Brief Announcement: Gathering Despite Defected View

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Abstract

In this paper, we provide a new perspective on the observation by robots; a robot cannot necessarily observe all other robots regardless of distances to them. We introduce a new computational model with defected views called a (N,k)-defected model where k robots among $N-1$ other robots can be observed. We propose two gathering algorithms: one in the adversarial (N,$N-2$)-defected model for $N \geq 5$ (where N is the number of robots) and the other in the distance-based (4,2)-defected model. Moreover, we present two impossibility results for a (3,1)-defected model and a relaxed (N, $N-2$)-defected model respectively. This announcement is short; the full paper is available at [1].

2012 ACM Subject Classification Computing methodologies → Self-organization

Keywords and phrases mobile robot, gathering, defected view model

Digital Object Identifier 10.4230/LIPIcs.DISC.2022.46

Related Version *Full Version*: https://arxiv.org/abs/2208.08159

Funding This work was supported in part by JSPS KAKENHI Grant Numbers 18K18031, 19H04085, 19K11823, 20H04140, 20KK0232, 21K17706, and Foundation of Public Interest of Tatematsu.

1 Introduction

An autonomous mobile robot system is a distributed system consisting of many mobile computational entities (called *robots*) with limited capabilities. Each robot observes the other robots (*Look*), computes the destination based on the observation result (*Compute*), and moves to the destination point (*Move*). Each robot autonomously and cyclically performs the above three operations to achieve the given common goal. Since an autonomous mobile robot system is firstly introduced in [2], many researchers are interested in clarifying the relationship between the capabilities of the robots and solvability of the problems.

Generally, in *Look* operation, each robot can observe all other robots to compute the destination point to move. In other words, each robot takes a snapshot consisting of all other robots' (relative) positions in its *Look* operation. However, from several practical reasons (e.g., memory restriction, memory corruption, or sensing failure), the positions of all robots may not be available necessarily available in *Compute* operation. This raises the main question we address: "*what occurs if a robot cannot observe some of other robots?*". More precisely, "*how many other robots should be observed to achieve the goals of the problems?*".

To provide some answers for the above research questions, we propose a new computational model with restriction on the number of the robots that each robot can observe, named the *defected view model*, where each robot observes only k other robots for $1 \leq k < N-1$, where N is the number of robots. It is obvious that when k becomes the lower, the problem becomes the harder (possibly impossible) to solve. We consider two different defected view models regarding which k robots are observed: the adversarial (N,k)-defected model and the distance-based (N,k)-defected model (see Definition 1 for details).

As the first step of the study on the defected view model, we address the gathering problem and get the following results: two gathering algorithms in the adversarial (N, $N-2$)-defected model for $N \geq 5$ and the distance-based (4,2)-defected model, and some impossibility results to show the necessity of the assumptions the above algorithms use.

2 Model

Let $R = \{r_1, r_2, ..., r_N\}$ be the set of N autonomous mobile robots deployed in a plane. Robots are identical, uniform, oblivious, and have no geometrical agreement; they do not agree on any axis, the unit distance, nor chirality. A point in the plane is *occupied* if there exists a robot at the point. We allow two or more robots to occupy the same point at the same time. We call a robot a *single robot* if the point occupied by the robot has no other robot. Otherwise, we call it an *accompanied robot.* Each robot cyclically and synchronously performs the three operations, *Look*, *Compute*, and *Move*, we call the time duration in which all robots perform the three operations once *a round.* Moreover, we assume an unlimited visibility range and a *weak multiplicity detection.*

▶ **Definition 1** ((N,k)-defected model). *Each robot r can get from* Look *operation the set of occupied points (in its coordinate system) where k robots not accompanied with r are located (i.e., the k robots contains no robot located at r's current point). When the number of robots not accompanied with r is less than k, all such robots are observed. The weak multiplicity detection concerning the k robots is assumed: a point occupied by only one of the k robots can be distinguished from that occupied by two or more of the k robots. Moreover, r can distinguish whether r is single or accompanied.*

We consider two options of the defected view model; *adversarial (N,k)-defected model* and *distance-based (N,k)-defected model.* In the *adversarial (N,k)-defected model*, k robots observed by each robot are determined adversarially. In the *distance-based (N,k)-defected model*, each robot r observes the k closest robots to the r's current point. Tie breaks among the robots the same distance apart is determined in an arbitrary way. In this paper, we consider the *Gathering Problem* to locate all robots at the same point under these models.

