Your Report Title

Your Name

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Contents

1 Introduction

In this study, we model a multi-agent system to manage fire-related emergencies in Lloret de Mar, Girona. For this purpose, we have designed five specialized response teams using CrewAI[1]: **medical services**, **emergency services**, **firefighters**, **public communication**, and **police**.

The report is structured as follows: in **Section** 3, we analyze the environmental characteristics affecting this system. In **Section** 4, we discuss the distinct agent teams and the attributes of their individual members.

1.1 Related Work

The increasing capabilities of Large Language Models (LLMs) have sparked greater interest in this area, as these models demonstrate early signs of general intelligence [3] and adaptability to novel situations [5]. These advances have catalyzed various approaches and applications of autonomous agents, as illustrated by Wang et al. [7].

However, new challenges accompany these advancements, including the optimization of **task allocation** to leverage agents' unique skill sets, enhancing intermediate outcomes through agent discussions, managing complex **context** layers related to tasks, agents, and shared knowledge, and handling multiple **memory types** essential for effective multi-agent collaboration [4].

While not within the scope of our current study, future work might benefit from exploring related topics such as Berthon et al.'s work on modeling environmental uncertainty [1] and Morales et al.'s research on synthesizing norms for multi-agent systems (MAS) [6].

Finally, for the design of our system, we reference key principles in Chapter 2 of [8] and insights from Michael Wooldridge's video on agent properties[2].

2 City Selection

This section presents an explanation of the city selection process.

2.1 Criteria

We carefully selected among several candidate cities, using the following criteria:

- A city the team is familiar with, so that we can better understand the practical implications of our work.
- A city with well-defined borders, so that we can easily define a realistic environment.
- A city with reasonable complexity, not too big and not too small.

2.2 Candidate Cities

We selected the following cities for consideration:

1. **Barcelona, Spain:** Our city, but relatively dense and complex.
2. **Seville, Spain:** Similarly very dense and complex.
3. **Salamanca, Spain:** Not as dense or complex, but lacks well-defined borders.
4. **Tossa de Mar, Spain:** Small and very compact. Includes a long single road.
5. **Lloret de Mar, Spain:** Relatively small, but includes densely connected city areas.
6. **New York, NY, USA:** Prohibitively large and complex.

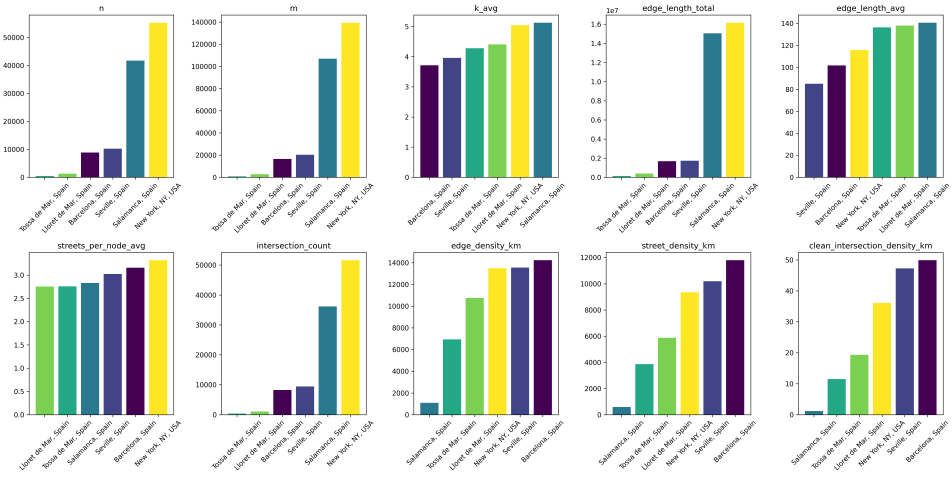

Figure 1: Map Complexity Statistics

2.3 Evaluation

We pulled 10 metrics from the OSMnx package [2] for each city. Plots of these metrics are shown in Figure 1.

