Earth Sciences Sector

Agent-based Modelling of Human Response to Climate Change in the Canadian Prairies

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Reducing Canada's vulnerability to climate change

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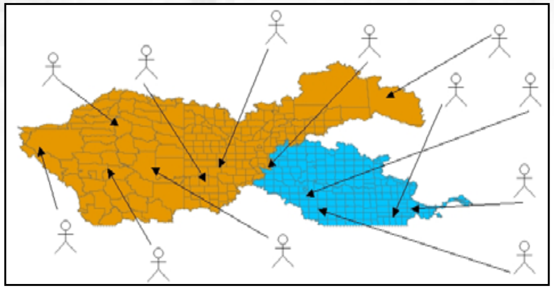


Agents interact with the environment through sensors and actuators.

South Saskatchewan River Basin

Assiniboine River Basin (blue)

Beliefs
Desires
Intentions

Beliefs = Data | Desires = Goals | Intentions = Plans

BDI Model of Behaviour

Beliefs encompass an agents' perception of his environment, others, trends, patterns, history and so on. They represent an agents' *perceived world knowledge*.

Examples: percepts from environment such as weather, market (including trends & patterns), economy, water availability.

Desires refer to goals, objectives, or any state the agent is programmed to bring about.

Examples: income stability, water supply stability, work less for greater payoff

Intentions refer to states of affairs that an agent has chosen and committed to. They tend to lead to *action*, and they typically *persist* or are not lightly abandoned. Often thought of as *currently executing plans*.

Examples: seek off-farm employment, raise more livestock and grow less crops, switch from crop A to crop B.

Abstract

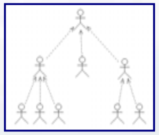
The impact of climate change on our society is strongly tied to how we choose to respond to it, adapt to it, and how we plan for change. This means that decisions will have to be made, at every level, the net effect of which is to map out an overall adaptation strategy. We aim to model the response of Prairie farmers to climate, policy and socioeconomic scenarios as part of a larger integrated assessment modelling system (IAM). This human response component, characterised by decision making, can be modelled using various techniques with varying degrees of success. For example, rule-based approaches, such as expert systems, tend to assign exact responses to every possible combination of circumstances that may arise. Optimisation approaches work to optimize the economic standing of an individual (Neoclassical) or equilibrate the payoffs of members of a group (Game Theory) engaged in negotiation or competition. Agents, apart from being the quintessential framework for modern artificial intelligence (AI), have the added advantages of autonomous decision making, decision making in the face of uncertainty, and communication both with one another and their respective environments. They may also take advantage of aspects from other approaches where appropriate. We thus aim to design and implement a multiagent system that relies on *Decision Theory* [3] and the *Beliefs, Desires, Intentions* (BDI) agent model [1,3] as a decision making framework for farmers facing changing climate, market and policy situations. Thus, we do not tell the system how to react to every possible scenario, but rather we endow it with the ability to decide for itself, *autonomously*.

In the Canadian Prairies, climate change is expected to impact crop and livestock industries. One of our main objectives is to assess adaptive capacity (autonomous and interventive) and community vulnerability under climatic, socio-economic and policy scenarios and to link the adaptation issue with the priority issues of policy agencies, facilitating the incorporation of adaptation into policy and decision making. This requires that the agent-based model interact with and draw from simulated climate, crop, livestock, population, policy and water models.

The agent-based model will contribute to the following objectives:

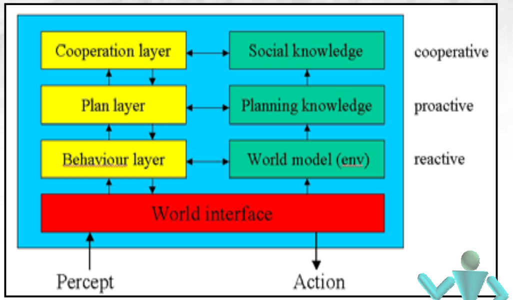
- Assessing the impacts of climate change, including droughts, on the yields of the crops and grasses that are currently grown or potentially could be grown in the Prairies.
- Identify appropriate time frames and spatial locations of adaptation with consideration to such constraints as water availability and the often lagged-feedback of human response to changes (i.e., the transitional process of adaptation), particularly land use change,
- Estimate the "net", direct impacts and costs of future climate change on Prairie agriculture under different greenhouse gas mitigation scenarios.

Intelligent Agents



1. Typical agents may have roles, responsibilities, permissions, beliefs, desires, intentions, preferences and communication protocols.
2. Agents may be grouped. A group of agents, for example, might share a common goal, orientation, or task. They may also be organised into a decision-making hierarchy.
3. Agents are equipped with decision making tools. Reasoning can be reactive, proactive or social.
4. They respond to a given scenario by selecting actions from a set of options or *capabilities*.
5. Each action or series of actions leads to *consequences*. Valuing these consequences helps weigh factors that contribute to decision making. Agents should at least have a probabilistic idea of the possible consequences of their actions.
6. Agents have become the quintessential framework for AI, and are being used for distributed/concurrent systems, simulation, land-use change, economics & game theory, social science, atomic modelling and many other purposes.

Decision Theory = Utility Theory + Probability Theory



Agent Decision Making Architecture

There are many agent decision making architectures to draw from. To the right is one that can be applied to our situation (InteRRap[2]). It is a vertically-layered two-pass architecture with three control layers. A control layer represents a level of planning or decision making. Sensory input (from the "world") and action output (applied to the the world) are dealt with by at most one layer.

Each layer has associated with it a knowledge base, that is, a representation of the world appropriate for that layer. Bottom-up activation occurs when a lower layer passes control to a higher layer because the lower layer is not capable of dealing with a situation requiring action. Top-down execution occurs when a higher level makes use of lower level facilities to achieve a goal. Integral to this scheme is a situation recognition and goal activation function. Note the similarity to the decision-making structure in a company or government organisation [1].

References

[1] Wooldridge, M., *An Introduction to Multiagent Systems*, John Wiley & Sons Ltd, West Sussex, England, 2002

[2] Muller, J. A cooperation model for for autonomous agents. In Intelligent Agents, V (eds J.P. Muller, M. Wooldridge and N.R. Jennings), LNAI Volume 1193, pp245-260. Springer, Berlin, 1997.

[3] Russel, J. and Norvig, P., Artificial Intelligence: A Modern Approach, Second Edition, Pearson Education Inc., New Jersey, 2003

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