Agents and Multi-Agent Systems (6CCS3AMS/7CCS3AMS)
Coursework 2: Forest Fires and Cooperative Agents[1]

Domain description

An advanced forest service has two types of autonomous agents that operate in its environment. The two types of agents have different abilities; however they are both able to communicate by exchanging simple messages which are similar to FIPA ACL messages.

- **Ground units** that are capable of extinguishing fires
- **Scouts** that do not carry any water, but have a set of sensors for detecting a fire.

Ground units are fire extinguishing autonomous vehicles that are able to travel around the forest environment and put out any fires they detect on their path. These units are equipped with GPS technology and therefore they can report their exact position, as well as travel towards a specific destination. (**Note that the world wraps both horizontally and vertically.**) A destination can be either specific coordinates or another vehicle in the environment. Ground units have the necessary equipment in order to communicate with any other agent in the environment. Ground units cannot go over areas that are on fire, and they must also avoid other ground units.

Scouts are light weight, small size autonomous vehicles that can move around the environment quickly. Although they do not have the ability to extinguish a fire, they have sensors to detect fires in the environment as well as the ability to communicate with any other agent in the environment (including the ability to broadcast their location). The only obstacles for scouts are trees on fire; they are small enough to co-exist in the same area with ground units or other scouts.

The agents mentioned above cooperate in order to extinguish fires in the forest. Their cooperation is currently rather simple. Scouts patrol the forest looking for spots of fire. When such a spot is detected, scouts broadcast a message to all ground units reporting the coordinates of the fire, and remain in the area until the fire is out (either an agent comes and puts out the fire, or the tree burns completely). Ground units remain idle until they receive a message, upon the reception of which they start travelling towards the fire spot in order to extinguish the fire. On their way to the spot, they put out any fires that are found on their path.

The NetLogo model

The agents described have been implemented as a model in the NetLogo platform, and the code of the model is available for you to download from the KEATS page (named *cw2-code.nlogo*). The model contains facilities for varying the environment parameters.

The ground units are hybrid agents, where the reactive layer deals with the low-level functions of the agent, such as extinguishing a fire upon detection, reloading with water, or moving towards a specific location. The proactive layer of the agent is modelled using a simple architecture related to BDI concepts, where intentions of the agent are stored in a stack. The agent responds to the intention on the top of the stack, removing the intention from the stack once the intention's condition has been met. The agent maintains a set of beliefs, where it stores information required for accomplishing its tasks, such as storing the locations of fires it has received through messages from scouter agents. The agents also maintains an incoming-queue where it receives all messages.

To allow the use of BDI concepts and FIPA ACL style communication within the model, two libraries are required (*bdi.nls* and *communication.nls* which are available on KEATs). To use these libraries, just ensure the files are saved in the same folder as the *.nlogo* file. Documents describing BDI agents and FIPA ACL like communication facilities provided by these libraries

[1] With kind permission from the authors, adapted from the coursework described in:
Ilias Sakellariou, Petros Kefalas and Ioanna Stamatopoulou, "Teaching Intelligent Agents using NetLogo", in *Proceedings of the ACM-IFIP Informatics Education Europe III Conference*, 2008.

are also available for you to download from the KEATS page (named *BDI-InNetLogo.pdf* and *FIPA-InNetLogo.pdf*). You should not make any changes to either of these libraries.

The ground units start with an initial intention of `find-target-fire`. This intention always exists as the bottom element in the intention stack of the agent. Depending on the messages received or conditions in the environment, the agent pushes new intentions to its intention stack, which are executed by the interpreter.

The scouts are also modelled as hybrid agents. Their reactive layer is merged in their `search-fire` behaviour; they explore the forest space using a very simple reactive architecture. Their proactive layer is responsible for initiating the search for a fire spot and for broadcasting the appropriate message when the spot is found. Initially scouter agents have the intention `look-for-fires`.

Before you attempt any of the tasks, it is recommended you read through the provided NetLogo model, and the documents describing BDI and FIPA ACL functionalities, to understand how the model works.

Tasks

1. In the implementation provided ground units select the reported fire spot which is closest to them, and then direct themselves toward it. However, multiple ground units might direct themselves to a single fire spot, even though only one ground unit is required to extinguish the fire. There are clearly efficiency problems with this naive approach, especially since ground units get in one another's way. Propose and describe a suitable cooperation protocol between scouts and ground units that could be employed to extinguish fires more efficiently. You should provide:

   (a) A description of your proposed protocol. You should specify:
   - the different messages that get exchanged;
   - which agents send which messages at each step in the protocol;
   - why you believe your proposed protocol will be effective.

   (No more than 500 words.)
   (6 marks)

   (b) An implementation of your proposed communication protocol. In your report, you should include a description of your implementation. This description should include *documented* code snippets of all new and altered code to help to describe your implementation - if you do not do this then you will lose marks. Code snippets do not count towards the word count. Do not include the whole NetLogo model in your report. (No more than 400 words.)
   (4 marks)

2. An experimental evaluation that shows how the performance of your extended model developed for task 1 varies compares with the naive approach provided. You should consider how the performance of your protocol varies for different starting conditions. Note that there are four different parameters you can modify. **For each experiment you run, you must fix `tree-num` as 300, and you must fix `number-of-fires` as 40.** You should vary only `fire-units-num`, `scouter-num` and `initial-water` to explore the performance of your model. (Note that the speed of ground units depends on the amount of water they are carrying; units that are loaded with a large amount of water move more slowly than units loaded with less water.) Please provide:

   - A clear description of the set of experiments used to evaluate the performance of your extended model in comparison with the naive model. This should include details of the parameters investigated, why you selected those parameters, and what you intend to demonstrate from the experiments. (No more than 400 words.)
     (3 marks)
   - A set of results obtained from your experiments detailed above (your results can be presented in graph or table format) together with an analysis of the results. Include details of any conclusions you have drawn from your analysis, and any justifications of your conclusions. Briefly comment on any limitations of your results. (Note, it is not necessary to provide any kind of statistical analysis, nor do you need to use the functionalities within NetLogo to produce/present your results.) (No more than 400 words.)
     (3 marks)

3. What are the advantages of using the hybrid design for the agents in this domain? What problems might you anticipate if the agents were modelled according to a pure BDI architecture? (No more than 300 words.)
   (**2 marks)**

Submission

Please ensure that you upload your submission with the specified formats and that you stick within the word limits. **Failure to do so may lead to you receiving 0 marks for your submission.** (Text in tables or figure captions does not count towards word limits.) You should submit two files:

- A written report (.pdf format) that contains appropriate solutions to the tasks above. **For each task, please start the answer on a new page.**
- *Documented* NetLogo code (.nlogo format) for your solution to Task 1. The results of your experiments (detailed in your report) should reflect those obtained by running your submitted code.

Assessment criteria

Note that the focus of the coursework is to assess your understanding of cooperative agent systems, and your ability to evaluate the performance of such systems based on simulation results. Your submission will be assessed according to the following criteria:

- Correctness and justification of the proposed solutions
- Analysis and presentation of experimental results
- Implementation and code documentation
- Clarity of the report