- `n`: Number of nodes in the graph
- `m`: Number of edges in the graph
- `k_avg`: Average node degree
- `edge_length_total`: Total length of all edges in meters
- `edge_length_avg`: Average edge length in meters
- `streets_per_node_avg`: Average number of streets per node
- `intersection_count`: Number of intersections
- `edge_density_km`: Kilometers of edge per square kilometer
- `street_density_km`: Kilometers of street per square kilometer
- `clean_intersection_count`: Number of intersections (cleaned)

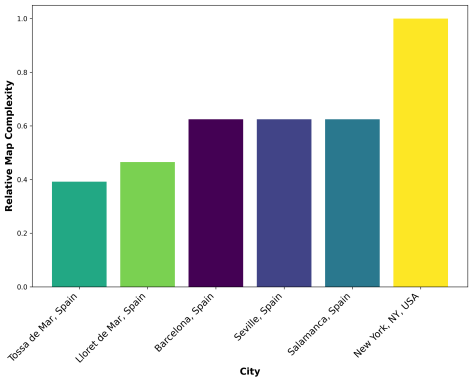

Figure 2: Relative Map Complexity

[1] `https://www.crewai.com/`
[2] `https://www.youtube.com/watch?v=vID-_uIfAvg&feature=youtu.be`

We ranked each city based on each metric, and then added the ranks, inverted them, and normalized them to derive a relative complexity score. As you can see in Figure 2, **New York** is by far the most complex city, and **Tossa de Mar** is the least complex. **Barcelona**, **Seville**, and **Salamanca** are of similar moderate complexity.

2.4 Selection: Lloret de Mar

We decided to select **Lloret de Mar** because it has a more interesting structure than the other large Spanish cities, but has a more standard layout and complexity than **Tossa de Mar**. This makes it a nice, well-balanced case study (see Figure 3).

