Emergency Episode - Rulebook
Delivery of medicines to isolated persons and accompany to a medical centre

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1. General Description

A medicine is ordered by a person in Bologna that cannot go out (due to quarantine-related issues or because the person is disabled). The robot must be able to move autonomously to the location where the citizen is waiting. The robot might need to detect and avoid possible obstacles on the way (static and dynamic), and it must consider that GPS coverage is not always guaranteed. Once the robot arrives at the citizen location, the robot should interact with him/her (in English) to deliver the proper medicine. Depending on the person's health, it could be also possible that the robot should accompany the person to the nearest medical centre to see a doctor.

2. Main scientific challenge

This episode aims at benchmarking some of the key functionalities required by an autonomous ground robot to operate in dynamic and challenging environments, such as localization, trajectory planning, and obstacle detection and avoidance. A secondary functionality, while being basic for the episode success, is the ability to interact with people through language (English).

A survey in social aware navigation can be seen in [5]. A human aware mobile motion planner and anticipative kinodynamic robot planner are explained in [6] and [9]. Prediction of human motion intentionality is described in [10]. Guiding people in a shopping mall and in an airport can be seen in [12] and [4]. Side-by-side accompanying people is explained in [1], [2], [3] and [8]. Accompanying a group of people is described in [7], [4] and [13]. Robots approaching a person can be seen in [11].

This episode wishes to push advanced developments in the context of Smart Cities and last-centimeter delivery, focusing on autonomous capabilities and navigation for ground robots, as these are important milestones to achieve for the emergency robotic systems of the future.

3. Platforms allowed

Ground robots that can navigate in outdoor (and maybe indoor spaces), detect and avoid obstacles (dynamic and static), and have incorporated basic human-robot interaction with the citizen.

The ground robots must have a system to carry and deliver items to specific locations (see Section 4 for details).

Specific limitations may be applied to large ground robots for safety reasons (maximum 60cm length, 60cm width and 160cm tall). Apart from this, any ground robot platform will be able to enter the competition for this episode.

The robot has to have an emergency switch button and optionally a Lidar or a bumper for avoiding collisions with close objects or persons.

4. Scenario Setup

The episode must take place in an urban area of Bologna. A minimum ground floor area of 10x10 m2 is expected for this episode.

A specific point inside the arena must be defined as the **medical centre** as the starting point for ground robots, ideally close to one of the entry points to the arena. This position on the ground will be the origin of the coordinate system of the arena, i.e. origin=(X=0, Y=0, Z=0). This position must be marked on the floor with some kind of visible marker (e.g. stickers).

A second specific point in the arena must be defined as the **citizen area** to which robots need to arrive. This position will be measured in meters from the start position, i.e. customer=(X=TBD, Y=TBD, Z=0). This position can be marked on the floor with some kind of visible marker (e.g. stickers). Around this marker, in a maximum radius of around 4m, there can be at most 2 people, where only one is the target.

The medicine can be represented approximately by a box of 15cm x 10cm x 10cm.

A small area for the team's **control station** must be set next to the medical centre location. There must be an entry point to the arena nearby, so it is directly accessible for team members. The control station must have electric power for laptops and battery chargers, and two tables with a minimum size of 2x1 m. Each table must be equipped with at least 4 chairs and 1 monitor (with power and HDMI cables).

Also, fixed (and mobile) **obstacles** could be included within this area. Depending on the specific area, dead ends and indoor spaces could be used to incorporate more realism into the episode.

Two main considerations for all the obstacles:
- The visual appearance of the obstacles should NOT be homogeneous (flat color), otherwise vision-based approaches will most likely fail.
- The minimum size of the obstacles in any dimension should be 20cm, to make sure onboard sensors can detect them (i.e. avoid the use of light poles).

As soon as a list of items to be used as obstacles is found by the local organizers, and agreed with the technical committee of this episode, the detailed descriptions with pictures of the obstacles should be provided to the participating teams.

There can be two different obstacle dispositions, so teams face the delivery task with increasing difficulty:
- Easy: use fixed obstacles between the medical centre and the citizen location.
- Hard: use fixed and mobile obstacles between the medical centre and the citizen location.

The disposition of obstacles in the arena must enable the navigation of the ground robots between the start and the customer location, in terms of available free space and safety separation from such obstacles (at least 1 meter).

