INTRODUCTION TO MULTIAGENT SYSTEMS

Emergency Response Problem
Task 1 - Design Activity

[1]

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1 Introduction

This document details the design of a city's emergency response problem, developed for the Introduction to Multiagent Systems (IMAS) course within the AI Master's programme. The objective is to coordinate a group of autonomous agents to develop a plan to effectively manage and mitigate fire incidents. The design follows the standard multiagent system architecture principles [2]. We outline the representation of the system, the definition of specialised crews, and the specification of the roles and tasks of each agent involved.

2 Environment properties

Our objective is to create a detailed textual description that specifies the location of the fire and its characteristics. The agents involved will collaborate to address this problem effectively. Information regarding the initial state will be securely stored, allowing each agent to access their own data to ascertain the specifics of the initial condition. With this context in mind, we will proceed to outline the various properties of the environment in which our agents operate.

The following environment classifications are based on the fundamental properties of multiagent systems as defined by [2].

2.1 Accessible or Inaccessible

In this instance, our environment shall be regarded as **inaccessible**, as each agent will possess access solely to the specific information required to complete its designated task. Agents will not have access to the entirety of available information or to data related to other agents. Although the information will be stored within the system, only a limited number of authorised agents will be granted access to that stored information.

2.2 Deterministic or Non-deterministic

A deterministic environment is characterised by the fact that any action yields a single guaranteed outcome, with no uncertainty regarding the resulting state after the action is performed. We have decided that our environment will be **deterministic**, as the absence of determinism could pose challenges for the agents. Furthermore, since our agents will be following a plan, we will assume that the plan is implemented correctly and that all actions produce the anticipated effects.

2.3 Episodic or Non-episodic

Our environment will be **episodic**, meaning that each episode functions independently from the others. Thus, the performance of agents in prior episodes will have no bearing on subsequent episodes; in other words, each new episode can be approached without reference to past performances. Nevertheless, more complex approaches are feasible in non-episodic environments, such as scenarios involving limited resources, where once utilised, they are unavailable for future episodes—for example, beds in a hospital setting. However, this complexity is unnecessary for the straightforward approach we have chosen, as we intend to maintain an episodic structure.

2.4 Static or Dynamic

This attribute within our environment will remain **static**, as any modifications to the environment will result solely from the actions of the agents, without influence from any external factors.

2.5 Discrete or Continuous

We consider our environment to be **discrete**, given that there is a fixed, finite set of actions available to solve our problem. In this context, we must develop a plan comprising a finite set of possible actions for each component, which characterises a discrete environment.

3 Agent Selection and Definition

This section outlines the design and composition of the agent crews within our multi-agent system. The architecture consists of four distinct crews, each tasked with specific responsibilities: the **Emergency Crew**, which attends emergency calls; the **Firefighter Crew**, which manages fire-related incidents; the **Medical Services Crew**, which coordinate medical services such as ambulances and hospitals; and the **Reporter Crew**, responsible for documenting and reporting all cases.

We decided to organise the system into these four crews to allow for the grouping of similar tasks, ensuring that each crew has a defined role within the system. Table 1 provides a summary of each crew, their main tasks, and the agents that compose them.
This organization follows established patterns for distributed artificial intelligence systems [3], where agents are grouped by functional responsibilities.

Table 1: Overview of Agent Crews

Crew Name	Main Task	Crew Agents
Emergency Crew	Attending emergency calls	- Distiller - Divider
Firefighter Crew	Addressing fire-related incidents	- Coordinator - Fire Expert - Material Expert - Planner
Medical Services Crew	Coordinating ambulances and hospitals	- Coordinator - Ambulance Manager - Hospital Manager - Planner
Reporter Crew	Reporting and documenting all cases	- Writer - Editor

The following sections provide more detailed information for each crew, outlining their specific responsibilities, their agent roles, and the tools they employ.

3.1 Emergency Crew

This crew is composed of agents responsible for receiving emergency calls, extracting relevant information, and relaying it to the appropriate response teams for swift action. The agents in this crew ensure that crucial details from the emergency call are accurately captured and efficiently distributed to the coordinators of the Firefighter Crew and Medical Services Crew.

