Comparison of Algorithms for Simultaneous Localization and Mapping Problem for Mobile Robot

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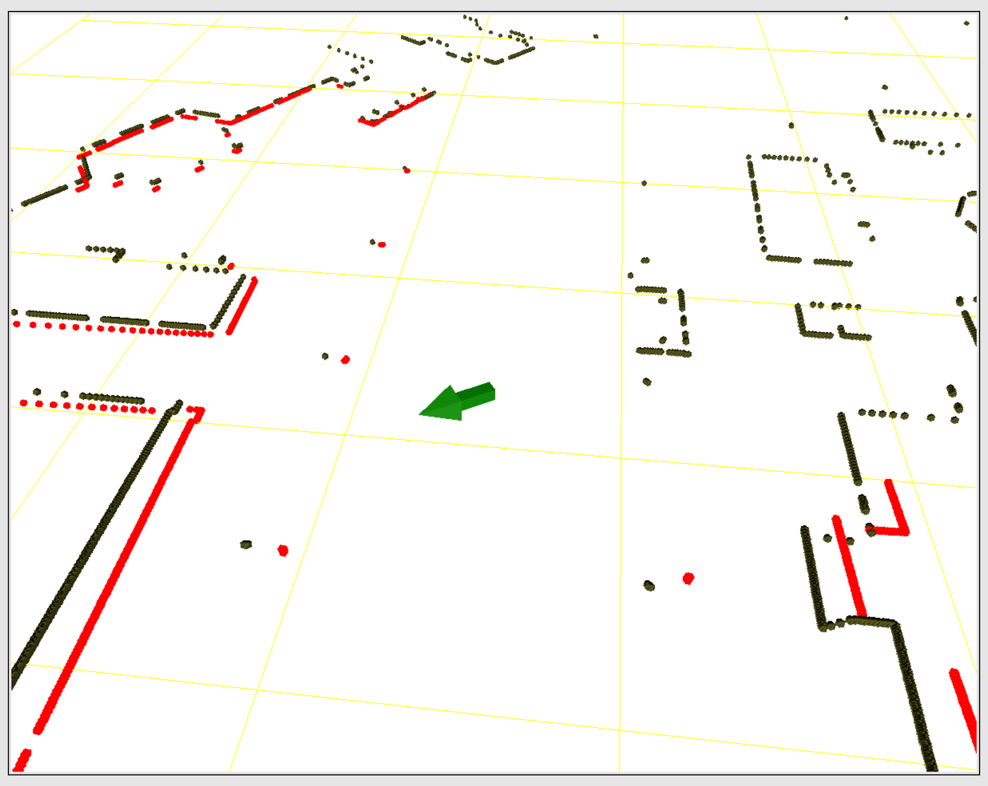
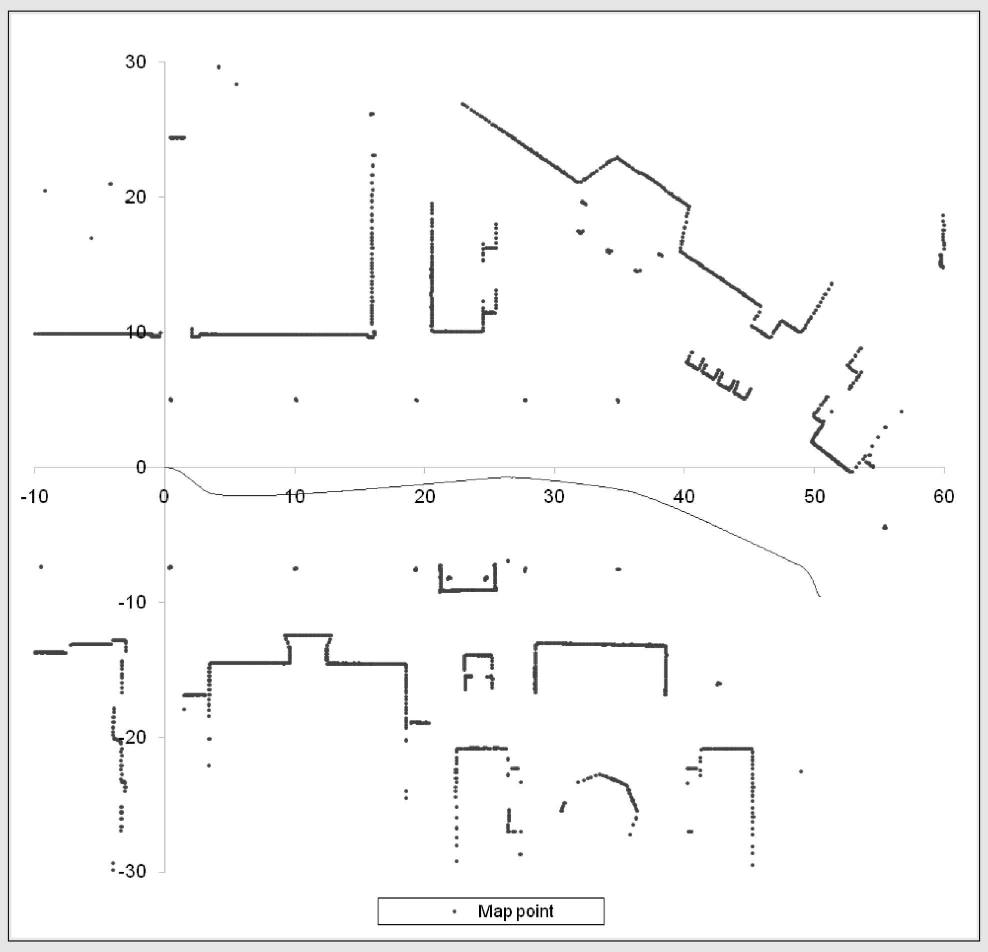
1. Introduction