3 Proposed Algorithms and Impossiblity Results

Algorithm 1 presents an algorithm to achieve the gathering for robot r_i in the adversarial (N, $N-2$)-defected model where $N \geq 5$: OPSET() is a function that returns a set of points $\{p \mid p$ is occupied by r_i or by the robots that r_i observed$\}$, and isMulti(p) returns TRUE if point p is occupied by two or more robots that r_i observed (weak multiplicity), otherwise FALSE. The following theorem holds (we omit the proof).

▶ **Theorem 2.** *In the adversarial (N, $N-2$)-defected model ($N \geq 5$), Algorithm 1 solves the gathering problem in three rounds.*

Algorithm 1 Algorithm for robot r_i in the adversarial $(N, N-2)$-defected model where $N \geq 5$.

if $\forall p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{TRUE}$ **then**
  move to the center of the smallest enclosing circle of $\mathsf{OPSET}()$
else if (r_i is single) $\wedge$ ($\exists p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{TRUE}$) **then**
  move to an arbitrary point $p \in \mathsf{OPSET}()$ such that $\mathsf{isMulti}(p) = \mathsf{TRUE}$
else if $\forall p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{FALSE}$ **then**
  move to the center of the smallest enclosing circle of $\mathsf{OPSET}()$
end if ▷ No action if (r_i is accompanied) $\wedge$ ($\exists p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{FALSE}$)

Algorithm 2 Gathering algorithm for robot r_i in the distance-based (4,2)-defected model.

if $\forall p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{TRUE}$ **then**
  move to the center of the smallest enclosing circle of $\mathsf{OPSET}()$
else if (r_i is single) $\wedge$ ($\exists p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{TRUE}$) **then**
  move to an arbitrary point $p \in \mathsf{OPSET}()$ such that $\mathsf{isMulti}(p) = \mathsf{TRUE}$
else if $\forall p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{FALSE}$ **then**
  if $\mathsf{OPSET}()$ forms an equilateral triangle **then**
    move to the center of the triangle (i.e., incenter)
  else if $\mathsf{OPSET}()$ forms an isosceles triangle **then**
    move to the midpoint of the base of the triangle
  else ▷ the other triangle or collinear three points
    move to the midpoint of the longest line
  end if
end if ▷ No action if (r_i is accompanied) $\wedge$ ($\exists p \in \mathsf{OPSET}() : \mathsf{isMulti}(p) = \mathsf{FALSE}$)

We do not know whether the gathering problem in the adversarial (4,2)-defected model is solvable or not yet. However, the gathering problem in the distance-based (4,2)-defected model can be solved by Algorithm 2 (Theorem 3). Moreover, there is no (deterministic) algorithm to solve the gathering problem in the defected view model for $N = 3$ (Theorem 4).

▶ **Theorem 3.** *In the distance-based (4, 2)-defected model, Algorithm 2 solves the gathering problem in four rounds.*

▶ **Theorem 4.** *There is no (deterministic) algorithm to solve the gathering problem in the distance-based (3,1)-defected model.*

The (N, k)-defected model assumes that k robots observed by robot r are chosen from the robots that are not accompanied with r and that r can detect whether it is single or accompanied. Natural relaxation of the model is to choose the k robots other than r (i.e., robots at r's current position can be chosen) and assume the weak multiplicity detection for the k robots and r itself. We call the model with the relaxation the *relaxed adversarial* (N,k)-defected model. The following impossibility result holds.

▶ **Theorem 5.** *There is no (deterministic) algorithm to solve the gathering problem in the relaxed adversarial $(N,N-2)$-defected model.*

References

1 Yonghwan Kim et al. Gathering despite defected view, 2022. doi:10.48550/ARXIV.2208.08159.

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