Distiller Agent

The Distiller Agent is responsible for receiving emergency calls and documenting key information from the caller in a concise, bullet-point format. Its main task is to capture the essential details of the emergency in a structured way, making it easier for further processing. Once completed, this information is passed to the Divider Agent for review and distribution. The Distiller Agent utilises a reading tool to access the emergency call.

Divider Agent

The Divider Agent is responsible for reviewing the notes provided by the Distiller Agent and identifying the most relevant information for each crew. Its main task is to compile the bullet points and send the necessary information to the coordinators of the Medical Services Crew and Firefighter Crew, ensuring that each team has the data required for a quick and effective response. The Divider Agent does not utilise any tool.

3.2   Firefighter Crew

This crew consists of agents responsible for managing fire-related incidents. In the event of a fire emergency, various agents collaborate to evaluate the situation and coordinate firefighter units to efficiently extinguish the fire. We decided to base our approach on the operations of the Barcelona Fire Brigade to simulate our firefighter crew and their operational methods as closely to reality as possible. We obtained information on their different fire units and vehicles from [4] and [5].

Coordinator Agent

The Coordinator Agent oversees the operation of the Firefighter Crew, ensuring that all agents function correctly. Its main task is to receive Emergency Crew calls and relay the situation details to both the Fire Expert Agent and the Material Expert Agent. This agent utilises a tool for reading a JSON file to access all relevant information related to the firefighter crew, such as the number and types of available firefighter units and fire trucks. Additionally, it transmits the necessary information to the respective agents based on their specific roles and the data they require.

Fire Expert Agent

The Fire Expert Agent is responsible for evaluating fire incidents using the information provided by the Coordinator Agent. Its main task is to assess various aspects of the fire, such as its severity and type, to determine the optimal number and type of firefighter units needed to effectively extinguish the fire. The Fire Expert Agent does not utilise any tools, it just has access to the initial information received from the Coordinator Agent.

Material Expert Agent

The Material Expert Agent is responsible for assessing the equipment needs based on the fire incident information provided by the Coordinator Agent. Its main task is to evaluate different aspects of the fire, such as its severity and type, to determine the optimal number and types of fire trucks required. Additionally, it selects optimal routes and organises the deployment of fire trucks to ensure they reach the scene as efficiently as possible. This agent utilises a distance calculator tool that has access to the city's map to select the best route for each vehicle based on proximity and traffic conditions.

Planner Agent

The Planner Agent is tasked with generating a comprehensive plan for managing the fire incident based on the assessments provided by the Fire Expert Agent and the Material Expert Agent. Its main task is to develop a strategic plan for the deployment of firefighter units and to document the case thoroughly. The Planner Agent does not utilise any tools in its operations.

3.3 Medical Services Crew

This crew consists of agents responsible for coordinating ambulances and hospitals. In the event of a fire emergency, various agents collaborate to assess the situation and coordinate medical service units to efficiently rescue and treat affected individuals.

Coordinator Agent

The Coordinator Agent oversees the operation of the Medical Services Crew, ensuring that all agents function correctly. Its main task is to receive Emergency Crew calls and relay the situation details to both the Ambulance Manager Agent and the Hospital Manager Agent for a swift response. This agent utilises a tool for reading JSON files to access all relevant information related to the medical services crew, such as the number of available ambulances, hospitals, and their capacities. Additionally, it transmits the necessary information to each agent based on their specific roles and the data they require.

Ambulance Manager Agent

The Ambulance Manager Agent is responsible for coordinating the number of ambulances dispatched and determining the most efficient routes for each vehicle to reach the emergency scene, using information provided by the Coordinator Agent. Its main task is to evaluate factors such as proximity and traffic conditions to ensure rapid response and effective deployment. The Ambulance Manager Agent agent utilises a distance calculator that has access to the city's map to plan the optimal routes for each ambulance.

Hospital Manager Agent

The Hospital Manager Agent is responsible for the allocation of rescued individuals to hospitals based on each hospital's capacity, the severity of the patients' conditions, and the availability of specialised medical facilities, using information provided by the Coordinator Agent. Its main task is to assess these factors to ensure that each patient is sent to the most appropriate hospital. The Hospital Manager Agent utilises a distance calculator tool to determine the distance from each hospital to the fire.