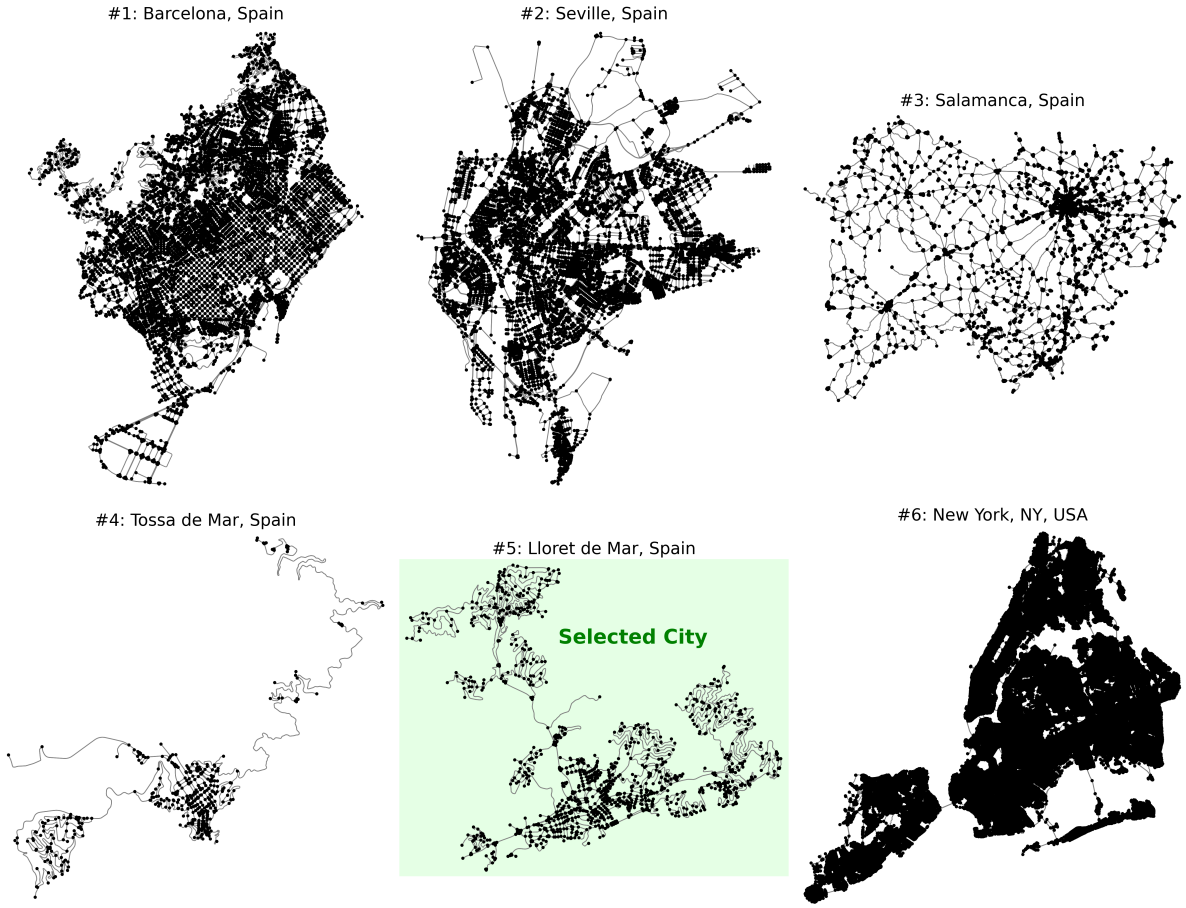

Figure 3: Maps of Candidate Cities

3 Environment

This section presents an analysis of the multi-agent system environment in the context of emergency response.

3.1 Accessibility

The environment is **partially observable**. In a partially observable environment, agents cannot obtain complete, accurate, and up-to-date information on all aspects of the environment. Here, each agent may have limited knowledge about the current state of other agents, such as their exact locations or the resources they are carrying at any given time. For example, a fire truck may not know the precise location or availability of ambulances in the vicinity. This limitation requires agents to operate with incomplete information and make decisions based on their local observations and periodic updates.

3.2 Determinism

The environment is **non-deterministic**. Although agents follow specific instructions, the outcomes of their actions are uncertain due to unpredictable environmental changes and external factors. For example, the fire may spread or intensify, and resource availability (like ambulances or fire trucks) may vary. This requires agents to continuously adapt to changing conditions, as there is no guaranteed single effect from each action.

3.3 Episodicity

The environment is **non-episodic**. Actions taken by agents have interdependent consequences. For instance, dispatching a fire truck to one location affects its availability for future incidents. This interconnectedness means agents must consider the consequences of their actions over time, as each decision affects future outcomes in a continuous sequence rather than isolated episodes.

3.4 Static vs. Dynamic

The environment is **dynamic**. Fires can evolve, spread, or be partially contained over time. Additional injuries may occur, and the status of resources (such as the availability of hospital beds or medical staff) can change unexpectedly. The dynamic nature of this environment necessitates that the system's agents are capable of frequent plan updates and re-coordination to respond effectively to evolving situations.

3.5 Discrete vs. Continuous

The environment is **continuous**. The city is represented as a graph with coordinates, which means agents have a wide range of possible positions, paths, and interactions. Additionally, factors such as fire severity and the capacity of resources are continuously changing, requiring agents to process ongoing updates and adjust their actions accordingly.

In summary, the emergency response environment for this multi-agent system is partially observable, non-deterministic, non-episodic, dynamic, and continuous. The agents operating within this system must be designed for adaptability and responsiveness, capable of handling incomplete information, and prepared to respond to a sequence of interconnected events across a continuously changing city landscape.

4 Agents

In this section we will describe the five agents crews.

4.1 Emergency Service Agent Crew

This crew is responsible for handling emergency calls and coordinating communication responses with the appropriate teams.

4.1.1 Emergency Call Agent

The Emergency Call Agent serves as the main point of contact for incoming emergency calls, responsible for collecting essential information from the caller and assessing the severity and nature of the incident.

- **Main task:** To receive, assess, and categorize emergency calls, and subsequently notify the appropriate response units.
- **Tools:**
  - *Communication Software*: A digital call-taking software to communicate with callers and to log the conversation.
  - *Data Entry Interface*: A computer system or software for systematically entering and recording emergency details.
  - *Incident Assessment Tools*: A map to quickly locate and verify the caller's position and assess the scene, potentially including software for prioritizing the severity of the incident if necessary.

