

Intelligent Agents in the Australian Bureau of Meteorology

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ABSTRACT

The Australian Bureau of Meteorology is the national weather service of Australia. It has a strong need for complex and evolving systems for managing its weather forecasting, monitoring and alerts and is currently updating and reviewing software and processes to this end. The rapidly growing area of intelligent agent technology is an excellent candidate for the kind of distributed, complex and open system that is required. However in order for intelligent agents to be successfully used in this kind of system, there are some fundamental questions that must be addressed, such as how agents will find and use newly added services and how services will communicate with each other, given that they are developed independently.

The Bureau environment is an excellent test bed for these fundamental research questions, as it is a highly computerized information processing organization, with a mixture of humans and existing systems. An intelligent agent operating in this system would be able to act autonomously, making optimal decisions and finding the best possible way of achieving goals in the given environment.

The key objective of the project is to develop the required mechanisms to allow agents to locate and make use of data and services in a distributed open system. Specific technical objectives are:

- To develop system infrastructure and architecture that facilitates agents (and other software) working together.
- To develop mechanisms that support dynamic and evolving systems of agents where software agents may be added — or removed — at any time.
- To identify appropriate languages for the description of data to allow sharing and understanding of data by agents with differing but related ontologies.

In this paper we describe the project which is intended to fulfill these objectives.

1. INTRODUCTION

The Australian Bureau of Meteorology¹ head-quartered in Melbourne is the national weather service of Australia. It has a strong need for complex and evolving systems for managing its weather forecasting, monitoring and alerts and it is currently in the process of updating and reviewing software and processes to this end.

¹<http://www.bom.gov.au>

In this paper we describe the requirements within the Bureau for “Intelligent Alerts”, a system for informing forecasters of significant events in the weather, and for a “personal digital assistant” (PDA) for assisting forecasters in their work. We then go on to describe an existing agent system within the Bureau that currently detects microbursts. We come to the conclusion as a result of this experience that agent networks are a strong contender for satisfying Bureau requirements. In Section 4 we describe a pilot study now being conducted in which agents are trialled in a limited forecasting environment, and in Section 5 we list some tasks for agents we envisage in the future. In Section 6 we discuss research issues raised by these tasks.

2. ALERTING REQUIREMENTS

The Forecast Streamlining and Enhancement Project (FSEP) is a major project within the Australian Bureau of Meteorology. FSEP seeks to improve the quality, quantity, consistency and timeliness of weather products and services to the community and major clients such as the aviation industry, fire fighters and emergency services. Increasingly clients require real-time alerting of significant weather events. To improve the timeliness of weather alerts to clients, and to help streamline the work-flow of forecasters, intelligent alerting within the forecast system has a high priority in FSEP.

There is a particular requirement for improved aviation forecasts, and an important component is the rapid amendment of forecasts as soon as the need for amendment is indicated. This may be achieved by continual comparison of weather conditions against forecasts, which would be labour intensive if done by humans. An automated alerting system can perform a continuous weather watch and ensure forecasters will be alerted to significant weather developments in real time so that amendments may be quickly issued. Less severe weather changes will also be alerted by the system. The quality and timeliness of current aviation forecasts will thus be continuously monitored and corrected.

The Australian Integrated Forecast System (AIFS) [6] is the hardware and software platform on which FSEP is being implemented. Forecasts (currently mainly textual) will be prepared and stored numerically to allow ready comparison with weather observations and forecast guidance. Guidance includes numerical weather model predictions that forecasters use to help guide their forecasting. With further integration of forecasts, observations and guidance into the numerical FSEP database, the AIFS platform will provide

the opportunity for inter-comparison of:

- Forecasts with observations,
- Observations with guidance,
- Guidance with forecasts.

This will make possible a richer stream of alerts to forecasters.

The Intelligent Alerts user interface should reduce forecaster time and effort and not result in excessive or intrusive alerts. The interface must be user friendly and intuitive with personal default settings, alert categories, alert priorities, manual and automated threshold setting, and easy access to alert details.

Some alerts will be better presented graphically, such as an overlay of the current (numerical) forecast with the model forecast (guidance) just issued. An arrival alert could advise forecasters that the model is now available in the system, and a single line discrepancy alert could advise the forecaster of the existence (or non-existence) of significant discrepancies between the forecast and guidance, rather than delivering a series of alerts. The forecaster would then look at the graphical representation of the forecast, the guidance and the discrepancies between them.

Verification alerts will provide *post hoc* feedback to forecasters. After the forecast period has elapsed and sufficient observational data has arrived, the accuracy of the forecast can be assessed. A systems approach to verification, providing immediate alerts to forecasters while the forecast is fresh in memory, will provide the basis for continual improvement and higher forecaster satisfaction.

Intelligent alerts will provide the opportunity to automate the notification of forecasters and external agencies of significant weather changes via email, event messaging, telephone, pager or PDA. The demand on forecasters and ancillary staff to respond to telephone queries at the height of a severe weather situation may thus be reduced, while providing a more timely and consistent real time alerting service to important clients.

