COMMUNICATION MODULE FOR A HETEROGENEOUS MULTI-AGENT SYSTEM

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Abstract - The communication module plays a critical role in a heterogeneous collaborative multi-agent system, determining its performances. The SICOLET heterogeneous multi agent system consists in a terrestrial vehicle equipped with a serial manipulator, an aerial drone and an ekranoplan cpntrolled by a human operator from a control centre, but also capable of semi-autonomous operation based on intelligent decisions and control algorithms, being designed for inspection and intervention in areas affected by various natural or anthropic disasters. The papers presents the design and functioning of the communications and control module.

Keywords: Communication module, Control module, Multi-agent system, Heterogeneous system, Control algorithms.

1. Introduction

The main goal of the project is to develop a demonstration model for a heterogeneous collaborative system consisting of a ground vehicle, a drone-type aerial vehicle and an ekranoplane, whose semi-autonomous operation is determined by intelligent decision and command algorithms, intended for inspection and intervention quickly and efficiently in areas affected by various natural or man-made disasters. The consequences of disasters such as earthquakes, volcanic eruptions, hurricanes, floods or fires are particularly severe, manifesting in loss of human life and significant property damage. Although expensive efforts are made to train the response teams, the activities of rescuing victims are difficult and often even endanger the lives of the rescuers. Currently, there are various remote-controlled ground or aerial robotic systems that facilitate inspection and intervention actions in hard-to-reach affected areas. Due to extremely diverse conditions, the mentioned systems may be effective in some cases, but inappropriate in others. For this reason, it is proposed to create a system consisting of three different vehicles, hereinafter called inspection/intervention agents, hence the name heterogeneous system. In fact, the SICOLET system is a Heterogeneous Multiagent System (HMAS), whose communication algorithms are described in [1], [2], [3], [4], [5]. It is considered that at this stage of the research, the number of three agents is most appropriate. Due to the radically different characteristics, the three agents can complement each other, significantly expanding the capabilities of the system. Moreover, as the main scientific objective of the project, the aim is for the system to function autonomously on certain segments of the intervention process, with the three agents collaborating to varying degrees with each other, based on algorithms that will be developed during the project.

The communication modules between the agents that make up the collaborative system play an important role, determining the system performance. From hardware point of view, the communication module was designed and mounted on each device, with the role of isolating the components as effectively as possible and having easier access to them in the event of malfunctions. As software, several previously versions were improved in order to obtain a higher accuracy of data sent/received.

2. SICOLET Heterogeneous Multi Agent System

The system consists mainly of three different vehicles, called inspection/intervention agents, hence the name Heterogeneous Multi Agent System. As the main scientific objective of the SICOLET project, the aim is for the system to function

autonomously on certain segments of the intervention process, with the three agents collaborating to varying degrees with each other, based on their own algorithms. The system is composed of, constructive detail being given in [6], [7], [8]:
- An aerial drone – figure 1;
- An ekranoplan – figure 2;
- A terrestrial drone, equipped with a serial robot capable of intervening in the environment - figure 3;
- The control centre (CCO) – figure 4.

Figure 1: Agent 1 - Aerial drone

Figure 2: Agent 2 - Ekranoplane

Figure 3: Agent 3 – Terrestrial Drone

Figure 4: Control centre

The system is also equipped with a mobile solar recharging equipment – figure 5, showing the response of the system to the variation of the light intensity [9] – figure 6:

Figure 5: Mobile solar recharging equipment

The system is also equipped with a mobile solar recharging equipment – figure 5:

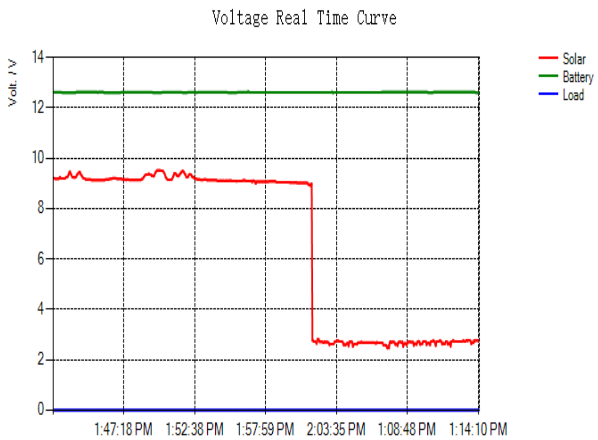


Figure 6: Response to variation in light intensity

3. Communication Module Electronics

All agents are equipped with cameras, so the main data acquired by MAS consists of digital images. Images can be processed either locally, within each agent, or transmitted to the control center. Also, each agent has a GPS device, which allows knowing their position in real time.

