Human Machine Interface Design for Robotized Road Works in InfraROB project

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Abstract:

This paper presents technical developments of the H2020 EU-funded project InfraROB, which proposes a new concept of collaborative operation between robotic safety cones, automated road machinery and Unmanned Aerial Vehicles (UAVs) to improve the segmentation and signalling of the work zone, thereby enhancing safety and efficiency.

Automating civil infrastructure assessment aims to reduce human involvement in maintenance by using specialized automated equipment. Automation tools enhance inspection efficiency, minimizing repetitive tasks and hazards in environments like roads. Road maintenance automation involves diverse robotic agents in dynamic settings, necessitating adaptable hardware and software to optimize robot motion and behaviour in variable environments. UAVs find increasing use in transportation infrastructure management, particularly in road safety, traffic monitoring, and highway infrastructure management (Outay et al., 2020). Notably, UAVs assist in vehicle detection and traffic flow analysis using advanced models like R-CNN and YOLO. Despite technical complexities, safety implications require experienced personnel supervision. To address this, the development of Human Machine Graphic Interfaces (HMI) is crucial, focusing on spatial information and reducing cognitive load (Drury et al., 2004).

The HMI is an essential component of the project, as it is closely associated with the supervision and safety of operations. The project proposes a new concept of collaborative operation between robotic safety cones and a Remotely Piloted Aircraft System (RPAS) to enhance the segmentation and signalling of the work zone. The aim of this approach is to ensure the safety of both road users and maintenance personnel, combining the benefits of real-time monitoring with Deep Learning techniques to prevent accidents and mitigate risks. Advanced signalling alerts will be deployed from robotic safety cones to enhance safety and efficiency by providing warnings to both road users and workers.

The interface design focuses on operational requirements, notably featuring an interactive graphical application for on-site and remote monitoring. It displays collected data like RPAS coordinates, safety cones, and machinery positions on an integrated map. The app updates information from the database every second, depicting site status (normal, alarm, low visibility), device conditions (on/off, charging, faulty), battery levels, and fuel status. Real-time AI-processed RPAS video playback offers an aerial view, detecting potential safety threats. Alongside monitoring, the app enables device control: moving cones, machine activation, and triggering site alarm, all accessible within the interface.

A cloud database accessed via Road Side Unit (RSU) controls the communication system. Safety cones transmit status, battery level, and position data individually to this database, while the drone relays work area information and vehicle detection. Autonomous machinery shares its positioning data with this database too. Data concerning positioning and alarms use the V2X protocol based on IEEE 802.11p. Python, pyCharm, and QtDesigner were chosen for programming, development, and GUI assembly, respectively. The application, intended for Windows OS, operates on desktops or laptops or remote-control station, meeting specified requirements.

The interface features a side menu with tabs: Start, File, Control, Monitor (Figure 1), and Help (Figure 2). The Start tab enables project selection, allowing creation or opening of existing projects. The Archive tab displays project entries with details and options to Open or Delete. Opening a project provides database information visible in Control and Monitoring tabs. The Control tab manages on-site devices, presenting weather data, a map centred on RPAS, real-time movements, alarm indicators, and device identification. The Monitor tab shows idle screen details: weather, alarm status, project info, and an enlarged map. Additionally, the Help tab offers a legend of system states and symbols for easy reference, eliminating the need for a printed manual. This user-friendly interface organizes project management, device control, monitoring, and assistance tools effectively within the application.

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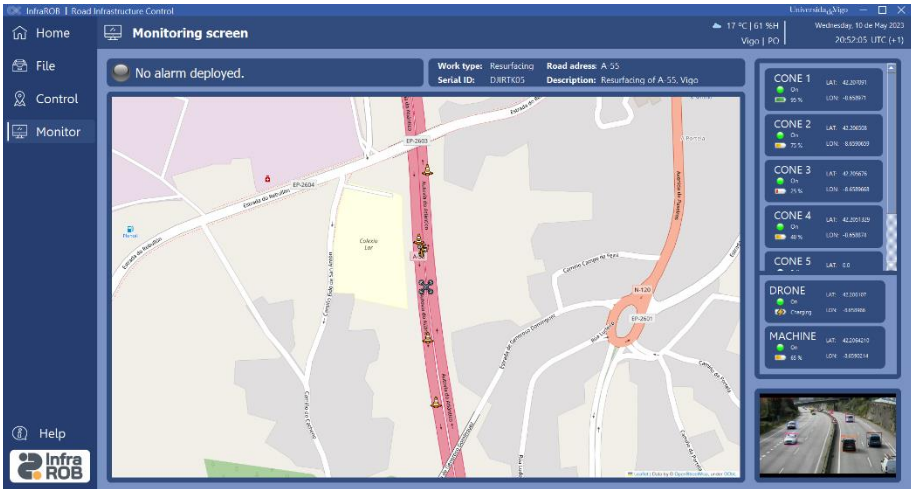

Figure 1. HMI Monitor screen.

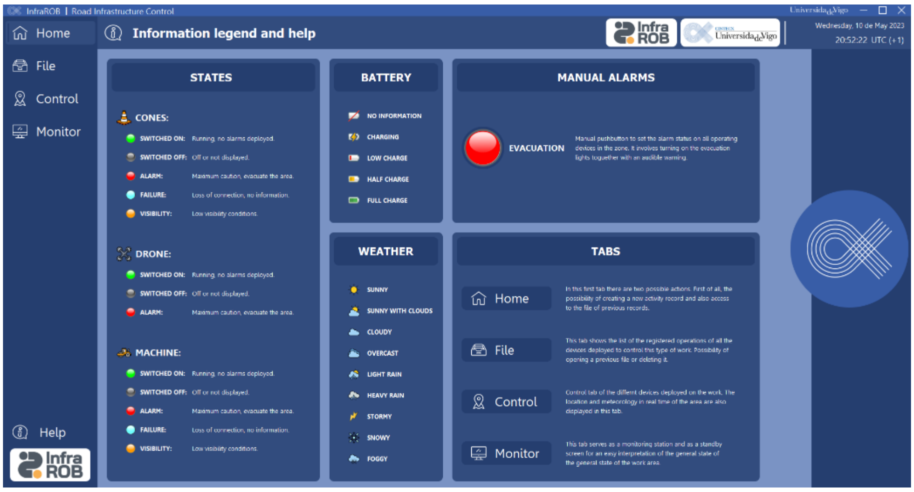

Figure 2. HMI Help tab.

In order to simulate a real case and test the application, the HMI was tested with a simulated deployment of six safety cones in A-55 highway in Puxeiros, Vigo, Spain. The interface design was simple, focusing on showing a display of the robots on the site map, status information and a video of the incoming traffic with vehicles detected by an Artificial Intelligence. This work showed that it is possible to perform a remote monitoring of the status of the construction site, using a fluid interface and low computational consumption.

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