Distributed Algorithms For Swarm Robots in R^2

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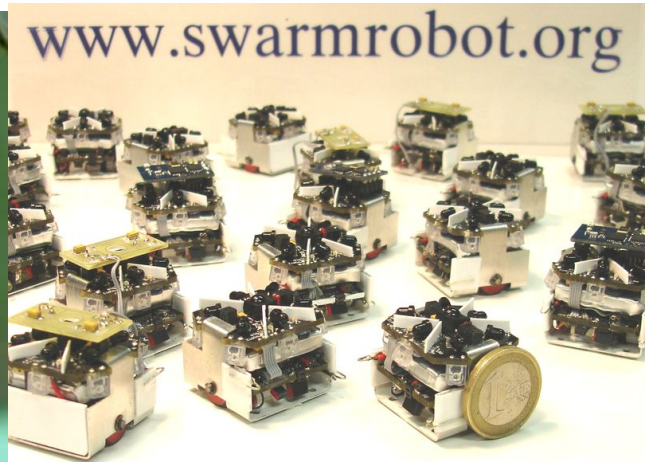
Outline of the lechture

- Introduction
- Leader Election
- Gathering
- Pattern Formation
- Circle Formation under Limited Visibility
- Circle Formation under Unlimited Visibility
- Conclusion

Swarm Robots



- Group of small, inexpensive, identical, autonomous, mobile robots.
- **Collaboratively executing work**
  - moving large objects, cleaning big surface.
- **Geometric point of view**: points moving on the 2D plane.
- **Objective**: Forming geometric patterns like point, circle, straight line etc.
- Distributed in nature.

General Characteristics of Swarm Robots

- Point/Unit Disc
- Autonomous
- Identical
- No message passing
- Sense surroundings
- Move on the 2D plane
- Limited computational power
- Oblivious

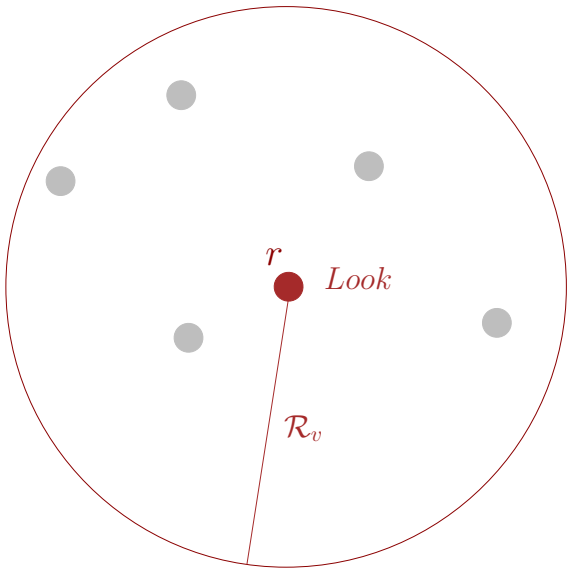
Computational Model of Swarm Robots

- Execute **wait**-look-compute-move cycle.

In wait state robots do nothing.

Computational Model of Swarm Robots

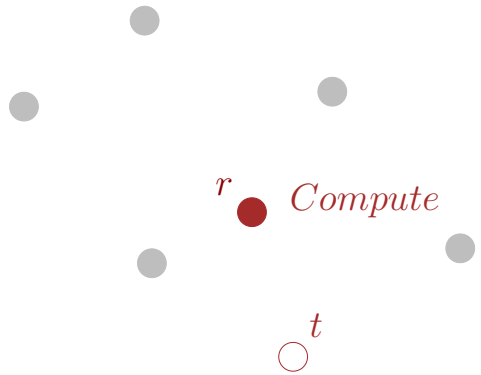
- Execute wait-**look**-compute-move cycle.



- $\mathcal{R}_v$ (**visibility range**) can be **limited** or **unlimited**

Computational Model of Swarm Robots

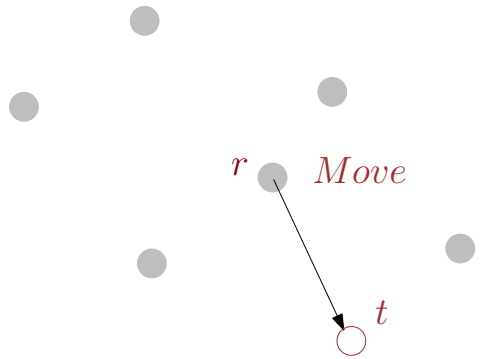
- Execute wait-look-**compute**-move cycle.



- r computes its destination t

Computational Model of Swarm Robots

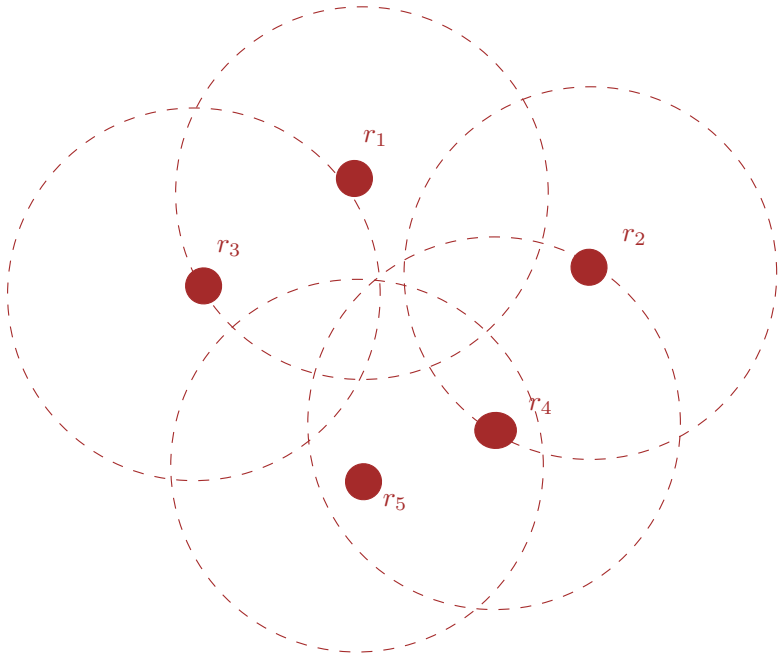
- Execute wait-look-compute-**move** cycle.