The role of the CCO control center is to process and centralize signals received from agents on the ground into an easily understandable form. The system is composed of:
- LAPTOP - the information received from the agents through the transmission-reception module and processed by the Arduino microcontroller is processed and stored in an Excel file;
- ARDUINO MICROCONTROLLER – interprets the radio signals received by the NRF24L01 which it transmits to the laptop via serial communication. In

emergency situations, a "return to home" command can be sent to agents who are in imminent danger or cannot cross an obstacle autonomously;

- NRF24L01+ - this module is responsible for receiving or transmitting data from or to agents;

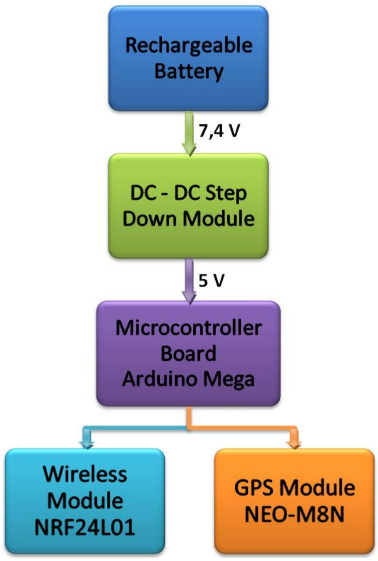
- DIGITAL AUDIO/VIDEO CONVERTER (CAVD) - the two CAVD modules convert analog audio/video signals into digital signals by means of dedicated LogiLink software. The software also allows recording video clips or storing photos taken from the agents' cameras. Each CAVD allows interfacing with a maximum of two AV receiver modules that have different channels.

* AV receiver - AV receivers receive analog audio/video signals from AV transmitters mounted on each agent. AV receivers have 8 channels ranging between 5.7 GHz and 5.9 GHz, but only have two analog outputs. As previously mentioned, analog signals are fed to the CAVD and converted to digital format;

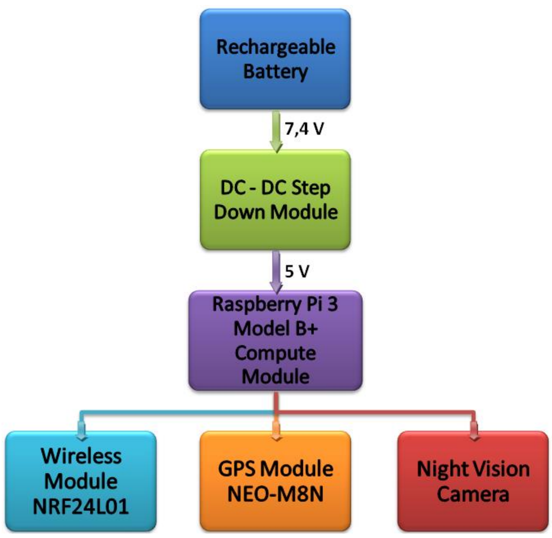
To facilitate communication between devices, a communication module was created for each agent in the heterogeneous system. It has the advantage of a compact design, which integrates the components that deal with communication and was made according to the block diagram – figure 7.

Two variants were designed for the module: the first variant for the ground drone and ekranoplan figure 7 a), the second variant for the air vehicle figure 7 b). The main difference between the variants lies in the microcontroller chosen and the additional element, the night vision camera.

This configuration was chosen because the aerial vehicle (drone) is equipped with the Raspberry Pi 3 Model B+ development board on which the fire detection algorithm is made, which takes data from the camera.