After offering the arena to teams for practicing during the first one or two days, we propose to organize the execution of the episode in two rounds of time slots (for each difficulty level), each one taking place on a different competition day. The idea is that teams are

accumulating achievements during all three rounds, so the best team is the one that achieves the most difficult task (see score sheet for more details). During the Final, the team will only face the Hard configuration of the obstacle, potentially with new unseen obstacles or a reduced available time to complete the objective.

Regarding the **variability** of the scenario, the medical centre and citizen locations may change depending on the difficulty level and the number of participants. Between runs, the obstacle configuration may change up to 2 meters, so we prevent teams to build the solution during practice using map-based or teach & replay approaches.

5. Bologna Data Hub Interaction

TBD. Will there be the same as in MK?

6. Procedure

This section describes the step-by-step procedure for a complete run of the episode. A single run consists of two phases that are executed sequentially without any interruptions. A robot can automatically continue to the next phase at any time if it is unable to execute or fully complete a phase. According to the episode description, the procedure is split into two phases.

Preparations and start

1. A medicine request reaches a pharmacy in downtown Bologna with the location of a person in need.
2. The responsible of the pharmacy attaches the medicine to the ground robot.
3. The run begins, and the time starts, with the medical manager placing the medicine on the ground robot.

Phase 1: Delivery of the medicine

1. The ground robot autonomously goes with the medicine towards the citizen location.
2. During the navigation, the robot may need to detect and avoid different obstacles (including pedestrians). There will be an increasing level of difficulty in the types and number of obstacles that the robot can encounter.
3. Once at the citizen area location, the robot has to find the target person by approaching the present people nearby.
   a. Approaching should try to be face to face, meaning the robot should approach from the front (angle around 180º)
   b. Once the robot is in front of the person, it should ask if it is the person in need of help (target person)
   c. In case it is not, it should try with the next person in the area.
   d. In case it is, it should deliver the medicine and continue with phase 2.
4. The interaction with a person can be done through a screen or with voice recognition.

Phase 2: Accompany to the medical centre

1. In case the person does not feel well and it is not enough with the medicine, the robot should ask the citizen to accompany him/her to the nearest medical centre.
2. Then, the robot will accompany the citizen until they arrive at the medical centre, overcoming dynamic (pedestrians or other robots) and static obstacles on the way. There will be an increasing level of difficulty in the types and number of obstacles that the robot can encounter.
    a. Accompaniment should be side by side (90º of the motion direction) when in a wide area, otherwise, the robot should move ahead or behind the person to pass through narrow spaces.
    b. The distance between the robot and the target person shouldn't be higher than 1.5m to be considered as close accompaniment.

7. Timing

The challenge will run on 3 days: 2 days for preliminaries (safety checks and robots compliance, and also for teams practice in the arena), and one day of finals.

Team participation can be organized in time slots of about 15 minutes. The start time will follow a fixed, and pre-defined time schedule (no delays for any reason). The referees will also inform the participating team 10 minutes before the start of the time slot to place their robots and equipment in one of the tables of the control station area, just outside the arena. They must leave the other table free for the next participating team.

After the time slot of 15 minutes finishes, the referees will inform that the next participating team has 10 minutes to place their robots and equipment in the free table of the control station, while the team that has just participated has the same 10 minutes to pick up all their things. In this way, the organizers' time schedule can be set as **blocks of 25 minutes** (10 minutes of preparation + 15 minutes of competition). Depending on how many teams finally participate, these numbers can be subject to modifications.

Teams will be able to attempt the delivery as many times as they wish within the time slot, always starting from the medical centre location. Take into account that the team score will not be the best attempt during the time slot, but an average of their top attempts (see Section 8). The time taken between the start and end of the run will also be recorded, as faster solutions are considered to be better in case of ties in the number of achievements.

It is a good idea to show on a big screen a time **countdown** of the time slot, so it is clear for all teams and also for the audience.

8. Score

The scoring mechanism used for this episode is the same one used for the Task Benchmarks of the European Robotics League. As such, it is based on three sets: Achievements, Penalising behaviours and Disqualifying behaviours. Apart from these sets, the whole time of the operation will be recorded, to break ties between teams with the same amount of achievements.

