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Modelling and simulation of multi-robot system and control methods developments

M.R. Hayajneh*, S. BaniHani, K. Al-Widyan, S. Mutawe
The Hashemite University, Jordan

Introduction (300 words)

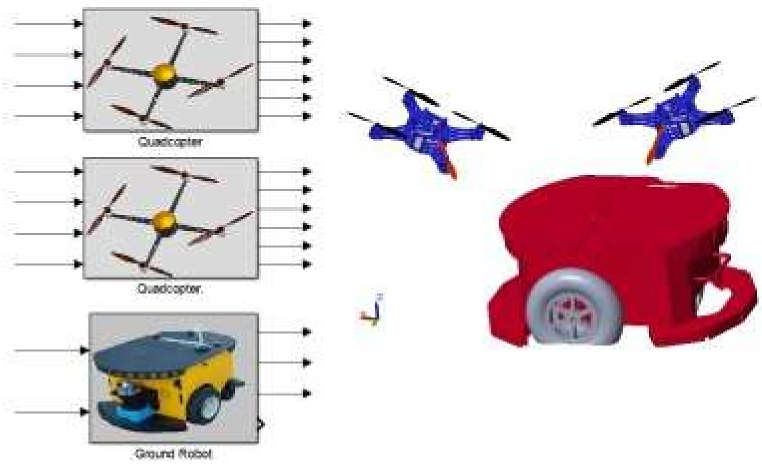
People continuously search for tools in the market that allow to design, simulate and test mechanical systems to reduce time, early to find errors, and to decrease cost. SolidWorks, or Pro/Engineer, etc., are the strong Computer Aided platforms in terms of designing, simulating and preparing machines for engineering process. These software help engineers to build 3D multi-body models. These models can then be transformed into MATLAB/SimMechanics models allowing for control implementations. Bringing physical models inside the MATLAB environment helps researchers to develop control methods to realize the system stability. The work by (Tang, Zhang, and Ru, 2012) employ LQR optimal control method to realize the system stability control of the linear double inversed pendulum, and implement the Kalman filtering approach for optimal estimation of system output to prevent the noise effectively. Moreover, One axis and two-axis inverted pendulum models have been studied by (Wang , 2011), and he successfully implemented PID controllers to stabilize the systems with good path tracking. Furthermore, the work of (Murphy, 2016) shows the performance of a simulated quadrotor under disturbances by using different PID controller configurations. A feedback linearization approach has been investigated by (Lotufo, Colangelo, and Perez- Montenegro, 2016) to design embedded model control for a UAV quadrotor.

Team of robots could help to accomplish missions easier and faster. A swarm of small aerial and ground robots is a set of inexpensive robots that explore a dangerous environment with aim to locate targets. In a multi-agent or multi-robotic system, accurately measuring the vehicles position with respect to other vehicles and the local environment helps to track a moving target effectively.

This work illustrates a high-level approach that designed and implemented aerial and ground robots and utilized Simulink to perform modeling, simulation, and control for the robotic system. A quadrotor and a ground robot were designed in ProEngineer CAD environment with all the mass and inertial properties were defined there, then these models were exported to XML files to be read by SimMechanics in MATLAB. At this stage, control methods can be applied on the robotic models to achieve stability in motion.

Methods (300 words)

This section describes the overall construction of a robotic system which were created by means of Simulink modelling and SimMechanic tool in MATLAB. The system combines between several aerial and ground robots as shown in fig. 1. In this system, the robotic platforms were created in CAD modeling environment (e.g. ProEngineer) and were interfaced with MATLAB tools for motion control developments. The proposed robotics system allows one to insert as many as needed of aerial and ground robots that demonstrate a mission performed by a multi-agent system.



The geometrical models of a quadcopter and ground robot were built for simulation. The parameter values for each robot that adopted in the simulations are presented in table I.

TABLE I
CAD-MODEL ROBOTS

Robot platform	Dimentions (m)	Weight (Kg)	Inertia ($kg.m^2$x10^{-3})
Ground robot	0.45 x 0.65 x 90	8.4	$I_{robot} = 175$ $I_{rotor} = 0.0105$
Quadcopter	0.2 x 0.4 x 0.4	1.2	[4.836 0 0; 0 4.836 0 ; 0 0 8.325]

Position and orientation stability of each robot were achieved by using PID controllers. The gains of the controllers were tuned properly to guarantee best performances. More precisely, attitude and position controller's gains were chosen in order to minimize oscillations and settling time.

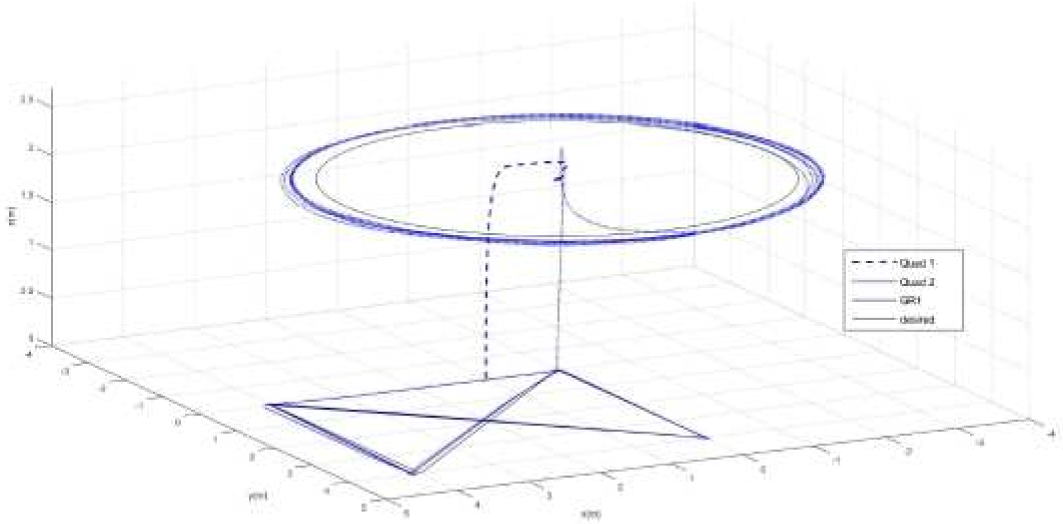
The adjusted gains of the PIDs in the quadcopter and ground robot are given in table II

