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Title: Assisted teleoperation for a dual-manipulator robot and coordination with aerial vehicles for nuclear decommissioning applications.

This paper summarises research at Lancaster University into the modelling and control of mobile robots with application to nuclear decommissioning. The work is based on use of a mobile, hydraulically actuated robot, which is potentially supported by information provided by unmanned aerial vehicles (UAVs). Modelling of the robot, which has dual seven degree-of-freedom manipulators is first considered, followed by discussion of a multi-channel time-varying sliding mode controller for UAVs. In part funded by the National Centre for Nuclear Robotics in the UK, the context for this research is the nuclear decommissioning challenge but the generic robotics results are relevant to other areas, such as new build and manufacturing.

Dynamic and kinematic models of the robot are developed and validated using symbolic and numerical techniques. The results are useful for later optimal trajectory design, system identification and controller design. A complementary study of the same platform is concerned with a genetic algorithm that aims to find parameter estimates for this non-linear and non-convex optimisation problem. The proposed genetic algorithm, which utilises multi-objective output error identification for parameter optimisation, has been validated using both simulated and experimental data. A related study is concerned with the identification of state-dependant parameter (SDP) models for joint angle control. Innovative regret-regression methods are used to propose a way of representing and parametrising the state-dependant gain. This approach integrates the input signal calibration, system identification and nonlinear control system design steps, using a relatively small data-set, allowing for straightforward recalibration when the dynamic characteristics have changed due to age and use of the robot.

Complementary research considers use of UAV attitude control, using a novel multi-channel robust nonlinear control algorithm based on time-varying sliding mode theory. A time-varying sliding manifold has been proposed to enhance the robust performance whilst minimising chattering phenomena. Since performance parameters are affected by persistent radiation in decommissioning environments, time-varying external disturbances and uncertainties are simulated, with a quadcopter used to test the robust performance of the proposed algorithm. Finally, using remote pipe cutting as an example of the proposed system for assisted teleoperation, the user selects the object from an on–screen image, whilst the computer control system automatically grasps the pipe with one end–effector of the ground based robot and positions the second for cutting. However, the system potentially fails in some cases because of

data limitations, for example a partially obscured pipe in a challenging decommissioning scenario (simulated in the laboratory). Hence, coordination with the drone is required to increase the use case scenarios e.g. via the introduction of mobile cameras mounted on the drone.