THIS papers presents a comparison of selected algorithms for simultaneous localization and mapping (SLAM) problem in mobile robotics. Results of four general metaheuristics, Simple Genetic Algorithm, Particle Swarm Optimization, Quantum-Inspired Genetic Algorithms and Genetic Algorithm with Quantum Probability Representation, have been compared to results of classical, analytic method in this field, Iterative Closes Points algorithm. In the experiments the same objective function, drawn from Iterative Closest Points algorithm, has been used. Two situations have been considered: local and global localization problems of mobile robot. Both problems are import and often critical for successful navigation of robot in environment.

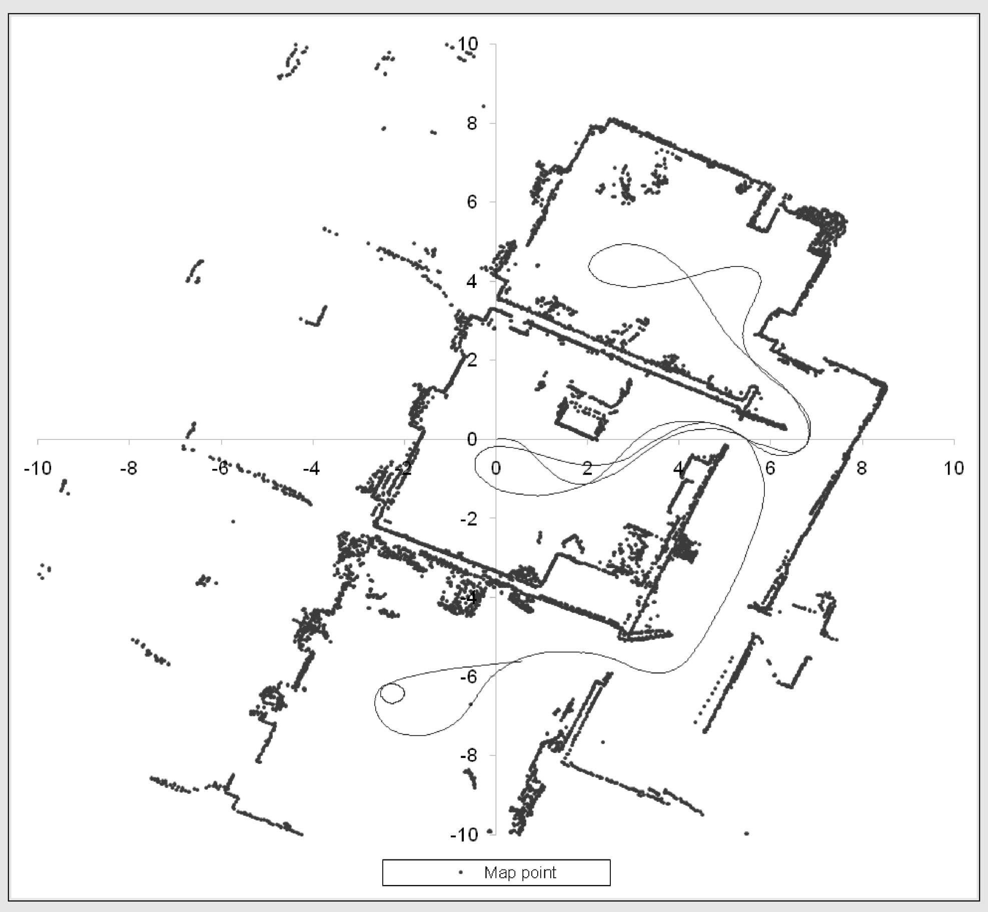


2. Empirical comparison

Map of simulated urban environment.

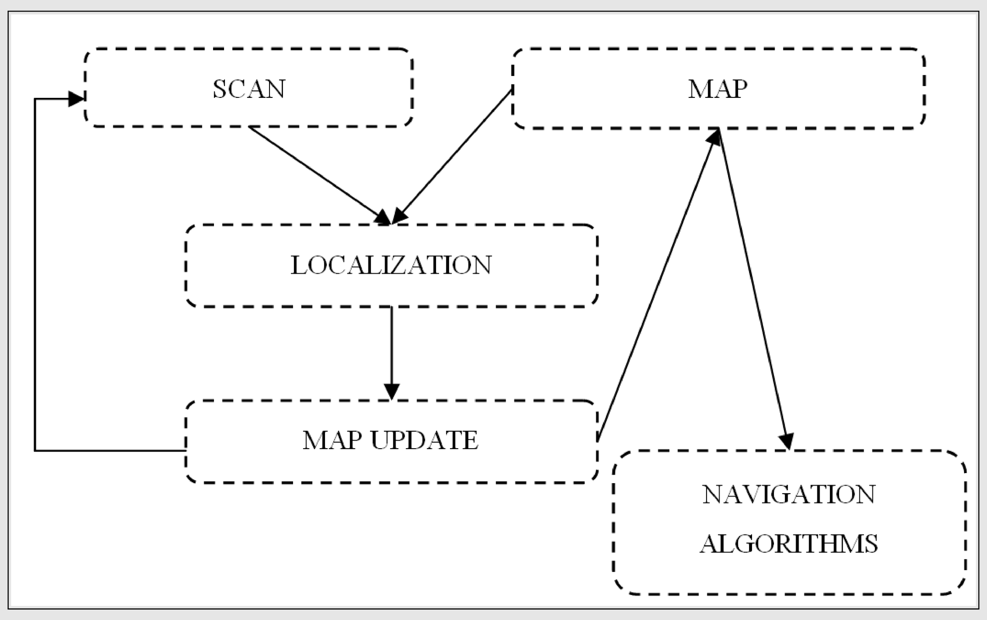


Real map of Computer Engineering Department building.



3. SLAM problem

The simultaneous localization and mapping problem is critical for efficient navigation and localization of autonomous robots. In a classical approach, SLAM uses different kind of sensors (e.g. sonar, infra red, lasers, laser scanners, cameras) to locate robot in its knowledge base, i.e. a map of environment. As the robot explores new areas, the knowledge base is updated and the new localization is calculated in the updated map.