a) Variant 1



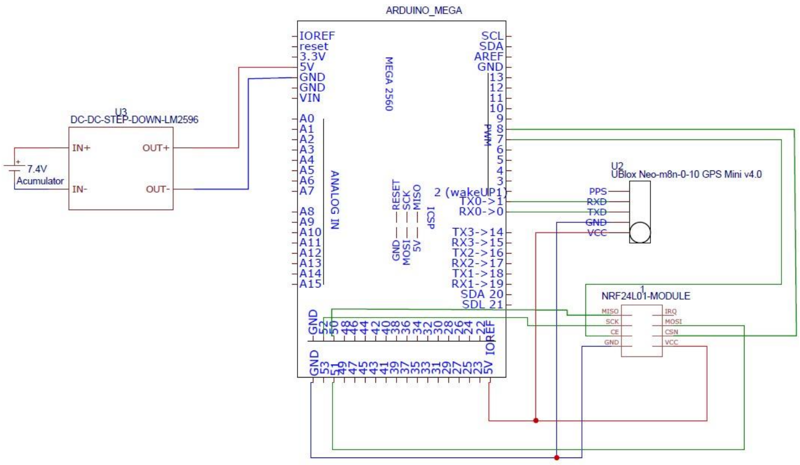
b) Variant 2

Figure 7: Communication module block diagram

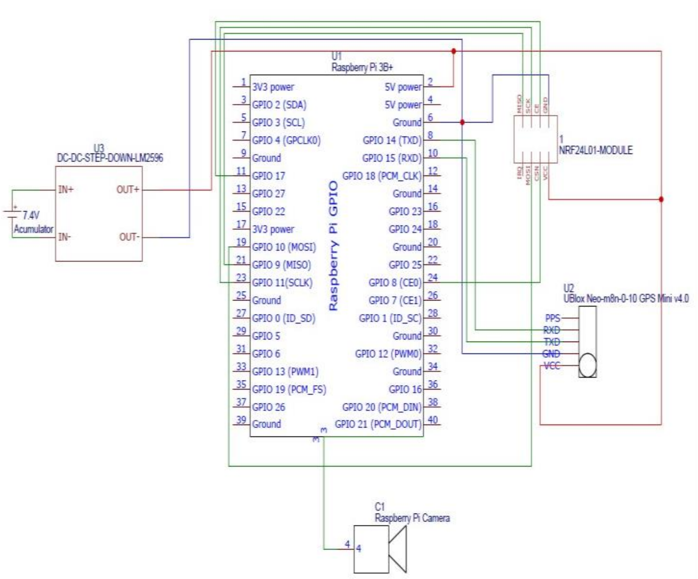
Figure 8 shows the wiring of the components for variants 1 and 2. To ensure the voltage required for the microcontroller and the development board (5V), a step-down voltage source LM2596 was used, which is powered from the 7.4 V battery.

Communication between the microcontroller and the NRF24L01 wireless module is realized through the SPI serial interface which works in full-duplex mode (data transfer is done in both directions simultaneously).

The NEO-M8N GPS module connects serially (RX TX pins) with the development boards and provides increased performance, receiving data from 3 GNSS systems (GPS, Galileo, GLONASS). In the electrical diagram in figure 8 b) an additional camera with night vision is added.



a) Variant 1



b) Variant 2

Figure 8: Communication module wiring diagram

4. Communication Module Software

The intention of the project was to develop a software application where human operator intervention is minimal, at least in the intermediate phases of disaster localization [10], [11]. Of course, launching agents will be done manually, and final decisions will be made by the human operator. He can also intervene in intermediate phases, in actions of great complexity, which exceed the technical possibilities of a certain agent. The expected mode of operation is as follows:

Phase 1. In the event of a natural (e.g. high-intensity earthquake) or man-made (e.g. explosion of pipelines or gas tanks, military actions, etc.) disaster, the human operator (or operators) commands via joystick from the control centre of the successive movement of the two aerial agents – the drone and the ekranoplane – in a certain area of interest, without having a clearly identified objective. Each agent constantly communicates, with a certain sampling rate, its position and images taken by the cameras.

Phase 2. The captured images are automatically processed by image processing programs, in order to detect possible fires, which we will call events in the following. Ideally, this image processing is done on agent-mounted devices, or if this is not possible, the images are transmitted wireless to the CCO and processed there.

Phase 3. If multiple events are detected, along with their associated position coordinates, the application program ranks the events according to their importance using the same image processing software. The event of first importance is selected.

This process is affected by some uncertainty, due to the different positions and altitudes of the agents, but it is assumed that the outcome will still be selected from the events of greatest significance. The output consists of the GPS coordinates of the detected event, with a relatively high initial imprecision, coordinates associated with each agent. Based on the two sets of coordinates, the application makes an estimate of the most likely position of the event, improving the initial location accuracy. Estimated coordinates are transmitted to both the CCO and the other two agents.

Based on the coordinates determined in the previous phase, the two aerial agents approach the point associated with the event, transmitting increasingly clear images, based on which the coordinates associated with the event are recalculated within 3 - 4 iterations. To avoid the collision, the two aerial agents will operate at different, predetermined altitudes. While the drone is placed at a certain distance from the vertical of the event, the ekranoplan performs a circular flight around this vertical.

