Thesis Proposal

Title	**DIONISO – Wearable Sensors and Augmented Reality for Automous Mapping and Navigation in Search&Rescue**
Supervisors	**Carmine Recchiuto (University of Genoa)** **Antonio Sgorbissa (University of Genoa)**
Team/Company	**Laboratorium, University di Genova** **(upon student's request, it may be possible to make this Thesis in a different institution out of Italy – to be evaluated together with students)**
Research field	**Wearable Robotics, Search&Rescue**
Motivations and general objectives:	<u>Description</u> *The scenario described in this thesis is very similar to the one described in a different thesis project, named **MEUS** (see the list of Theses at Laboratorium): however, the focus of the thesis will be completely different, as clarified in the **Objectives** section.* *The two theses "DIONISO – Wearable Sensors and Augmented Reality for Automous Mapping and Navigation in Search&Rescue" and "MEUS - Management of Emergencies through Ubiquitous Sensing" may lead to unprecedented results when performed individually, but can also be a great opportunity for two students that want to perform two thesis in close collaboration.* In emergency situations, **First Responders may need to acquire in real-time a huge amount of geolocalized data** about the surrounding environment, which can be partially or completely unknown. Figure 1 shows the earthquake of magnitude 6.2 that occurred in Italy at Amatrice in 2017: almost 300 persons were killed in the earthquake, and aerial images taken by drones show houses and walls collapsed and swathes of the city completely flattened. The data to be acquired in this scenario may include, for instance, **2D / 3D maps of the environment** (e.g., required for damage assessment and for identifying dangerous areas needing a prompt intervention), the **location of people needing assistance** (e.g., injured or trapped in buildings), the **availability of access routes for emergency vehicles**, well as **any other data that can help operators** speeding up operations and increasing Search&Rescue efficacy. Analogous requirements may emerge in other natural or industrial disasters, or even in presence of crime and terrorist attack. In all these contexts, ensuring a prompt aid in Search&Rescue operations may be achieved by endowing First Responders with mobile and wearable systems with the two Functionalities 1 and 2 below:

- **Functionality 1 (investigated in this thesis)**: build a map of the environment and localize First Responders in the map by merging data provided by wearable sensors, even in situations where the topology of the environment can be altered and/or the GPS signal can be partially or totally occluded;
- **Functionality 2 (investigated in MEUS)**: label the map with geolocalized semantic information manually introduced in the system by First Responders themselves, provided by other people in the affected area, or returned by smart system allocated to the area before or after the event (drones, surveillance cameras, etc.).

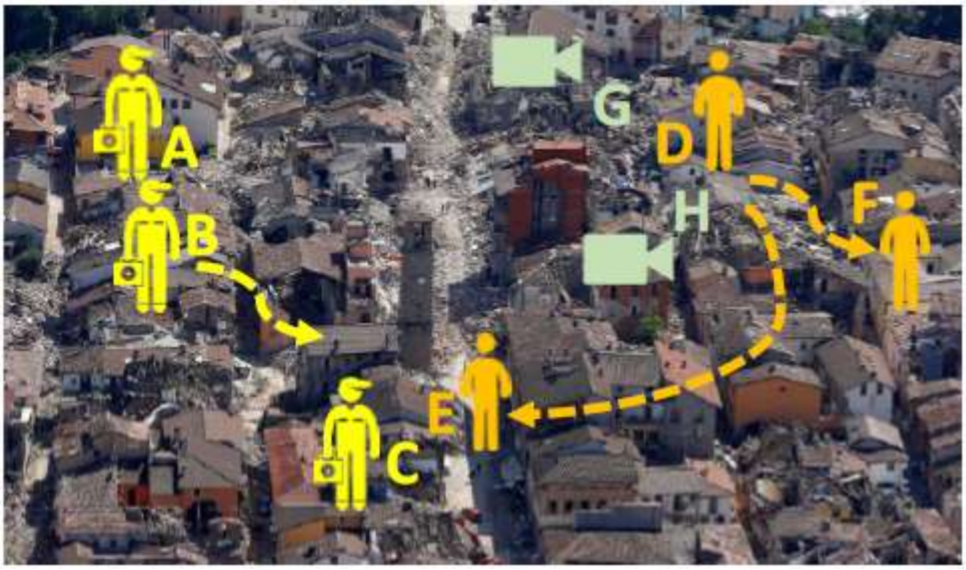

Figure 1 Aerial view of Amatrice in 2017.

To clarify these concepts, consider Figure 1. Icons **A, B, C correspond to First Responders** that are exploring an area after an earthquake, assessing damages and searching for people needing assistance. They are equipped with:

- **wearable devices**, e.g., IMUs and GPSes for localization, laser rangefinders and/or RGBD or event cameras for building or updating a 2D/3D map of the environment.
- **augmented reality, visual-, touch- or speech-based interfaces** to interact with the system, e.g., to manually tag the map with geolocalized semantic data during the exploration, and visualizing suggestions about actions to be taken and their priorities.
- **communication technology** (e.g., WiMax, TETRA, etc.) to enable information exchange between nearby operators, as well as to transfer the information acquired during exploration to a control station and ultimately to a database on the Cloud.