In our research, performance of ICP algorithm has been compared with four metaheuristics. The experiments have been conducted on the two maps:

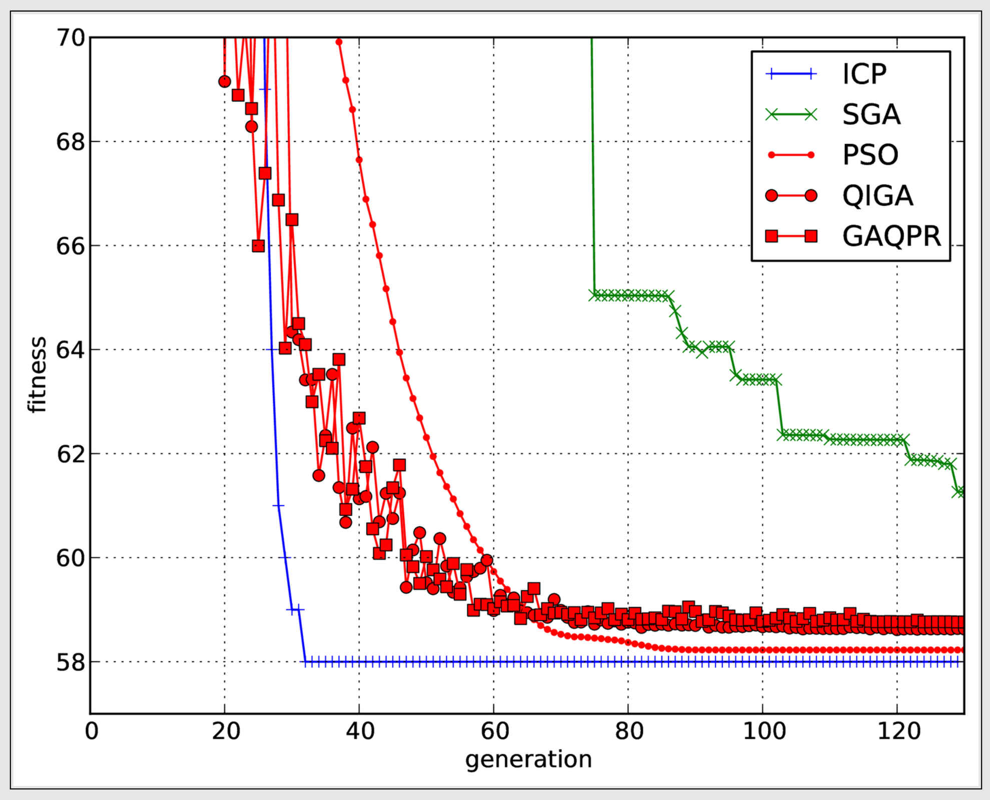
- Localization on artificial map - one of the environments provided by Microsoft Robotics Developer Studio has been used. The size of this artificial map is approximately 70x60 meters.
- Localization on real map - the map has been created for the Computer Engineering Department building. The size of the map is approximately 20x20 meters. The map has been presented in figure 5. Much more irregularities and noise from the laser scanner are visible in comparison to the artificial map.