Once the coordinates of the event are established, the human operator moves the land mobile robot remotely, using a joystick, to the determined point, allowing the capture of images of the same event, but from ground level. This completes the perspective on the magnitude of the event and allows the operator to assess the situation on the ground as accurately as possible and decide what type of action is required.

The drone agent is a quadcopter, a flying vehicle with 4 motors arranged in an X. The drone has an autopilot, which plays a vital role in maintaining the balance of the drone during flight, even in adverse environmental conditions. The autopilot software solution of choice is INav.

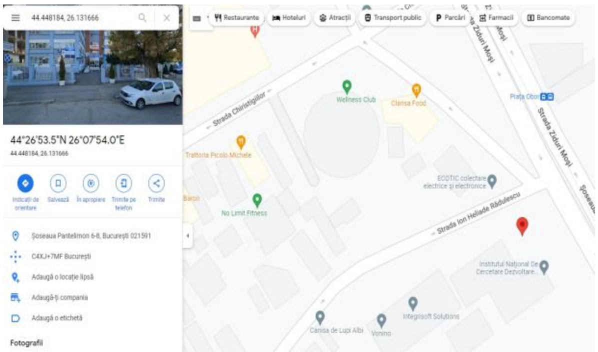
INav allows the operator to set a pre-set flight path for the drone that can later be modified by the on-board Arduino microcontroller, whose bootloader is connected to the autopilot chip. When the drone receives the override signal, the microcontroller commands the drone to land to load a new flight mission using the GPS coordinates received via the radio transmitter. Once the mission is loaded, the microcontroller sends a PWM signal to rearm the drone and it will head towards the danger identified by another agent.

In addition to the microcontroller and autopilot, there is also a Raspberry Pi 3 on board, which has the role of image processing with the opencv library. The drone is equipped with two cameras, a RunCam for navigation and a Pi Camera V2, for identifying possible dangers, such as fires, in real time.

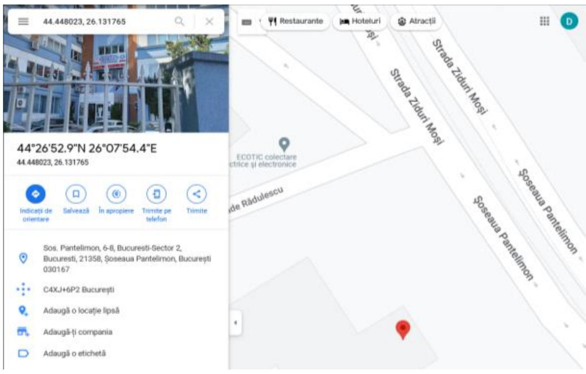
When a fire is detected, the Raspberry sends a PWM signal to the microcontroller, which in turn starts transmitting the override signal along with the GPS coordinates to the other agents via the radio transmitter. In addition to the GPS coordinates and the override signal, the microcontroller sends a PWM signal to the autopilot that will put the drone into hover mode. The drone will return to an operational level unconditioned by external signals, enter hover mode until it receives the command to return home or the operator takes control via a radio control.

From a software perspective, the code has been improved over previous versions with the aim of increasing GPS location accuracy and sending/receiving a response at a higher speed.

The main objective of the program is to transmit the coordinates of the drone's location in case of detection of an event to the other agents to intervene in the shortest time. After conducting the tests, it was observed that the data is sufficiently accurate with a small margin of error, the communication is fast and without interference. Next, the output data and GPS coordinates indicated for two of the agents, namely Agent 3 (the drone) and Agent 1 (the transporter), were illustrated.