Planner Agent

The Planner Agent is tasked with generating a comprehensive plan for managing medical services in response to an emergency, based on the assessments provided by the Ambulance Manager Agent and the Hospital Manager Agent. Its main task is to develop a strategic plan for the deployment of medical units and to document the case thoroughly. The Planner Agent does not utilise any tools in its operations.

3.4 Reporter Crew

This crew consists of agents responsible for documenting and reporting the response plan for each emergency incident. The agents within this crew collaborate to create a comprehensive report that captures the course of action of both the Firefighter Crew and the Medical Services Crew.

Writer Agent

The Writer Agent is responsible for compiling a complete plan that details the coordinated actions of both the Firefighter Crew and the Medical Services Crew, using the plans generated by their respective Planner Agents. Its main task is to generate a unified report describing the full scope of both crews' operations. Once the report is compiled, the Writer Agent sends it to the Editor Agent for review. The Writer Agent does not utilise any tools.

Editor Agent

The Editor Agent is responsible for refining the plan provided by the Writer Agent, ensuring clarity, accuracy, and completeness in the final report. Its main task is to edit and finalise the documentation of the case, producing a comprehensive report that accurately reflects the response efforts. This agent utilises a file-writing tool to save and format the final report.

3.5 Agent Interaction Diagram

To illustrate the relationships and interactions between the agents, the following diagram shows the communication flow, tools, and roles of each agent across all crews.
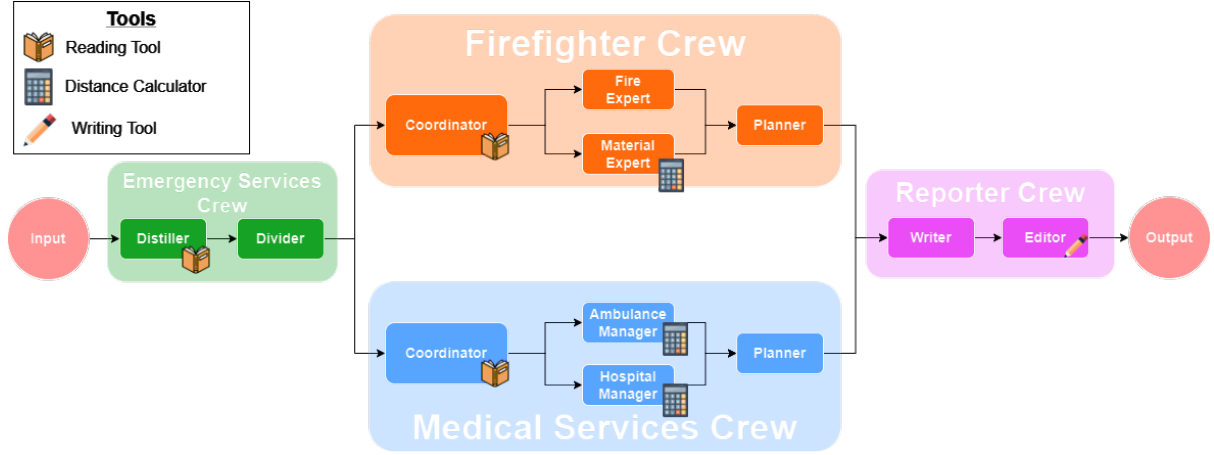

Figure 1: Diagram of Agent Crews and Inter-Agent Communication in the Emergency Response System. Each agent is displayed along with the crew they belong to, the tools they use, and the directed arrows indicate message flow and coordination between agents.

4 Agent Taxonomy

In this section we discuss how the different agents that we have presented in the previous sections fit with the classifications presented in class. As all of them share some common traits as established in multiagent systems theory [2, 6], we will first discuss these here to avoid repetition.

- **Flexibility: flexible**. Even though each agent has a specific task that is well defined, as they are language models, they can adapt to new situations and unforeseen events that are within a certain range of their intended tasks.

- **Reactivity: reactive**. All agents in the system react to the inputs of the problem and have no way of interacting with the environment, as the environment itself is static (the details of the accident, the map of the city and the resources available do not change).