4. Compared algorithms

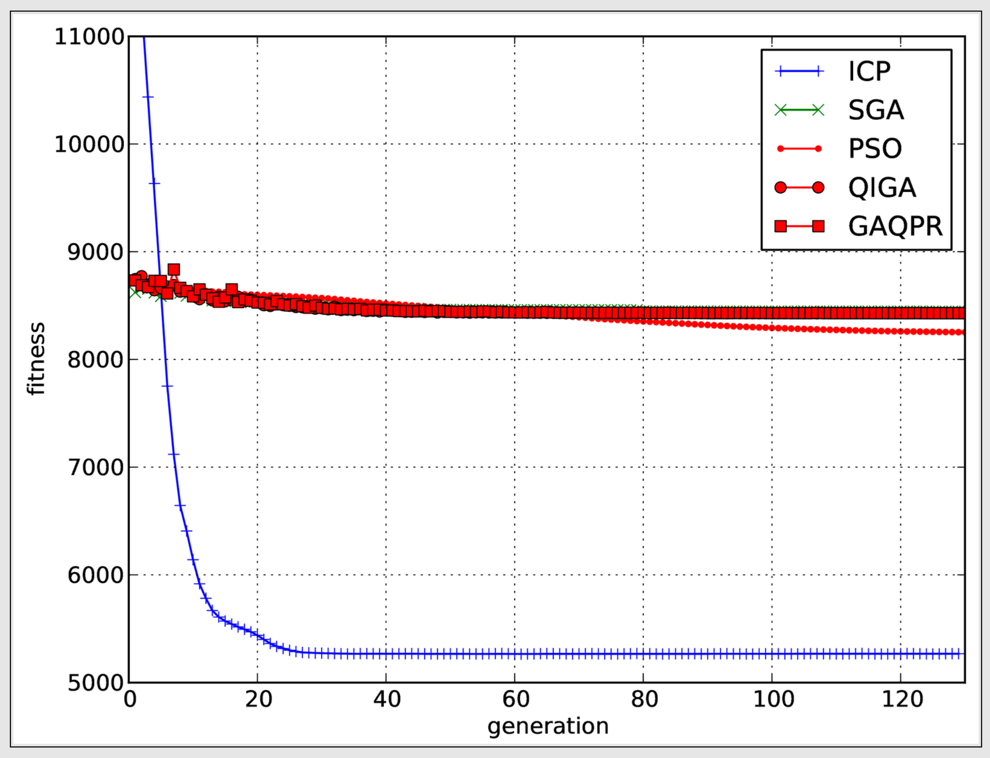
- Iterative Closest Points (ICP) is a classical, analytic method for solving the localization problem. The objective of the algorithm is to find the value of $(\Delta x, \Delta y, \Delta\alpha)$ transformation that identifies current robot pose on the map. The algorithm is based on squared Euclidean distances between scan and map points.
- Simple Genetic Algorithm (SGA) - a classical evolutionary algorithm which mimics the process of natural evolution. In Simple Genetic Algorithm, solutions are represented as binary chromosomes and two genetic operators are applied: crossover and mutation. The algorithm is based on concepts drawn from biological evolution: adaptation, feature inheritance, selection pressure and survival of individuals that fit best in the environment.
- Particle Swarm Optimization (PSO) - a method located in the subfield of swarm intelligence. In the algorithm, a swarm of particles move in the search space. The algorithm draws its inspiration from collective behaviour of decentralized systems such as birds flocking, fish schooling or animals herding. This method is particularly suitable for numerical optimization problems as solutions, i.e. positions of particles, are encoded in real numbers.
- Quantum-Inspired Genetic Algorithm (QIGA) - an evolutionary algorithm, that draws inspiration from both: biological evolution and unitary evolution of quantum systems. The algorithm is based on concepts and principles of quantum mechanics such as qubits or superposition of states. Genes in the algorithm are modelled upon qubits, two-level quantum systems, which brings additional element of randomness and a "new dimension" into the algorithm. Genetic operators are based on quantum rotation gates that modify probability distributions of sampling the search space, encoded in quantum genes.
- Genetic Algorithm with Quantum Probability Representation (GAQPR) - a relatively novel algorithm. This algorithm is an extension to Quantum-Inspired Genetic Algorithm. To prevent premature convergence of the evolutionary process additional genetic operator is employed, exchanging information between quantum chromosomes.

