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REAL-TIME OPTIMAL COLLISION-FREE CONTROL FOR ROBOTIC ARM MANIPULATORS IN  
THE PRESENCE OF WANDERING OBSTACLES

**Abstract**

Modern space missions require high intelligent robotic system to perform complex tasks including cooperative transportation, capturing, release of payloads and even aid in space station construction. The increasing complexity of missions tends to increase the likelihood of collision between robotic arms and obstacles in the surrounding environment. Such undesirable collision should be avoided to prevent causing damage to the robotic arm and payloads during operation. Therefore, optimal control of robotic arm manipulators becomes increasingly critical to the achievement on mission objectives.

Previous publications have successfully demonstrated the methodology of collision-free trajectory planning for robotic arm manipulators in the presence of morphing mobile obstacles by minimising the user-defined objective functions such as time of transfer and actuation efforts. Recent research at RMIT University has further extended the capability into a real-time optimal control system which continuously predicts the change of the obstacle's position, velocity and shape to generate an optimal path for the robotic arm manipulators resulting in safe deployment. This paper aims to present a generic method for the real-time continuous optimal trajectory planning for robotic arm manipulators in the presence of chaotic wandering obstacles. We design a projection algorithm to transform the position and attitude of the obstacle into the restricted configuration space of the manipulator, to obtain the free-space for optimal control problem.

In this paper, the solutions of the associated nonlinear differential equations of motion are obtained numerically using the direct transcription method. The direct method seeks to transform the continuous optimal control problem into a discrete mathematical programming problem, which in turn is solved by using a non-linear programming algorithm. By discretizing the state and control variables at a series of nodes, the integration of the dynamical equations of motion is not required. The Chebyshev pseudospectral method, due to its high accuracy and fast computation times, was chosen as the direct optimization method to be employed to solve the problem. We obtain solutions for the cases involving slewing and deployable links and highlight their differences.

In order to present the methodology and results of simulations, Virtual Reality animations are used to visualize the complex motion of the robotic arm systems and their position relative to the wandering obstacles in a virtual interactive 3D environment. Such Virtual Reality simulations have been proven as a very effective and reliable tool for revealing the complex dynamic nature of robotic systems.