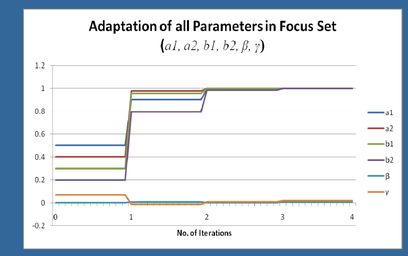

Chart 1. Adaptation of all parameters in focus set.

CONCLUSIONS

- In this paper an agent model is proposed that can perform model-based reasoning about the environment, based on a numerical (dynamical system) model of the environment.
- It does so in an adaptive manner by adjusting the parameter values in the environment model that represent believed environmental characteristics, thus adapting these beliefs to the real characteristics of the environment.
- The described agent model can be used for any agent with an environment that can be described in a continuous manner by a dynamical system (based on a set of first-order differential equations).
- For future research, one of the plans is to validate the model using empirical data within an example domain.
- Other approaches for sensitivity analysis can be used to compare the convergence and speed of the adaptation process.

Chart 2 Trend in change of densities of species s1 during the adaptation process of a1.