- **Type:** Interface agent: This agent emphasizes autonomy and learning to support users. In this case, the Emergency Call Agent acts as a user interface for emergency call handling, gathering caller input and making proactive decisions on incident categorization.
- **Properties:**
  - *Reactivity*: The Emergency Call Agent continuously interacts with the environment (incoming calls) and rapidly assesses each situation to provide an appropriate response.
  - *Proactiveness*: While primarily reactive, the Emergency Call takes initiative by categorizing and prioritizing incidents, ensuring the most urgent cases receive immediate attention.
  - *Social Ability*: Capable of basic communication with other agents and potentially human responders, using a structured communication protocol for efficient incident coordination.
  - *Autonomy*: Operates independently once set up, requiring minimal external input to manage call processing and categorization.

4.1.2 Notification Agent

A bridge agent that ensures timely and accurate transmission of information between the Emergency Call Agent and emergency response teams.

- **Main task:** To relay details about the incident to the respective emergency teams and manage ongoing updates throughout the response.
- **Tools:**
  - *Communication protocols*: Passes the information collected by the Emergency Call Agent to the appropriate teams (firefighters or medical services).
  - *Notification system*: Continues to relay new updates or details as they come in, ensuring no one is left out of important updates.
- **Type:** Facilitator agent: This type emphasizes communication and interaction, managing the connections and information flow between agents. The Notification Agent serves as the coordinator in the emergency response communication network.
- **Properties:**
  - *Reactivity*: Monitors changes from both Emergency Call inputs and emergency response team feedback, adjusting notifications and updates based on dynamic incident progress.
  - *Social Ability*: Engages in continuous communication with multiple agents in real-time, ensuring all parties are kept informed and aligned on incident status.
  - *Temporal Continuity*: Remains active throughout the duration of an incident, managing and providing updates until the situation is resolved.
  - *Flexibility*: Adapts to various communication protocols and priority levels, adjusting its actions according to the severity of the situation and the availability of response teams.

4.2 Medical Services Agent Crew

This agent crew is responsible for treating those injured in the fires. They manage the available health and first-aid services, such as hospitals and ambulances. The agents that are part of this crew include a **medical services operator**, one **hospital coordinator** per hospital, and multiple teams of **paramedics**.

4.2.1 Medical Services Operator

The medical services operator takes calls from emergency services and reports back.

- **Main task:** Receives information from other crews and relays the relevant information to the rest of the Medical Services agents. Also gathers information from its own crew and sends it to other crews who might be interested.

- **Tools:**
- **Type:** Facilitator agent.
- **Most relevant properties:**
  - *Reactivity:* This agent is in constant contact with its own crew, as well as with the other crews, reacting to events that occur during the emergency.
  - *Proactiveness:* As a facilitator, this agent maintains a two-way communication channel between crews at all times without needing to be called into action.
  - *Social Ability:* The primary task of this agent is communication between agents, making it essentially social in nature.
  - *Temporal continuity:* The *medical services operator* is constantly receiving and sending messages to update other agents about the current status of the emergency.

4.2.2 Hospital Coordinator

The hospital coordinator manages the available resources of its corresponding hospital and coordinates with other *hospital coordinators* to discuss the distribution of resources and patients.

- **Main task:** Manages knowledge of available beds, ambulances, and paramedics at the hospital. Assesses the hospital's capacity to treat the injured and deploys aid teams to fire sites. Communicates this information to other *hospital coordinators*.
- **Tools:**
- **Type:** Information agent.
- **Most relevant properties:**
  - *Social Ability:* Communication with the *medical services operator* and other *hospital coordinators* is crucial to properly allocate and manage Medical Services resources.
  - *Rationality:* This agent understands the limitations of its hospital and will not trigger a call to action if the necessary resources are unavailable.
  - *Reasoning:* Real-time knowledge of available resources and communication with other *hospital coordinators* enable sound response plans during emergencies.
  - *Learning:* As an information agent, the *hospital coordinator* must continuously update its knowledge based on world changes and performance of emergency response plans.

4.2.3 Paramedic

Paramedics provide medical care in the field and transport people to hospitals as needed. They work in teams of multiple *paramedics* to manage emergency site situations.