Achievements

1. Reaching the citizen area location avoiding obstacles.
2. Reaching the citizen area location within the first 2 minutes after the time slot starts.
3. Approaching at least one citizen.
4. Approaching at least one citizen face to face.
5. Interacting with both citizens to confirm their identity.
6. Interaction done with voice recognition.
7. The medicine is delivered within the first 5 minutes after the time slot starts.
8. Accompanying the person side-by-side and adapting position in narrow areas (see section 6).
9. Accompanying the person staying close to the target person (see section 6).
10. Reaching the medical centre accompanying the person.
11. Reaching the medical centre accompanying the person in 8 minutes after the time slot starts.
12. Transmitting live information (images/video, robot position, etc) to the control station.

Penalising behaviours

1. Manual interventions to the ground robot in case it needs to be recovered from a failure (more details in Section 10).
2. Hitting any of the structures in the arena (obstacles…).

Disqualifying behaviours

1. The robot hits the citizen.
2. The robot damages the structures in the arena (obstacles, safety net…).

8.1 Admission to the ranking

Each (scheduled) execution of the episode by a robot is called a **run** of the benchmark. The final score achieved by the robot depends on its performance over multiple runs of the benchmark.

In order to be admitted to the ranking, a robot must have performed **at least 3 successful runs** of the benchmark.

A *successful* run is one where the robot collected at least one achievement.

8.2 Overall score

The competition is arranged in two stages: 1) Competition Days, 2) Final. The top 3 teams in the ranking of the Competition Days qualify for the final to be held on the last day of the competition. The final ranking for assigning the first, second and third place will be determined by the performance in the Final. During the competition days, several runs will be available to each team (let this number be M). Notice that M is the number of slots available for each team, it may differ from the actual number of performances of each team, if teams are not ready to attend some runs. During the Final, only one run will be performed.

Aggregate score of the Competition days. The aggregate score for each team for the M episodes performed during the Competition days will be determined according to the scoring system of the European Robotics League as follows:

- select the best N trials of the team
- determine the median of the scores of the N trials selected.

Let n be the position of the median in the ordered list of team scores, i.e., n = (N + 1) / 2 (when N is odd), then N (and consequently n) are determined according to the number of episodes scheduled M, according to the following table

M	N	n
6-9	5	3
10-12	7	4
13-15	9	5

In case of a tie score for access to the Final, the policy for tie-breaking is described below. If such policy does not break the tie, all teams with the same score will enter the Final.

Tiebreaker: In the case in which two teams have the same score, the minimum execution time over all the runs of the teams will break ties.

In case of tie score again, the rank will be the same. If teams with the same score are in the border limit to access the Final, all such teams will enter the Final.

9. Detailed instructions for referees

There must be two referees for evaluating this episode. The referees/organizers must prepare a schedule to ensure equal access of the arena to the participating teams for the setup and competition days.

BEFORE THE EPISODE

Safety checks
During the setup days, all robots will be checked by the referees for compliance. Only robots that successfully pass the safety checks will be able to participate in the competition.
Referees will check the safety mechanism of all the robots that intend to participate, which must be communicated by each team. If the robot has other mechanical devices (e.g. a manipulator), their safety must be demonstrated as well.

Scenario setup
Referees must place obstacles in the arena according to the level of difficulty of the time slot.

Before each time slot, referees must determine the medical centre and citizen locations. Referees must communicate to the participating team that they can start moving their robots

and equipment to one of the tables of the control station 10 minutes prior to the time slot start.

After these 10 minutes, referees must take a medicine to be delivered, and hand it to the team for attaching it to the robot. At this point, referees can announce the start of the time slot and start the countdown of 15 minutes.

DURING THE EPISODE

Between runs within a time slot, the obstacles should be moved up to 2m around their current location to prevent teams from using training-based approaches.

Referees must take notes of all achievements and penalising behaviours using a score sheet per time slot. One of the referees, Referee 1, will be in charge of filling the score sheet and will stay at the control station with other team members. The other referee, Referee 2, must be able to move throughout the arena close to the robot, will check the robot performance and other achievements, and will have a timer to record the time of each run. Ideally, both referees should have a direct communication link via walkie-talkie or similar.

Referee 1 will check the live transmission of data at the ground station, among other achievements. Special attention must be put when scoring the obstacle detection and avoidance. Teams must show Referee 1 an online proof that obstacles are being autonomously detected and avoided, for example explaining and showing the control station screen using the received images, highlighting the obstacle and/or the robot trajectory.