5. Results

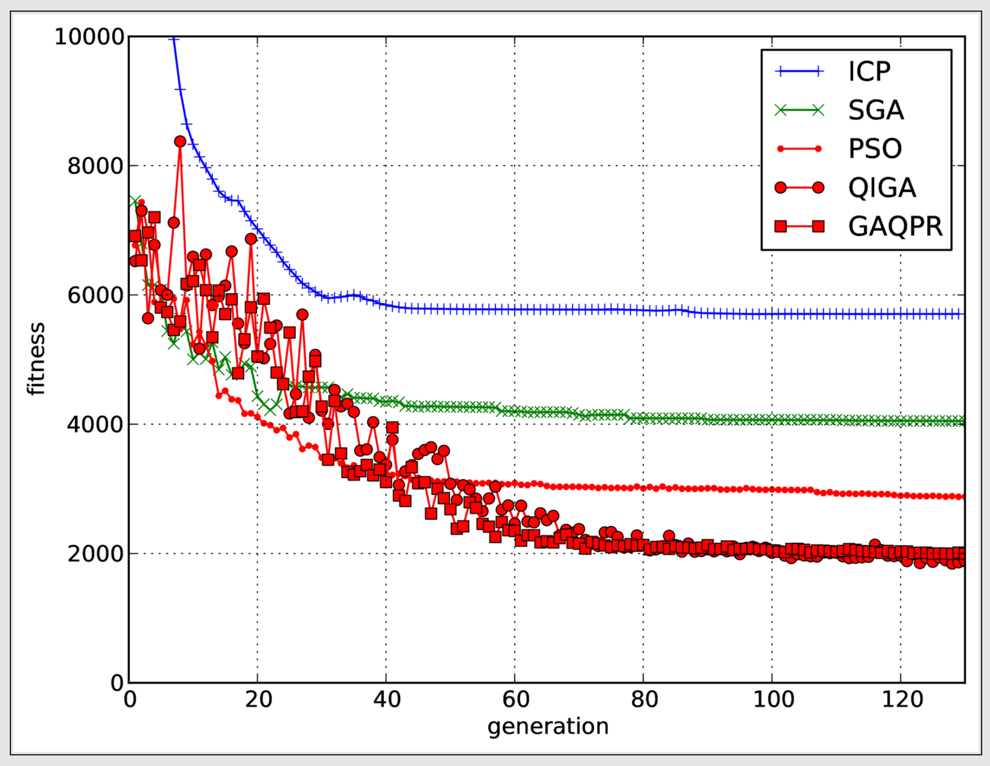
Local localization problem in simulated environment.



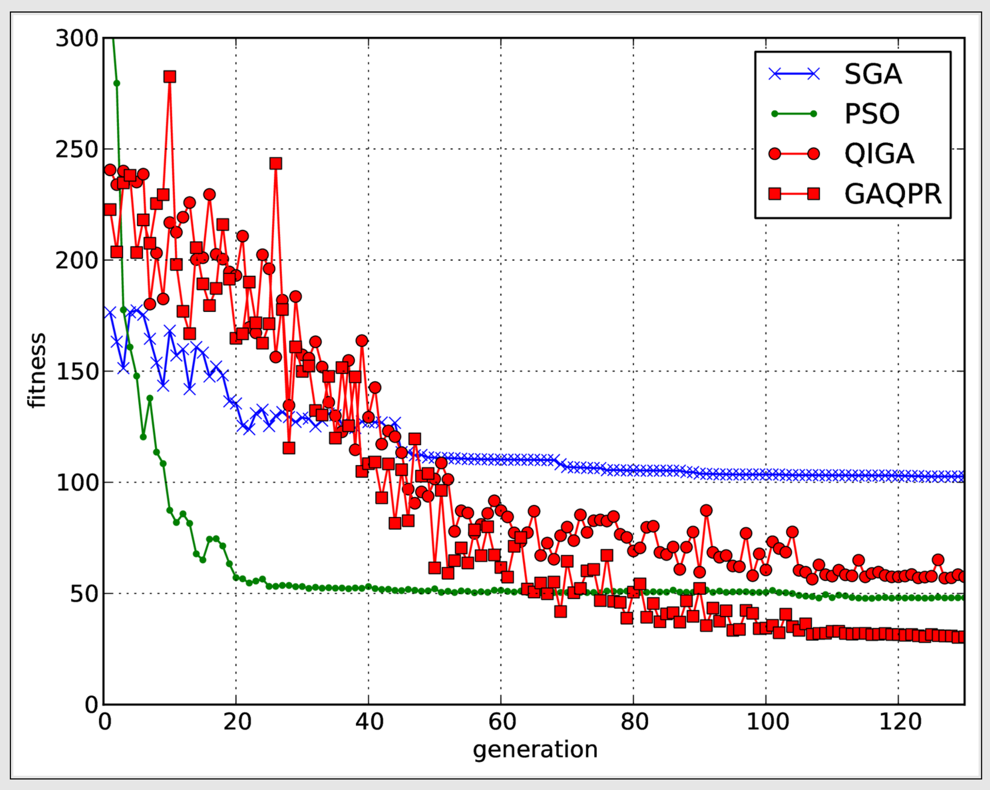
Local localization problem in real environment.



Global localization problem in simulated environment.



Global localization problem in real environment.



6. Acknowledgments

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