



## Research Statement: Osama Elshazly

**Broad research interests and related applications:** My research focus on the development and validation of new artificial intelligent control systems(Fuzzy control), iterative learning control and computational methods for sensing, estimation, and control problems, with a focus on robotic and mechatronics systems. In real-world systems, uncertainty (both in the system model and sensory readings) is omnipresent. A few of the vast set of applications for this research include (i) Motion planning for mobile robots and manipulators under uncertainty, (ii) precise control of mobile robots in an unstructured environment under imperfect measurements, (iii) motion control for robots working in operating conditions in changing and uncertain environments with people.

**Approach/philosophy of research & existing challenges:** Specifically, I am interested in principled tools that can robustly deal with such problems in a probabilistic setting, such as nonlinear control methods, learning algorithms, and AI-based decision making methods under uncertainty. Fuzzy control and iterative learning control are one of the most principled general algorithms that model and solve the problem of controlling such systems under uncertainty.

**Research goals and contributions:** My main research goal is to development of the missing links between theory and practice in motion planning under uncertainty especially in an unstructured environment by creating principled tools and algorithms with an emphasis on robustness, reliability, and scalability. In particular, in my PhD dissertation, I investigate the connections between the simulation and real validation of nonlinear control systems for motion control of skid steering mobile robot. I show that establishing such a connection can solve many problems in the domain of planning and control under slip conditions, and more importantly can lead to principled theoretical tools that are applicable to practical systems. Accordingly, my current research is highly interdisciplinary, lying in the intersection of control systems, computational methods and my PhD dissertation is conducted jointly at the Catania University-Italy (Dipartimento di Ingegneria Elettrica Elettronica e Informatica) and Egypt-Japan University for Science and Technology (E-JUST)- Egypt (Mechatronics and Robotics Department).

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## My Dissertation Research

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**Problem:** My PhD research focuses on the development of a nonlinear controller of motion control skid steering mobile robot under slip conditions. This problem calls for control of motion of the robot in an unstructured environment which provides slip conditions for the operation of the robot. One of the most general formulations of this problem is the nonlinear controller.



**Challenge:** Nowadays, mobile robotics constitute an attractive research field with a high potential for practical applications. Skid Steering Mobile Robot (SSMR) is one type of mobile robots with non-explicit steering mechanism, in which the motion direction is provided by turning the left-side and right-side wheels at different velocities. SSMR are widely used as outdoor mobile robots due to the absence of a steering system which provides simple and robust mechanical structure, faster response, high maneuverability, strong traction, and high mobility. So, they are suitable for terrain traversal such as loaders, farm machinery, mining and military applications.

**State-of-the-art:** Many disturbances and environment variations may be found in the unknown and inhospitable environment in which the robots operate inside such as slip phenomenon. These disturbances can affect the robot's control performance and can lead to the robot cannot follow the desired trajectory in the trajectory tracking problem. Moreover, the SSMR wheels must have lateral skidding for the robot to move in a curved path due its steering. This lateral skidding can be considered as an inherited slip. So, slip constitutes one of the most important phenomena when dealing with skid steering mobile robots. For the success of such robots mission in trajectory tracking, they must be controlled effectively especially if there are disturbances and uncertainties in the working environment. Moreover, those autonomous robots must track such trajectories with stable movement. So, to accomplish this trajectory tracking task, motion control of such mobile robots must be considered.

For these reasons, the first and the foremost focus of this work is to design a motion controller to guide the robot to track a reference trajectory with as minimal tracking error as possible, taking into account the slip conditions which may be unavoidable and constitute a key issue in the robot working environment.

**Contributions of my PhD research:** In this thesis, two research directions, kinematics direction and dynamics drive direction, are considered. Firstly, the kinematics model was developed and extended to include the slip conditions in the SSMR model. Then, the design of a kinematics model based controller optimized based on two optimization techniques, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO), is introduced for comparison purpose. Secondly, the dynamics and the drive subsystems of SSMR are augmented to obtain a reduced order model of the dynamics-drive subsystems. Then, a linear Quadratic Regulator (LQR) with feed-forward compensation and an inverse dynamics controller are designed for reference tracking of a dynamics-drive augmented model of SSMR.

Simulation results are presented for the two directions which illustrate the effectiveness and enhancement provided by the proposed motion controllers. Moreover, experimental verifications of the proposed controller in the first direction, kinematics subsystem, are introduced due to the inaccessibility on the low level control of the second direction; dynamics-drive subsystem, in the experimental system. Simulation and experimental



results show the significant improvements provided by the kinematics model based controller optimized based on the PSO algorithm over those provided by GA algorithm.

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### **Future research**

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I would like to explore a broad range of topics within the area of iterative learning control, planning and control under uncertainties found in unstructured environments. In particular, I like to see closure between theory and physical realization. My PhD research paves the way to tackle many challenging problems in planning under uncertainty for real-world robotic systems. It also provides many opportunities for future collaborations and new projects. Some specific future research directions that I am planning to pursue are outlined in the following paragraphs. In most of the following projects, I have already taken some initial steps.

1. Motion control in dynamic uncertain environments.
2. Multi-robot systems and cooperative Motion control under uncertainties.
3. Application of the proposed algorithms to varieties of robotics systems found in real life