Transfer Learning for Autonomous Recognition of Swarm Behaviour in UGVs

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Abstract

Swarm behaviour recognition becomes popular due to the applications of swarm agents in industry, civil aviation, military and human-swarm interactions. This paper proposes a novel rule-based value function that can recognise swarming in homogeneous swarms of simulated and real Unmanned Ground Vehicles (UGVs) from limited data. The main objectives are as follows:

1. Train decision tree to recognise swarm behaviour of boids the same as human, and extract an if-then rule engine from this trained decision tree for faster and accurate swarm behaviour recognition.
2. Extend the rule engine by transfer learning, with training on a small UGV data samples.
3. The extended rule engine could recognise swarm behaviours of UGVs.

Introduction

Due to the increase use of autonomous robot swarms, many computerised systems has been designed for self-positioning of robots. The first step to self-positioning robots in a way they could maintain their swarm behaviour is to recognise swarm behaviour continuously. The work in this paper proposed such an approach that can recognise swarming in homogeneous swarms of simulated and real Unmanned Ground Vehicles (UGVs). The value function is based on a pruned decision tree trained on human labelled point-mass data [1]. Transfer learning is applied on this rule engine to make it applicable in a new domain. We test the value function on swarms of point-mass, simulated and real robots, and it can detect swarming in at least 89% of cases.

Rule Extraction

Swarm behaviour recognition of supervised learners trained with point-mass data, tested on Pioneer3DX and Turtlbots has been examined in Figure 1. As it is presented in this figure the DT is the most reliable approach for detecting swarming, even in certain cases where training and testing sets are different. However, it becomes less reliable for detecting swarming in robots, controlled by a different BGA.

The weakness of this DT is resulting in many rules. Thus, while the fastest of the techniques examined, it is still relatively slow (approx. 10s). Pruning is one way to resolve this problem [2]. As it is shown in Figure 2, the accuracy of the decision tree changes smoothly until the prune in level 758. This level of pruning leads to 73 rules.

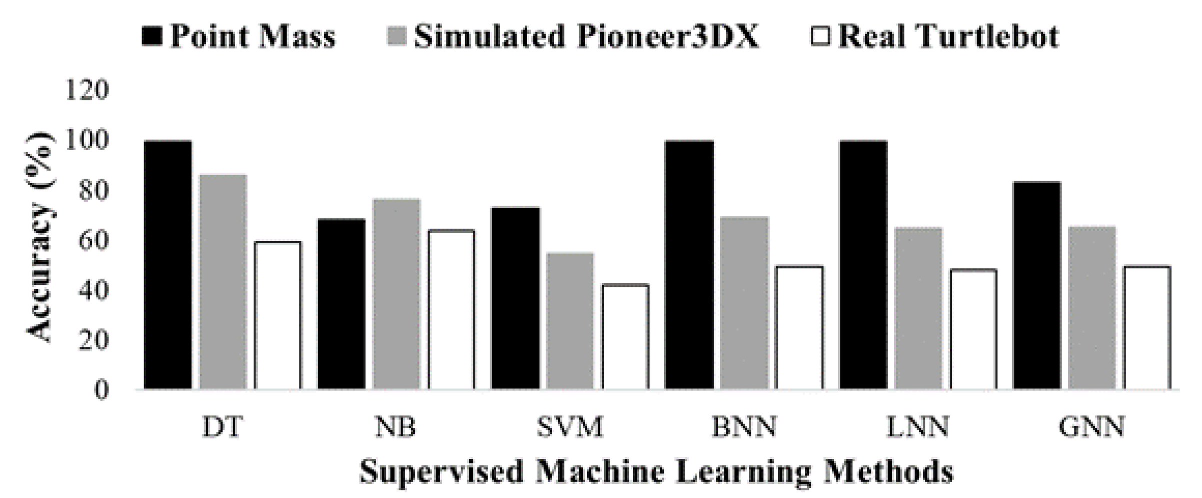

Figure 1: Classification accuracy of supervised learners

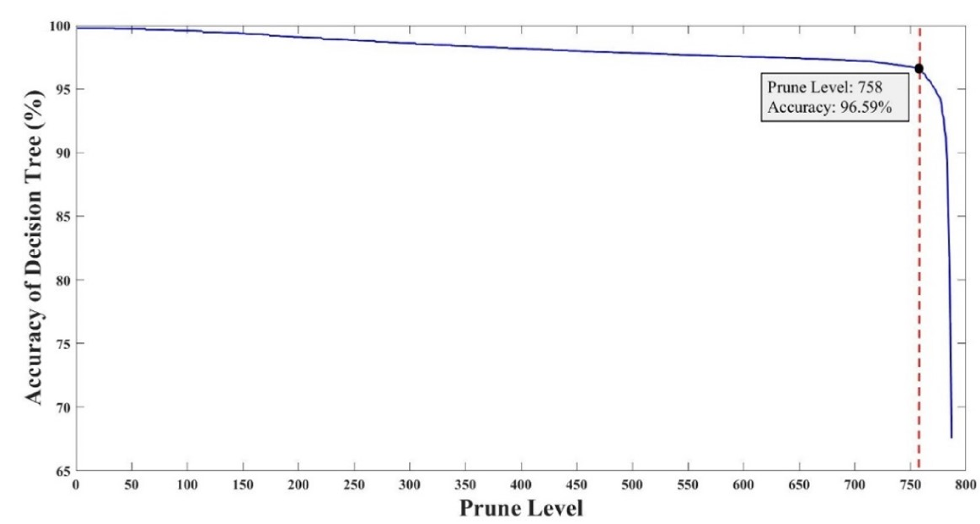

Figure 2: Accuracy of pruning levels of the decision tree

Transfer Learning Applied on the Rule Engine

Algorithm 1: Evolution from source to target tree for swarm recognition

Input: Pruned if-then rule engine as the source tree.
Output: Updated if-then rule engine as the target tree.

