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Towards Automatic Design of Controllers: Implementation of Machine-Learnable, Cooperative Behaviors for Khepera IV Robots

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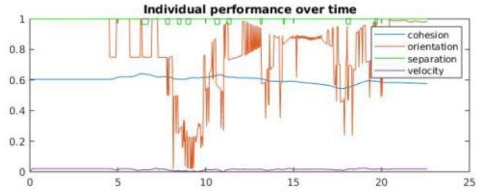
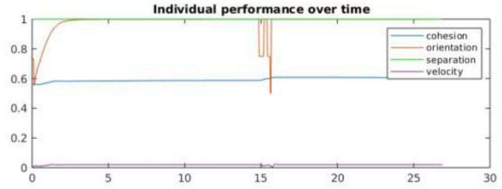
Today, robots are part of our daily lives. Initially intended as simple human assistants, they now have to be able to perform increasingly complex tasks. In this context, our chosen approach in order to program the robotic platform was to use automatic control design methods. In this project, complex controllers have been obtained by combining relatively simple fundamental behaviors implemented in the form of blocks and by using a probabilistic finite state machine as behavioral arbitrator. Its topology, the transition rules and all further parameters had to maximize a task-specific objective function.

The case study chosen for this project was flocking. We used the three Reynolds rules to implement the behavioral blocks, namely cohesion to maintain closeness to neighbors, separation to avoid neighboring robots and alignment to match neighbors' speed and direction. Moreover, we also added an obstacle avoidance behavior. These behaviors have been implemented using only local information based on infrared (IR) sensors for both range and bearing (R&B) and communication. At first we approximated the velocities of the neighboring robots using only the R&B measurements. An interesting general flocking behavior has emerged from this implementation. However, this approach was not entirely successful as the flocking was not stable (see the figure below) and it showed poor results in presence of noise.



Therefore, in order to improve the flocking and to make it noise-resistant, an explicit cooperative mechanism has then been added in the form of communication among the robots. Moreover, an extended (nonlinear) Kalman filter (EKF) has been implemented to deal with the noise on the R&B measurements. This new version really improved the behavior of the robots (see figure below). The EKF had two main advantages. It first allowed a more stable flocking thanks to the good estimation of the relative orientation of the neighboring robots. Then, the control of flocking behavior was possible even in an environment with noise because, as the pose of the robots' neighbours could be more precisely estimated due to the inherent noise resistance obtained through the EKF.



Finally, it is worth highlighting two interesting contributions of this semester project in relation to the more or less similar articles consulted during our work. On the one hand, a finite state machine has been used to obtain collaborative behaviors of robots in the context of flocking. On the other hand, no absolute reference system has been used in our approach. Instead, we have proposed a relative kinematics which has been developed both from the theoretical point of view and in terms of its numerical implementation. In this context, the communication between the robots proved to be essential in order to obtain good performances results for the flocking. Furthermore, although the extended Kalman Filter is well known and used in various applications, its design for our problem was not trivial and the EKF was crucial to obtain a reasonable flocking behavior.