we should make it wide " just Machine Learning

# ~~Reinforcement~~ Learning and Swarm Intelligence: A ~~Small~~ Literature Review

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**Abstract**

Machine learning and swarm robotics are arguably the perfect ingredients for any futuristic sci-fi movie. However, these technologies are not just a piece of fiction, but legitimate and interesting areas of research in the academic and scientific societies. This paper, discusses a small intersection between the two fields by providing a small historic background of the fields, followed by some examples and algorithms currently being used, and finally hinting at how these technologies might change the near and far future of humanity.

**Keywords:** Swarm Robotics; Machine Learning

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## 1 The Idea Behind Swarm Robotics

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Swarm robotics (SR) has been a popular topic in science fiction and the entertainment industry for years, but making such technology a reality is not a particularly easy and trivial thing to do. To ~~paraphrase~~ professor Magnus Egerstedt, it is annoying to get a single robot to perform a single task, so getting a bunch of robots to do anything is an impressive achievement on its own. [1] However, to understand swarm robotics, it is important to understand the concept of swarm intelligence(SI). SI refers to the principles that seem to generate the global behavior that arises in the interactions between the individual members of the system. [2, 3, 4, 5] Most of the algorithms behind SI are actually based on the behaviors of ant colonies, schools of fish, flocks of birds, bees, and many other related areas where swarms occur. [6] As an example, ants and termites seem to be able to communicate with each other without actually talking. They do not get together and decide on the schematics of their hives, or how they are going to build it, they just start building without knowing what everybody else is doing. [7, 1] Continuing this example leads to the next concept, stigmergy. As a group of termites work in a section of the hive, other termites may see this construction and proceed help, or work on a different task, without any one telling them what to do. As each individual modifies a small part of its environment, other members react to this modification and know what to do next. Stigmergy, in short, refers to the idea that the individuals communicate through the world, rather than directly with each other. [8, 7]

Swarm robotics, as a field of research, is the study of how multiple autonomous robots can be used to accomplish collective tasks that would otherwise be impossible or highly impractical to achieve if they were done by a single robot. [4] Currently, there are over 1,500 results if you search for the keywords swarm robotics on IEEE Xplore alone, and plenty of projects in the field such as RoboCup, COLLMOT, Kilobot and TERMES, showing how popular this subject has become in the scientific community. [9, 3]

Significant research in swarm robotics can be found in papers as far back as the 1980s, and the vast theoretical applications of SR have since lead to a vast increase in the research being done in the area. [10] However, it's only in the past 2 decades that the theoretical research has started to take form in the physical world, as computational requirements were finally starting to be met, and the price for the construction of simple robots has been dramatically decreasing compared to the 80s and 90s. [4, 3] Bakhshipour et al. briefly describes over 25 heuristic algorithms that could be used for SR search tasks in a single table: one from 1975, 20 algorithms from 2005 to 2015 alone, and the other 4 from the 80s and 90s, hinting at the idea of just how many more advancements in the field have actually occurred in the new millennium. [11]

Although swarm robotics is technically a branch of the study multi-robot system, experts like to differentiate SR from other robotics fields. In a general sense, the literature indicates that any given SR system must have all of the following characteristics:

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1 Robots are completely autonomous: no need for direct human interaction, or a centralized or universal controller
2 Robots are safe and reactive
- Capable of adapting to their environment
- Able to continue their individual tasks regardless of the number of other robots added or removed

3 Robot sensing and communication is local: global knowledge may not be available to any of the bots
4 Robots cooperate to achieve a given task
[12, 1]

Large areas to cover, highly dynamic terrains, and constantly changing environments are just some of the main reasons why robots have not yet been adopted for mass scale in certain areas. [13] However, the characteristics of swarm robotics, may offer a solution to many of these problems, as autonomy, adaptability, and the ability to cooperate with others, are essentially the same characteristics one would want to see in any human team.

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## 2 Machine Learning

Even though Machine learning(ML) is considered to be a branch of artificial intelligence, it is actually a multidisciplinary field that makes use of probability and statistics, computational complexity theory, information theory, neurobiology, control theory, philosophy, psychology, and many other fields. Professor T.M. Mitchell in his Machine Learning book explains, "A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E" [14]. Ultimately, the purpose of machine learning is to program computers to optimize their performance for a certain task using example data or past experience. [15] As a quick summary to the history of machine learning, one can take a look into the following historic highlights: the beginning in 1943 with the introduction of the first neural network, contributions from Alan Turing in the 1950s, the creation of Eliza and ALPAC in the 1960s, a shift in research towards knowledge based systems in the 1970s, the discovery of backpropagation and the application of neural networks in new domains in the 1980s, IBM's Deep Blue in the 1990s, and IBM's Watson in the 2000s. Current research in the area focus on natural language processing, image processing, computer vision, hearing, pattern recognition, and the list goes on. [16]

Since ML is such a vast area, it is actually divided into 4 categories: supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning. Figure 1 provides

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Machine l

Fig 1. "figure 1.2 page 7 Machine Learning: Algorithms and Applications BOOK" [16]

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## 3 Uniting Machine Learning and Swarm Intelligence

Can scientist and researchers combine ML and SI to obtain better and more efficient algorithms, and how? Based on the literature reviewed for this paper, the simple answer is yes, but defining how to combine methods varies from paper to paper. *To paraphrase Professor Lourdes Pena-Castillo, there is no such thing as a free lunch in machine learning, and depending on what the desired outcome might be, multiple algorithms and techniques need to be tried and tested before a final decision can be made.* In other words, selecting algorithms for a particular task need to be analyzed on a per scenario basis, rather than simply assuming that one method will always perform better than another one. The SI methods are used to optimize already existing ML models, and ML methods are used to optimize SI behaviors.

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* Base on Litrature review

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## 4 Reinforcement Learning in SR

4.1 Example 1
4.2 Example 2
4.3 Example 3
4.4 Example 4
4.5 Example 5

## 5 SI in Machine Learning

5.1 Example 1
5.2 Example 2
5.3 Example 3
5.4 Example 4
5.5 Example 5

## Searching Algorithms

Searching tasks focus primarily in the activity of looking in the interior of structures, or wilderness, with the purpose of finding a victim, or potential hazards, while reconnaissance and mapping tasks extend the tasks of searching by providing more general information about the situation and surroundings. [17]

## Communication

[18]

## Some Real World Examples

An example of reconnaissance is described by Penders et al., in which swarm robots were designed to establish a network between them, and move around a firefighter using a potential force field method. As smoke starts

to impede a fireman's vision, the robots are used to do a reconnaissance of the area around the firefighter, and provide feedback to the firefighter letting him know of potential obstacles and hazards around him. [19]

Vijay Kumar provides a clear example of the potential of swarm robotics in real world scenarios. [20, 21]

## 6 Conclusion

**Acknowledgements**
We would like to thank Memorial University, specially Dr. Lourdes Peña-Castillo, for the support, guidance, and patience during the semester. . . .

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