1 For each scenario find the matching rule in the source tree, as rule k

1.1 Recognise the behaviour based on the rule k

1.2 If the recognised behaviour is not correct (comparing to the nature of the behaviour) Then Keep this sample in the Not Matched Set "NMS".

1.3 Else Keep this sample in Matched Set "MS".

1.4 For current feature F_i', find the upper and lower bound value of F_i' regarding to: "NMS"" as $UB_{(NMS_i)}$ and $LB_{(NMS_i)}$, and "MS" as $UB_{(MS_i)}$ and $LB_{(MS_i)}$.

1.5 Find lowest coverage of F_i' in $[LB_{(MS_i)}, UB_{(MS_i)}]$ and $[LB_{(NMS_i)}, UB_{(NMS_i)}]$ as $[L, U]$.

1.6 Split rule k based on the middle of the $[L, U]$, and update the source if-then rule.

2 Return the target rule engine

Swarm Recognition of UGVs by Transfer Learning

The rule engine after applying transfer learning, was then tested for recognizing swarms of Pioneer3DX and Turtlebot. Based on the results shown in Figure 3, the accuracy is improved by transfer learning.

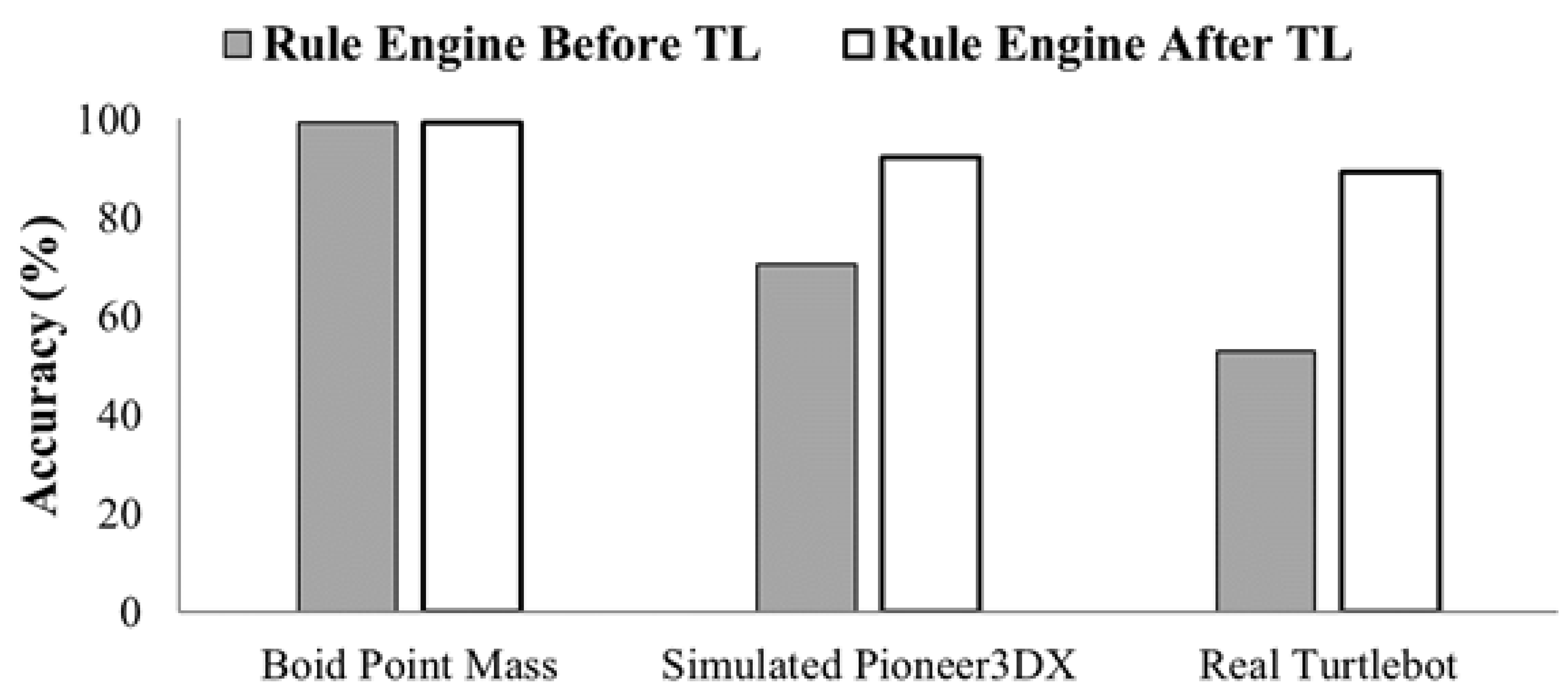

Figure 3: Swarm recognition in UGVs after transfer learning

Conclusion and Future Work

In this paper an if-then rule engine is designed, which is extracted from a pruned decision tree, trained by point-mass data. An extension of this rule engine after applying transfer learning is accurate in swarm behaviour recognition of UGVs, while no further training is required.

In future we aim to:

- embed this for swarm behaviour tuning in UGVs.
- extend the rule engine for other environments and other robots, like UAVs.

References

1 . S. Abpeikar, et al., Swarm Behaviour Dataset on UCI Data Repository. 2020, UCI Data Repository: UCI Data Repository.

2 . Segev, N., et al., Learn on Source, Refine on Target: A Model Transfer Learning Framework with Random Forests. IEEE Transactions on Pattern Analysis and Machine Intelligence, 2017. 39: p. 1811-1824.

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