Icons **D,E,F correspond to people that are present in the affected area.** They may hold a portable device, which however is not necessarily connected to the Internet due to temporary lack of connectivity. Whenever they observe a relevant thing (e.g., a man in a house) they may wish to upload the information to the database in the Cloud (and, ultimately, share it with First responders connected to such database) either

- by using a **dedicated app or website** through their smartphone (if connectivity is available) or
- by interacting with a **First Responder patrolling the area** they may encounter, who will then update the database accordingly.

Finally, icons **G,H correspond to autonomous systems** in the area, either deployed before (e.g., surveillance cameras, possibly equipped with algorithms for recognition of relevant situations) or after the emergency to support the operations (e.g., drones).

<u>DIONISO Objectives</u>

In this general scenario, the thesis will have the **objective to develop and test, in a real-world scenario, algorithms for mapping, self-localization and navigation** using wearable sensors embedded in the clothes of First Responders in the emergency area. The maps built in real-time shall then be visualized on augmented reality eyewear (e.g., HoloLens) thus providing useful information for First Responders to explore the area the more efficient way as possible, and will be additionally usable by decision makers in a remote Control Room for resource allocation.

The **main theoretical problems** addressed by the thesis will be two (the students may choose to focus more on 1 or 2 depending on their preferences):

1) Simultaneous Localization And Mapping (SLAM) and Collaborative Localization And Mapping (CLAM) are known to be affected by errors, that increase as the travelled path increases. One of the most critical aspects to be considered in SLAM and CLAM algorithms is the so called "loop-closure" problem, i.e., when the agent comes back to an area that it already visited in the past and should therefore match previously built maps with the last acquired information. To address this problem, many approaches have been proposed. In the thesis, the student will start from pre-existing SLAM algorithms, which are already available in ROS [Madhira et al., 2017] and have already been used for human-based SLAM [Recchiuto et al., 2017], and expand them with unprecedented techniques for loop-closure. Specifically, First Responders, while the system builds the geometric map of the environment through laser data, will be allowed to introduce information in the system through audio and touch based interfaces, to the end of describing what they see around them (e.g., I see a "shop", a “church”, a “fountain”, and so on): this will be done through “semantic labels”, that will ultimately characterize significant locations of the environment through the “urban features” that the First Responder can recognize when in that location. Semantic labels will then be used by the system as additional information to solve the loop-closure problem, i.e., when the First Responders reaches an already visited areas that is characterized by the same visible features, paving the way to an unprecedented usage of SLAM techniques using wearable sensors.

2) Presentation of the information through multimodal audio/visual interfaces is known to play a crucial role whenever the information available is “too much” compared to the possibility of presenting such information. This is particularly relevant in the DIONISO scenario, where First Responders will be equipped with earwear as well as augmented reality eyewear, with obvious limitations concerning the possibility of visualizing complex information about the environment. In particular, the thesis will explore the integration of HoloLens in the DIONISO system, and will refer to Literature in the field of adaptive user’s interfaces [Lavie et al 2010; Gajos et al 2008] to elaborate strategies to visualize geometric maps, semantic information and navigation directions in the most proper way, by taking into account technological constraints as well as other characteristics in terms of ergonomics, the current situation (i.e., in terms of visibility, environmental noise, etc.) and the operational and health state of the First Responders.

<u>Required skills:</u>

- Good programming skills (C/C++ and ROS are welcome)

<u>Proposed work plan and expected results:</u>

- Making practice with the existing solution for sensor acquisition and mapping through SLAM and CLAM algorithms implemented in ROS [4 weeks];
- Expanding the system with solutions for acquiring semantic knowledge from First Responders, in order to improve loop-closure algorithm and/or presenting information through multimodal, adaptive audio/video interfaces, with a specific focus on augmented reality eyewear (HoloLens) [16 weeks]
- Testing of the system in a real-world scenario in the maze-like historical center of Genova, data analysis, and creation of a Dataset to be published for the scientific community [4 weeks];
- Writing of the thesis [4 weeks].

The thesis may also produce a scientific article to be submitted to an international conference or journal (the students may contribute to the writing of the article, if they want, but this is not mandatory).

<u>Place of activity:</u>

The thesis will be performed at the Laboratorium, Pad E, Second Floor.

(upon student's request, it may be possible to make this Thesis in a different institution out of Italy – to be evaluated together with students)

References:

1. K. Madhira, J. Patel, D. Kothari, D. Panchal and D. Patel, "A quantitative study of mapping and localization algorithms on ROS based differential robot," *2017 Nirma University International Conference on Engineering (NUiCONE)*, Ahmedabad, 2017, pp. 1-5, doi: 10.1109/NUICONE.2017.8325609.
2. Carmine Tommaso Recchiuto, Antonello Scalmato, Antonio Sgorbissa, A dataset for human localization and mapping with wearable sensors, Robotics and Autonomous Systems, Volume 97, November 2017, Pages 136-143
3. Lavie, T., Meyer, J. Benefits and costs of adaptive user interfaces (2010) International Journal of Human Computer Studies, 68 (8), pp. 508-524.
4. Gajos, K.Z., Everitt, K., Tan, D.S., Czerwinski, M., Weld, D.S. Predictability and accuracy in adaptive user interfaces (2008) Conference on Human Factors in Computing Systems - Proceedings, pp. 1271-1274.

Contacts:

Carmine Tommaso Recchiuto
Email: carmine.recchiuto@dibris.unige.it

Antonio Sgorbissa
Email: antonio.sgorbissa@unige.it