- **Main task:** Takes an ambulance to the scene to treat individuals with minor injuries on-site. Decides when critically injured persons need hospital transport. Each *paramedic* has specialized knowledge, applied collaboratively depending on the situation, and reports the health status of treated individuals after deployment.
- **Tools:**
- **Type:** Collaborative agent.
- **Most relevant properties:**
  - *Flexibility:* This agent must adapt to unpredictable issues at the emergency site.
  - *Reactivity:* During deployment, this agent continuously reacts to unfolding events and makes decisions in a chaotic environment.
  - *Social Ability:* Since *paramedics* are deployed in teams, they must collaborate to manage the situation effectively.
  - *Reasoning:* Each *paramedic* leverages specific medical abilities to determine treatment and prioritize patients based on their conditions.
  - *Autonomy:* Once in the field, this agent independently decides actions based on the situation.

4.3 Public Communication Agent Crew

This agent crew is responsible for managing public communications regarding incident zones, summarizing weekly reports, and analyzing societal behavior. The agents in this crew are: a **facilitator agent** (team coordinator), an **information agent** (information repository), an **article writer** (collaborative writer), a **mayor** (official spokesperson), and a **social media commentator**.

4.3.1 Facilitator Agent

Serves as the main point of contact, bridging communication between other emergency crews (firefighters, police, etc.) and updating the Public Communication Team on all pertinent activities.

- **Main task:** Receives updates from other emergency crews and relays the necessary information to agents within the Public Communication Team. Additionally, gathers insights from the team to share with other relevant crews when needed.
- **Tools:**
- **Type:** Facilitator agent.
- **Properties:**
  - *Flexibility*: Must adapt to and handle varied formats of incoming information from multiple sources.
  - *Reactivity*: Responds to new messages and incidents promptly.
  - *Proactiveness*: Initiates communication with other agents and emergency crews as necessary.
  - *Social Ability*: Facilitates collaboration within the team and interacts effectively with external agents.

4.3.2 Information Agent

Acts as the central information repository for the team, handling data storage and retrieval as required.

- **Main task:** Manages a well-organized database of factual data, ensuring timely access to accurate information for other agents.
- **Tools:**
  - *Long-Term Memory*: A structured database for reliable information storage and retrieval.
- **Type:** Information agent.
- **Properties:**
  - *Reactivity*: Responds promptly to data requests from the facilitator and article writer, efficiently storing and retrieving information as needed.
  - *Social Ability*: Engages with both the facilitator and article writer to ensure access to necessary details.
  - *Learning*: Continuously updates knowledge of city-wide incidents and facts.

4.3.3 Article Writer Agent

Responsible for drafting, organizing, and refining articles to provide the public with clear and concise updates.

- **Main task:** Plans and develops well-structured, informative articles, ensuring consistency in public announcements based on current reports.
- **Tools:**
- **Type:** Collaborative agent.
- **Properties:**

- *Proactiveness*: Independently decides when to begin and publish articles based on recent events.
- *Social Ability*: Collaborates with the information agent to acquire data on specific neighborhoods or timeframes.
- *Reasoning*: Applies logical structure and clarity when crafting announcements.

4.3.4 Mayor Agent

Represents the city officially, approving important articles for public release and maintaining the city's voice in communications.

- **Main task:** Reviews significant articles for release, ensuring they align with the city's position and information standards.
- **Tools:**
  - *Official Communication Channels*: Direct access to official public announcement platforms.
- **Type:** Collaborative agent.
- **Properties:**
  - *Reactivity*: Responds to articles slated for publication to approve or request revisions.
  - *Proactiveness*: Can halt articles and issue a modified announcement directly if necessary.
  - *Social Ability*: Coordinates with the article writer to ensure messaging aligns with city standards.
  - *Reasoning*: Assesses news content for potential public impact, adjusting as needed for public communication strategy.

4.3.5 Social Media Commentator

Offers lighthearted, constructive commentary on emergency operations to boost public morale and encourage positive feedback.

- **Main task:** Provides insights on emergency crew operations in a casual, humorous style to foster constructive improvements in a relaxed format.
- **Tools:**
  - *Social Media Platforms*: Direct access to platforms like "Twitter" for posting feedback.
- **Type:** Collaborative agent.
- **Properties:**
  - *Flexibility*: Adapts tone and style to maintain a balanced, lighthearted approach.
  - *Reactivity*: Responds to public and team updates with timely commentary.
  - *Proactiveness*: Actively comments on recent activities, providing feedback in a humorous way.
  - *Social Ability*: Communicates with a friendly, approachable tone.
  - *Reasoning*: Crafts feedback to be constructive and engaging.

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