Autonomous Robotic System with Tunnel Inspection Tool Positioning

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Abstract –

This paper presents the ROBO-SPECT European FP7 project, funded under the ICT-2013.2.2 programme on Robotics use cases & Accompanying measures. The main objective of the ROBO-SPECT system is to provide a robotized, faster and reliable alternative to manual tunnel structural inspection and assessment. Physical developments include the design and implementation of a multi-degree-of-freedom (MDoF) robotic system, which uses a mobile vehicle to advance along the roadway, an extended crane capable of reaching the most commonly found tunnel geometries, and a robotic arm for positioning a specifically designed ultrasonic sensor (US) Inspection Tool with high accuracy. A semi-supervised computer vision system to detect tunnel defects, a Ground Control Station (GCS) to provide a Human-Machine Interface (HMI), and an Intelligent Global Controller (IGC) to command the robot and manage communications between the different parts have also been developed.

An overview of the fundamental aspects of the project architecture and design will be detailed. In addition, the developed and implemented algorithm for positioning the Tunnel Inspection Tool on detected cracks shall be presented. Finally, experimental evidence to validate the functionality of the ROBO-SPECT system in a real motorway tunnel with ongoing traffic will be provided.

Keywords –
Automation; Control of Robotic Systems; Tunnel; Inspection; Maintenance;

1 Introduction

When facing existing civil infrastructures, one of the greatest challenges that engineers may find is its inspection and assessment in order to to ensure that bridges, roads, pipelines and tunnels remain in safe condition and continue to provide reliable levels of service [1], [2]. The structural performance of tunnels is time-dependent because of the damaging process induced by natural and artificial impacts, inadequate maintance or the simple effect of ageing.

Water supply, metro, railway and roadway tunnels have increased in both total length and number, and will continue to do so on a global scale. Some tunnels still in service were constructed over 50 years ago, and many have exceeded their intended design service life [3]. Only in Europe in 2002, the overall length for operational transportation tunnels had grown up to 15000 km [4].

Tunnels are characterized by humidity, dust and absence of natural light. Inspection and maintance operations are commonly performed by human operators, taking time and expertise. Additionally, the human factor combined with the unfriendly environment could lead to lack of guarantee regarding quality control.

These facts highlight the need of automated, cost-effective and exhaustive solution to inspect tunnels that prevents such disasters. In this work, the final integrated ROBO-SPECT system is presented, followed by the safe positioning algorithm of the Ultrasonic Sensors (US) inspection tool on a detected crack. Finally, experimental evince, timing and accuracy results and conclusions are also presented.

2 The ROBO-SPECT European Project

ROBO-SPECT is a research project co-funded by the European Commission under the 7th Framework Programme (FP7) ICT-2013.2.2 on Robotics use cases & Accompanying measures. The project ran between October 2013 and October 2016 and was composed by a Consortium of 12 partners. The overall objective of ROBO-SPECT is to design and implement an automated, faster and reliable tunnel inspection robotic system that inspects cracks and other defects of the tunnel lining on one pass without interfering with tunnel traffic (Figure 1). The system also includes a detailed structural assessment software.

The specific objectives of this project are the