These requirements indicate the need for flexible, dynamic mechanisms to handle the Bureau's complex environment. Below we explain why we have chosen agent networks as the means of satisfying these requirements, and how we will go about implementing this solution.

3. MICROBURST DETECTION

As an indication of the usefulness of agents within the Bureau, one of us (Dance [2]) has recently developed an agent-based system for detecting microbursts. These are regions of high-shear and strong down-drafts associated with thunderstorms that are a hazard for aircraft, and can be detected with real-time weather radar. In the microburst system, the detection problem is broken down into a number of steps, each undertaken by its own agent. One agent seeks areas of high wind-shear in low-level radar sweeps, either autonomously, or as a result of inquiries from elsewhere in the system. Another seeks connected 3D regions of high radar reflectivity, indicating hail or high rainfall. These and other low-level agents alert a higher-level agent to the possibility of a microburst, which then looks for the signature of a mi-

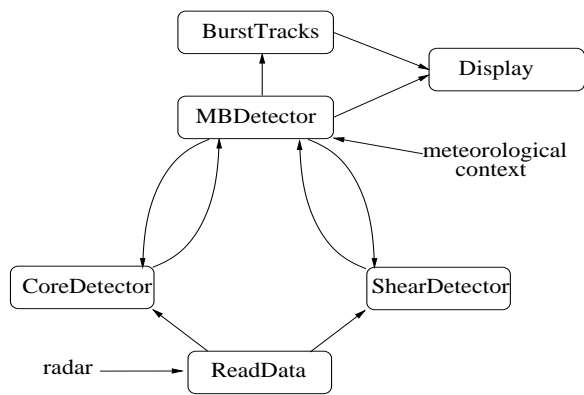


Figure 1: The network of agents used for microburst detection.

crobursts by sending queries to other lower level agents (see Fig 1). This system, simple as it is, compares well with other more complex conventional systems [1, 5] in its ability to detect microbursts.

This experience indicated to us the potential benefit in employing agents more widely in the Bureau.

4. PILOT ALERTS PROJECT

The initial pilot project under the aegis of FSEP will compare observational data with Terminal Area Forecasts (TAFs or forecasts near an airport, see Fig 2).

This pilot project is based on the interaction between an agent-based system and aviation weather forecasts. The system will monitor in real time the current TAFs looking for inconsistencies with current airport observations as provided by the automatic weather stations (AWS). When an inconsistency is found, the system will choose whether to issue an alert to the forecaster. Such an alert has the potential to cause forecasters to amend the currently issued TAFs, thus leading to removal or lessening of the inconsistency. Input to this system will be current TAFs and AWS data obtained from the Bureau's current real-time data system. The network of agents will compare these data streams and analyse them for various scenarios: for instance, inconsistency, AWS down, AWS malfunction, TAF not issued, TAF unrealistic. The agent system will need on-board intelligence to deal with a number of issues:

- whether this alert has previously been issued,
- how important the alert is,
- whether the alerts are being responded to,
- which forecasters to direct the alert to.

This system also requires a GUI for communicating with the forecaster. Ultimately this will also be under the control of one or more agents, but for the pilot study, will be a simple Java driven interface.

The pilot system will be implemented using JACK Intelligent Agents [7]. This is due to the good match between our requirements, and the characteristics of the BDI agent model [4] that JACK employs. Some of these characteristics are: it handles a rapidly changing world; actions of the

TAF YMLL 122218Z 0024
 24006KT 9999 FEW025 BKN030
 FM02 18015KT 9999 SCT040
 FM17 25006KT 9999 BKN025
 T 15 19 20 16 Q 1028 1026 1025 1026

Figure 2: An example of a TAF, encoding among other data the future temperature and pressure changes on the last line.

system can affect the world (in our case, this is the set of forecasts issued); and it has both reactive and goal-directed behaviour, allowing executing plans to be interrupted if the state of the world changes. The pilot system is expected to be functional by September, 2002, and is being undertaken in collaboration with Agent Oriented Software (AOS) and the RMIT Agents Group (RMIT) in Melbourne.

While the scope of the system is relatively small, it is an end-to-end demonstration of some of the capabilities required (ie, service subscriptions, data routing, communication with data sources, self-describing data, and simple service descriptions and service location mechanisms, see Section 6). The envisaged system should provide a basic prototype and a useful demonstration of concept.

5. INTELLIGENT ALERTS PROJECT

When the pilot is completed, we will have a better understanding of the issues around the use of agents within the Bureau. Our ultimate plan is to employ agents to satisfy the requirements of the FSEP program explained in Section 2. Some of these agents include:

- alerting agents reporting discrepancies between forecasts and weather observations. These are of the same type as the pilot project, but reporting not just on TAFs but various other forecasts.
- alerting systems based upon the current microburst detector experience to produce a number of detectors, for instance: severe thunderstorms, tornadoes, lightning, hail, wind shifts, and untimely fronts.
- agent networks surveying radar, satellite, or automatic weather stations to produce detectors for: fire danger index, road weather alerts, sheep weather alerts, crop fungal infestation danger, and other such complex products.
- from satellite imagery, agents to detect fronts and cyclonic structures that can be used to produce “payobs”: synthetic weather data for regions without weather stations such as oceans that can be used as input into the numerical atmospheric model.
- agents to directly compare the numerical atmospheric model output against weather observations and against forecasts as quality control for the modellers.