- **Proactivity: non-proactive**. The agents are non-proactive; they cannot autonomously initiate actions, as their only behaviour is to accomplish their task in the pipeline of actions that need to be done to organise the emergency service.

- **Social ability: social**. The agents in the problem cooperate in a coordinated manner among themselves to achieve a major goal. They are very specialised in a certain task and need each other help and work in order to perform their own.

- **Rationality and reasoning: rational**. One of the aspects of rationality is to have a knowledge base and to infer and make plans according to this knowledge. The agents in this problem have to take into account the input (from the problem or from other agents) and use common sense to either divide and synthesise the information to other agents, deliberate which actions need to be taken to solve the emergency or elaborate a document from the decisions taken by other agents. All these are aspects of a rational being.

- **Learning: unable to learn**. The agents are not capable of storing new information in between problems.

- **Autonomy: autonomous**. The agents are capable of solving an ambiguous goal (provide a plan for a certain emergency) and have control over their own actions and internal state.

- **Temporal continuity: non-continuous**. As mentioned above, the agents are only present when the program is running and do not transfer information from one run to the other.

- **Mobility: non-mobile**. The agents presented here do not have the ability to move through any kind of network.

Agents can be classified into 4 different types, based on its purpose [7, 8].

- Collaborative: Work cooperatively with other agents to solve large or distributed problems.

- Interface: Assist users by learning their preferences, offering proactive assistance.

- Information: Gather and manage information.

- Facilitator: Manage the flow of information between other agents.

In the following analysis, we examined the type that best aligns with each individual agent.

4.1 Emergency Crew

Distiller - Information Agent

The Distiller agent receives and identifies key details from emergency calls, which have already been recorded into a text format. It's focus is to **extract** the information of an incident and convert it to structured bullet points.

Divider - Facilitator Agent

The agent is responsible for **distributing** information to both the Firefighter and Medical teams, acting as a bridge between the Distiller and the specific operational crews. It ensures each one has all the necessary information for their tasks.

4.2 Firefighter Crew

Coordinator - Information and Facilitator Agent

The agent accesses JSON files to retrieve and provide **information** about the available resources. In addition, it **relays** emergency details to specialised agents within the crew (Fire Expert and Material Expert).

Fire Expert - Collaborative Agent

The Fire Expert determines the required type and quantity of firefighting units. By **working with** the Material Expert and the Planner, it formulates a firefighting response to the fire.

Material Expert - Collaborative Agent

The Material Expert assesses resource requirements and logistical plans, using tools like maps and distance calculations. It determines the fire trucks and the materials needed. By **collaborating** with the Fire Expert and the Planner, it formulates a firefighting response.

Planner - Collaborative Agent

The planner synthesises the output from both previous agents into a coherent strategy for the firefighter crew's actions. It later provides the **consolidated** information to the Reporter Crew.

4.3 Medical Services Crew

Coordinator - Information and Facilitator Agent

This agent gathers data on available ambulances and hospitals availability, making it an **information** agent. Simultaneously, it acts as a **facilitator** by communicating the medical details from emergency calls to the appropriate experts within the crew.

Ambulance Manager - Collaboration Agent

This agent is responsible for the ambulance logistics. It **collaborates** with the Hospital manager and the Planner to give medical response to the fire: it must determine the required number of ambulances and the optimal route to the emergency location.

Hospital Manager - Collaborative Agent

The Hospital Manager **collaborates** with other medical agents to give medical response to the fire: it allocates patients to hospitals based on capacity and available resources.

Planner - Collaborative Agent

The Planner combines assessments from the medical team into a coherent response strategy. It coordinates the medical crew, fitting as a **collaborative** agent. Additionally, it has the responsibility to **facilitate** the consolidated information to the Reporter Crew.

4.4 Reporter Crew

Writer - Collaborative Agent

Given the individual responses from the Firefighter and Medical Services teams, the Writer integrates these contributions into a single, comprehensive report. It **collaborates** across different agent teams to create a unified report.

Editor - Collaborative Agent

The functionality of the Editor is to ensure a high-quality and **cohesive** final report. It must refine, edit and finalise the report initiated by the Writer.

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