a) Agent 3

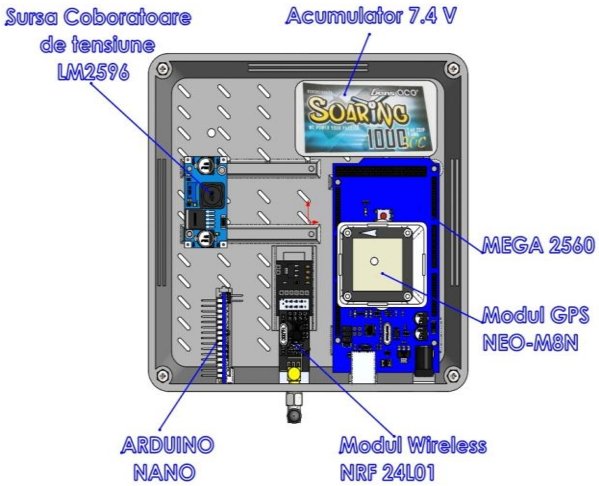


b) Agent 1

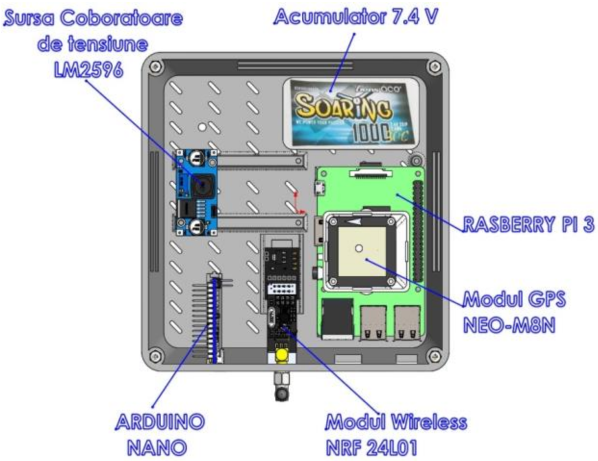
Figure 9: Output data and GPS coordinates

5. Design of the Communication Module

The design of the communication module assembly was carried out in the SolidWorks design software. To find the optimal solution for the integration of the components, the following criteria were taken into account: the size of the components, placing them as isolated as possible from each other to avoid overheating, the programmer's accessibility to the connections in the event of a breakdown and avoiding interference that could affect transmission/reception.



a) Variant 1



b) Variant 2

Figure 10: Integration of electronic components into the housing of the communication module

The NEO-M8N GPS module has been positioned in a separate housing to eliminate interference and better capture the signal from satellites. The method of attachment to the housing is illustrated in figure 11.

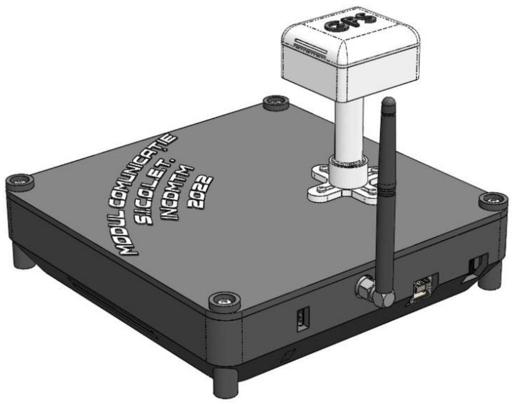
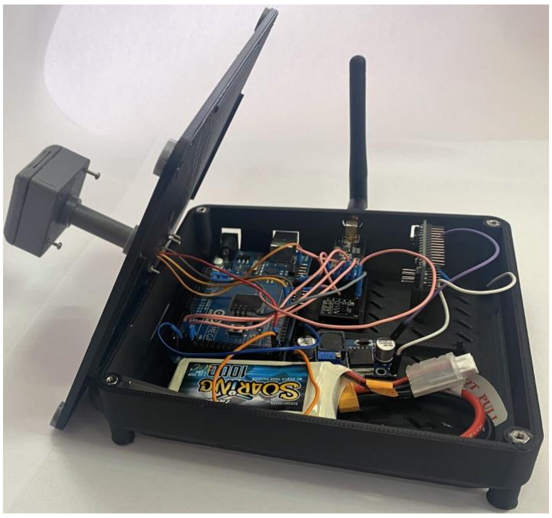


Figure 11: Overall design of the communication module

The components of the collaborative system control equipment prototype were executed by 3D-FDM-FFF printing technology. Afterwards, the components were assembled according to figure 12 a), and the final result can be found in figure 12 b).



a) internal view

b) external view

Figure 12: The prototype of the communication module of the collaborative system

6. Testing of the Communication Module

The operation of the CCO, which constantly receives cascaded information from each individual agent in a predetermined order, has been tested. The data update rate can be changed but a delay of 200 ms is recommended, which allows the data to be interpreted easily. During the tests, a clear image was obtained at about 250 m. A proper volume of datawas transmitted from 0.8 – 1 km, but the system allows transmissions from 2 – 5 km.

7. Conclusions

The SICOLET system proved its functionality with a small number of agents (three) and for a limited number of disaster cases that can occur in reality. Future work can develop its capabilities by expanding the number of agents and diversifying them, but especially by developing more sophisticated command algorithms.

Acknowledgements

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