Figure 3: Example set of agents and their relationships in the desired network. The set of detector agents and gateway agents are indicated. Many other possible agent types and interactions are not shown for simplicity.

- agents to act as an intelligent interface or PDA for forecasters, allowing and facilitating such activities as filtering forecaster output for reasonableness of the forecast (ie, “you are forecasting a record for this region”); automatic rendering of forecasts for different user classes, such as: aviation, marine, television, newspaper, radio (possibly involving automatic text-to-speech), fax, web, surfer (and other special groups); and agents to flexibly keep forecasters aware of meteorological events by filtering detector alerts.

These agents (see Fig 3) will potentially be produced by different groups at different times, using different methodologies. Some will be tried and true production systems, others will be highly experimental and unreliable. These all need to sit in the same “world” compatibly.

The system will need a number of “gateway” agents, whose job it is to mediate between the growing agent network, and a plethora of existing systems, for instance, the real-time weather observations from around Australia, and from the World Meteorological Organization’s² data network providing world-wide observations; from radar, satellite imagery, lightning and other detection systems; from the various numerical weather models available around the world; from various databases residing within the Bureau like the climate database; and from the various forecasts being generated by forecasters throughout Australia.

6. RESEARCH ISSUES

The list of potential agents in the previous section raises some interesting questions. How are these agents going to find the resources they need? How are they going to advertise their products? How are competing agents that produce

²<http://www.wmo.ch>

the same product going to be discriminated? How are agents going to be added to the network, or removed?

The key research issues are the description of data, the description of services, and mechanisms for timely and continuing location of data and services in a dynamic environment.

Self-describing data: Data needs to be self-describing so that any agent receiving data from any other agent (potentially written at different times by different people) will be able to sensibly interpret it. Clearly a standardized flexible syntax such as XML is required. It is also clear that ontologies play a key role in defining concepts. What is not clear is the representation of the ontologies — how are concepts captured and related to each other? What notation is used to describe concepts and to reason about them? How can two agents realize that two differently named concepts are similar and determine how to translate between them?

Service description: Agents provide services. These services need to be described in a manner that allows for searching. The challenge is how to represent services (which are considerably richer and more complex than data) in a way which allows for efficient reasoning and search. At the same time, the representation must capture both the functional characteristics of the service (e.g. what information is provided, what transformations are available, how these can be controlled) and the less tangible characteristics of the service (e.g. efficiency, reliability of the software, reliability of the data, current workload).

Location of services: Agents actively seek data which is required for making decisions or which is required for monitoring a condition of interest. This implies that the data routing mechanism used needs to be flexible enough to handle high-level descriptions of data of interest. An agent should also pro-actively and continuously seek better and new sources of data and ways of obtaining data which is relevant to its goals. Thus, finding relevant services is a continuous process, not a one-off query.

There are a number of technologies that could facilitate service description and location. For instance, DAML³+OIL⁴ utilizing RDFS⁵ is one possibility. Another less likely contender for our needs is UDDI⁶ which is primarily aimed at web service discovery for business. A major component of this project is concerned with exploring and possibly extending available service location technologies.

Service description here must be distinguished from that described in d’Inverno et al [3] which deals with state-based agents. Here we will be using JACK-based BDI agents [4], so the theory behind service description in this context will also need to be dealt with.

With our proposed system the addition or removal of agents follows naturally: when an agent is removed, dependent agents note the loss of service, and thus seek alternatives.

³<http://www.daml.org/>

⁴<http://www.ontoknowledge.org/oil/>

⁵<http://www.w3.org/TR/rdf-schema/>

⁶<http://www.uddi.org/>

Upon addition of a new agent, potential “customers” will discover it due to their continuous search for better data sources.

The existing data sources within the Bureau, for instance radar and satellite data, will appear to the network as a set of fairly constant services delivered by the gateway agents. If in the future an existing system is upgraded, this will in a natural way be represented by a new, possibly competing, gateway agent.

7. CONCLUSION

In this paper we have presented the Bureau’s requirements for sophisticated software for handling a complex, dynamic environment. We have proposed that networks of agents could satisfy these requirements, and have backed up this proposal with arguments from experience with a microburst detector, and the good match between the requirements and the nature of agent networks. We then described our plan for a pilot system to test the proposal, and go on to describe a larger system in the longer term. We also describe the research issues highlighted by consideration of this larger system. We plan to carry out this research over the next four years in collaboration with AOS and RMIT.

8. ACKNOWLEDGMENTS

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