ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

# Scientific Report

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| First name / Family name | Ramesh Chandra |
| Nationality | Indian |
| Name of the *Host Organisation* | Norwegian University of Science and Technology, Ålesund, Norway |
| First Name / family name of the *Scientific Coordinator* | Dr. Robin T. Bye |
| Period of the fellowship | 01/06/2019 to 31/05/2020 |

## I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During the fellowship, the main focus was to investigate the best algorithms based on artificial intelligence (AI) for path planning, collision avoidance, and intelligent situational awareness for autonomous surface vessels (ASVs).

In the first phase of fellowship, I explored the travelling salesman problem (TSP) and how to use a genetic algorithm to solve it in order to improve my skills and knowledge in the field of evolutionary optimization algorithms. The TSP is an NP-hard combinatorial optimization problem with applications in many domains and there are synergies towards path planning of ASVs. At the same time, I learned about the swarm and evolutionary algorithms (EAs), especially genetic algorithm (GA), including recent developments and modifications in the GA for path planning. I also explored how path planning problems in the real world can be formulated as a TSP and solved using GA and other intelligent algorithms.
As a result of the survey and continuous discussions in the group, it was decided to work on path planning and collision avoidance of autonomous surface vessels using genetic algorithm for ASVs because autonomy and other connected vessels are becoming a reality. Evidently, several industries are seeing significant growth in the importance of ASVs to avoid collision and path planning to make safer vessels in future.

Considering the importance of the problem, I developed the code from scratch in Python for genetic algorithm and other methods such as line-of-sight (LOS), waypoint refining path smoother (WRPS), and Interpolation path smoother (IPS) to ensure collision avoidance, smooth and safe manoeuvring of ASVs. Safe and optimal guidance of autonomous surface vessels is an issue that depends on several factors, such as environmental disturbances, presence of static, dynamic obstacles, and the different types of criteria that can be used for optimization. The results show that the genetic algorithm converges to a collision-free, reaching the target whilst optimizing the objective function under constant ocean current.

## II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. Robin T. Bye, Magnus Gribbestad, Ramesh Chandra, and Ottar L. Osen, "A comparison of GA crossover and mutation methods for the traveling salesman problem", *International Conference on Innovations in Computational Intelligence and Computer Vision (ICICV 2020)*, - AISC Springer, Manipal University Jaipur, India, Jan 17-19, 2020. (under publication)

   Abstract: The traveling salesman problem is a very popular combinatorial optimization problem in fields such as computer science, operations research, mathematics, and optimization theory. Given a list of cities and the distances between any city to another, the objective of the problem is to find the optimal permutation (tour) in the sense of minimum traveled distance when visiting each city only once before returning to the starting city. Because many real-world problems can be modelled to fit this formulation, the traveling salesman problem has applications in challenges related to planning, routing, scheduling, manufacturing, logistics, and other domains. Moreover, the traveling salesman problem serves as a benchmark problem for optimization methods and algorithms, including the genetic algorithm. In this paper, we examine various implementations of the genetic algorithm for solving two examples of the traveling salesman problem. Specifically, we compare commonly employed methods of partially-mapped crossover and order crossover with an alternative encoding scheme that allows for single point, multipoint, and uniform crossover. In addition, we examine several mutation methods, including twors mutation, centre inverse mutation, reverse sequence mutation, and partial shuffle mutation. We empirically compare the implementations in terms of the chosen crossover and mutation methods to solve two benchmark variations of the traveling salesperson problem. The experimental results show that the genetic algorithm with order crossover and the centre inverse mutation method provides the best solution for the two test cases.

2. Ramesh Chandra, Anete Vagale, Mikael Tollefsen, Ottar L. Osen, and Robin T. Bye, "A study on path planning and collision avoidance of autonomous surface vessels using a genetic algorithm", (final stages before submission).

**Abstract:** Safe and optimal guidance of autonomous surface vessels is an issue that depends on several factors, such as environmental disturbances, presence of static and dynamic obstacles, and the different types of criteria that can be used for optimization. One method for solving the path planning problem is to employ a genetic algorithm. Here, we implement a genetic algorithm for solving the path planning problem while considering ocean current as an environmental disturbance. The method allows the autonomous surface vessel to successfully avoid static obstacles and reach the target. Also, the objective function is designed such that the genetic algorithm finds the path with the shortest length, shortest travel time, and the smallest average turning angle, to ensure smooth manoeuvring. Each chromosome consists of a vector of turning angles at every time step. The results show that the genetic algorithm converges to a collision-free solution relatively quickly, reaching the target whilst optimizing the objective function under constant ocean current.

## III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

Attended several seminars organized by Department of ICT and Natural Sciences, Faculty of Information Technology and Electrical Engineering, Norwegian University of Science and Technology (NTNU), Ålesund, Norway

Attended a seminar with my CPS Lab group at Centre for Autonomous Marine Operations and Systems (AMOS) - NTNU collaborators in Trondheim, who are authorities in the field of autonomous ships project, 2-3 September 2019.

## IV – RESEARCH EXCHANGE PROGRAMME (REP)

**Place:** Budapest, Hungary
**Duration:** November 18 - 22, 2019
**Host:** Prof. JózsefVáncza

During the fellowship, I had the chance to REP visit Research Laboratory on Engineering & Management Intelligence at Institute for Computer Science and Control (SZTAKI), Budapest, Hungary from 18th November to 22nd November 2019.

I was hosted by Prof. JózsefVáncza, SZTAKI, Budapest, Hungary. This research exchange visit was very useful. Researchers of the Engineering & Management Intelligence Laboratory group discussed their work which was related to our research work. Prof. József described his research work and demonstrated his recent models based on path planning using evolutionary algorithms, combinatorial optimization and artificial intelligence. Prof. József arranged some meetings with his research group members,

where we discussed research activities in more details. I also gave a seminar on my research work and results and received valuable feedbacks from the research members of the group. I could learn current research being conducted in the Engineering & Management Intelligence Laboratory research group and exchange the research ideas with other researchers of the group.

Signature of the *Fellow*

*Ramesh Chandra*

Signature of the *Scientific Coordinator*

*Dr. Robin T. Bye*