TABLE II
PIDS GAINS IN THE QUADCOPTER AND GROUND ROBOT

Quadcopter PIDs				Ground robot PIDs			
	P	I	D		P	I	D
Alt	15	10	5	Position x	20	0.3	0
Positions x,y	10	0.1	3	Position y	20	0.3	0
Roll/Pitch	2	0.2	1	Heading α	4	0.3	0
Yaw	0.5	0.1	0.1				

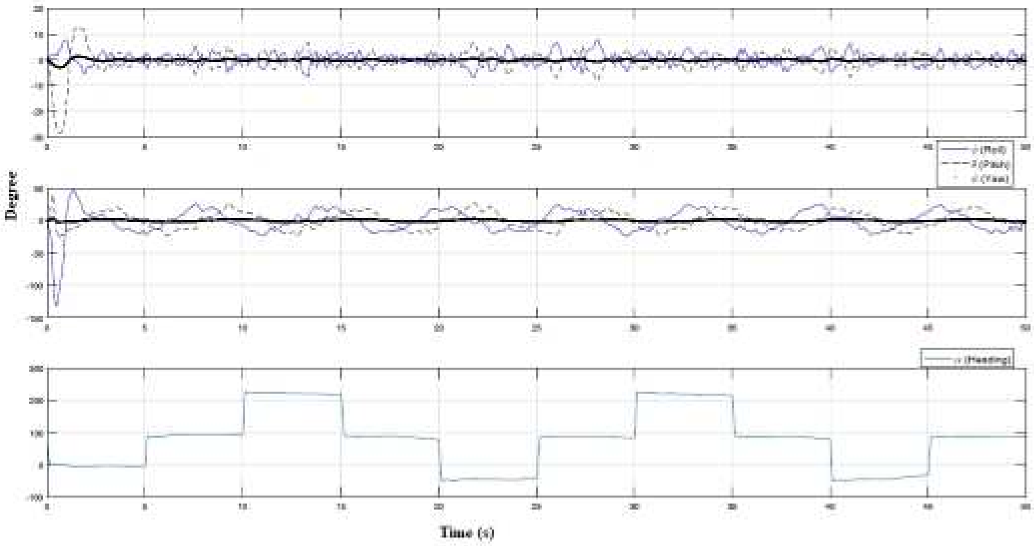
Results (300 words)

This section serves to introduce one to the performance of each robot independently and to study its stability and ability to track a pre-defined trajectory. Here the controlled variables are the robots positions and orientations. Figure 4 shows how the robots (i.e. two quadcopters and one ground robot) track the assigned paths correctly. In this scenario the three robotic platforms were initialized in the ground. The ground robot were demanded to reach a sequence of waypoints and to wait for a while at each point. In the meanwhile, one of the quadcopter were required to hover in home location at 2m of altitude, while the second quadcopter were needed to track a circular-shape trajectory at the same altitude. The vehicles maintain the performance of the motion in terms of stability and proves quite good characteristics in terms of ability to track the predefined trajectory.



To ensure the validity of the used PID controllers in the proposed robots, external disturbances as a random form signals were carried out on each robot. These signals are applied on all axes in body frame of each robot with a value range of (-0.4 _ 0.4) N.

The position control system in the quadcopter computes the angles necessary to achieve the desired position, while the altitude controller defines the thrust request for reaching the specified vertical position. In the ground robot, the desired forces that are needed to move the robot into the desired position are produced by the position controller while the heading angle of the robot is defined by the orientation angle controller. Figure 5 illustrates the orientation angles of the quadcopters and the ground robot during the motion proving the overall stability in motion of the vehicles.



Conclusions and Contributions (300 words)

The work presented the modelling and simulation of a multi-robot system (ground and aerial robots) and studied the motion stability and maneuverability of each robot in the system. The robotic system built in a simulation environment that helps one to insert and remove several robots in the system and to modify the characteristic of the robot model in CAD platform and reconsider it easily in the simulation of the robotic environment. In this work also, Multi loop control system was implemented for each robot to insure its stability and trajectory tracking under disturbances. The performance of the robotic system were tested and validated in different robotic motion scenarios. The results presented high stability in robots motions and good performance in trajectory tracking under disturbances. The tests also displayed very good maneuverability of robots that can be approved for collision avoidance and engaging in common tasks.

The next contribution to this research is the development of an appropriate control strategy to allow each agent in the system to use the location information for other agents and to take the advantage of this information in improving its guidance during a specific mission and keeping it from colliding with other agents.

From the practical point of view, the next stage of this work is to construct a multi-agent system of aerial and ground robots for real life applications that need a development of mapping and localization methods.