Referee 2 will check if the robot is running in autonomous or manual mode, will also check the proximity of the robot when it reaches the citizen location, as well as the actual interaction and delivery, and will also check if the robot hits any obstacles.

Manual interventions incurring in penalising behaviours are defined as physically interacting with the robot in order to continue the runs, for example due to: hitting any obstacles, malfunction if it does not respond to manual control, etc. Any manipulation of the robot is allowed without penalisation only if it is done in the starting medical centre location.

AFTER THE EPISODE

Referees must announce the end of the time slot, and let the following participating team 10 minutes to set up on the second table at the control station, while the current team also has these 10 minutes to pick up all their equipment.

Both referees must check the results of the participating team on the score sheet, and after agreement they must sign it. Then, they must show the results to the team leader in case there is any misunderstanding, and the team leader must sign it as well once discrepancies have been clarified, if any.

10. Detailed instructions for teams

BEFORE THE EPISODE

Safety checks

Teams may use different robots during different time slots. Teams must inform the referees of all robots that they intend to use, and each robot must pass a safety check before being used. Only robots that successfully pass the safety checks will be able to participate in the competition.

If the robot has other mechanical devices (e.g. a manipulator), their safety must be demonstrated as well.

This check can be done at any time during the setup days. When teams are ready for an inspection, they can request one from the referees.

Scenario setup

A medicine to be delivered will be provided by the referees at the medical centre location. Teams have 10 minutes to set up in one of the tables of the control station, and must wait outside the arena for the start of their time slot. Teams may power up their equipment during the setup time, including the robot.

DURING THE EPISODE

The referees will indicate the start of the time slot. Then, the team is allowed to enter the arena. They can attach the medicine to the ground robot using whatever mechanism they have designed for the competition.

There will be one referee next to the control station, and another one next to the ground robot. Team members at the control station must clearly show if the obstacles are being detected and avoided in an autonomous manner, for example explaining and showing the control station screen using the received images, highlighting the obstacle and/or the aerial robot trajectory.

Manual interventions incurring in penalising behaviours are defined as physically interacting with the robot in order to continue the runs, for example due to: hitting any obstacles, malfunction if it does not respond to manual control, etc. Any manipulation of the robot is allowed without penalisation only if it is done in the starting medical centre location.

AFTER THE EPISODE

At the end of the time slot, the team leader will receive the score sheet from the referees in order to check the team performance, and after solving any discrepancy, he/she must sign it.

11. Ethical issues

Volunteers involved in the episode, to act as citizens, will be selected by the referees among team members, members of the technical/organizing committees, or adult citizens. In case

of using real citizens they will be informed about the episode, its procedure, how to interact with the robot for communicating the order and about the safety procedures.

The citizens will be invited to sign a consensus form where they declare to have been informed about the above mentioned information and that they volunteer to participate in the episode.

12. Safety procedures

The only safety procedures concerning the setup of this episode concern the physical confinement of the arena. The area should be closed to external people that are not related to the competition.

Concerning the execution of this episode, there should always be someone carrying the remote emergency switch button, and paying attention to the robot behavior in order to stop its movement on any risk observed.

13. References

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Appendix A. Score sheet

Team Name: _____   Difficulty level (Easy/Hard): _____

Run Number: _____   Execution Time: _____

Referee 1: _____   Referee 2: _____

Achievements:
☐ Reaching the citizen area location avoiding obstacles.
☐ Reaching the citizen area location within the first 2 minutes after the time slot starts.
☐ Approaching at least one citizen.
☐ Approaching at least one citizen face to face.
☐ Interacting with both citizens to confirm their identity.
☐ Interaction done with voice recognition.
☐ The medicine is delivered within the first 5 minutes after the time slot starts.
☐ Accompanying the person side-by-side and adapting position in narrow areas.
☐ Accompanying the person staying close to the target person
☐ Reaching the medical centre accompanying the person.
☐ Reaching the medical centre accompanying the person in 8 minutes after the time slot starts.
☐ Transmitting live information (images/video, robot position, etc) to the control station.

Penalising behaviours:
☐ The robot hits any of the structures in the arena. Number of hits: _____
☐ The robot needs manual intervention during a run.

Disqualifying behaviours:
☐ The robot hits the customer.
☐ The robot hits and damages structures in the arena.

Notes:
_____
_____
_____
_____
_____

Referee 1 signature	Referee 2 signature	Team leader signature

Appendix B. Team information sheet

Not applicable.