- r moves to t
  - SYm: Rigid motion.
  - CORDA: Non-rigid motion.

Computational Model of Swarm Robots

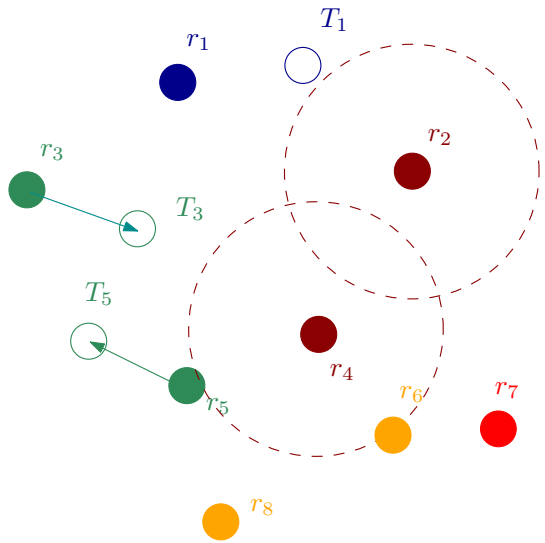
- Execute wait-look-compute-move cycle **synchronously**.



- All robots look at the same time

Computational Model of Swarm Robots

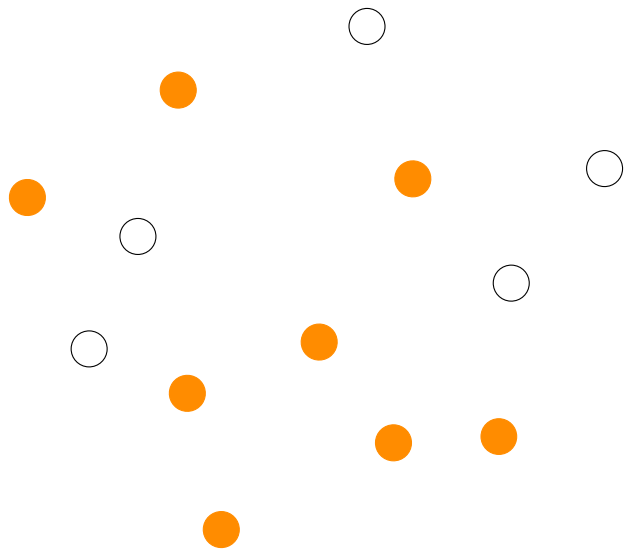
- Execute wait-look-compute-move cycle **asynchronously**.



- Different robots look, compute and move at different times.

Computational Model of Swarm Robots

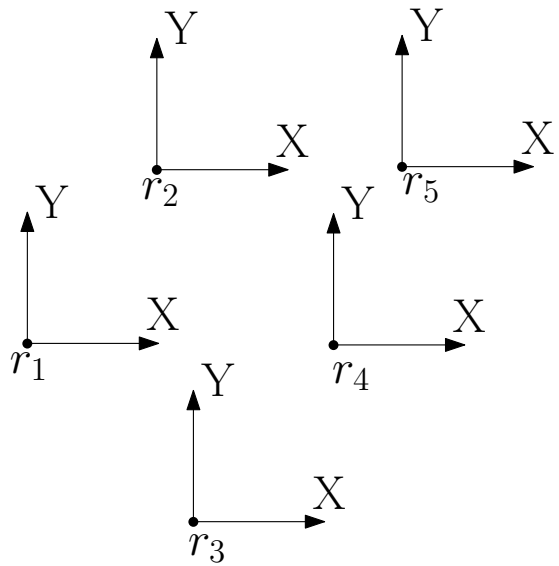
- Execute wait-look-compute-move cycle **semi-synchronously**.



- A arbitrary set of robots looks at same time.

Computational Model of Swarm Robots

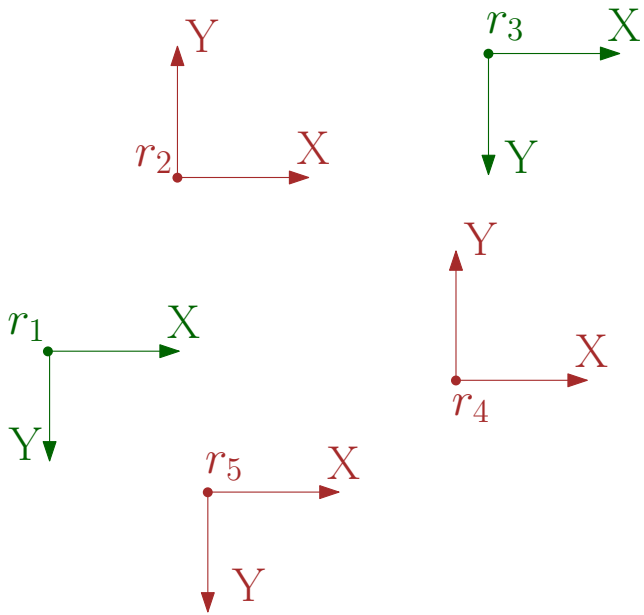
- Agreement on co-ordinate system.



- Robots having same Sense of Directions (SoD) and same chirality

Computational Model of Swarm Robots

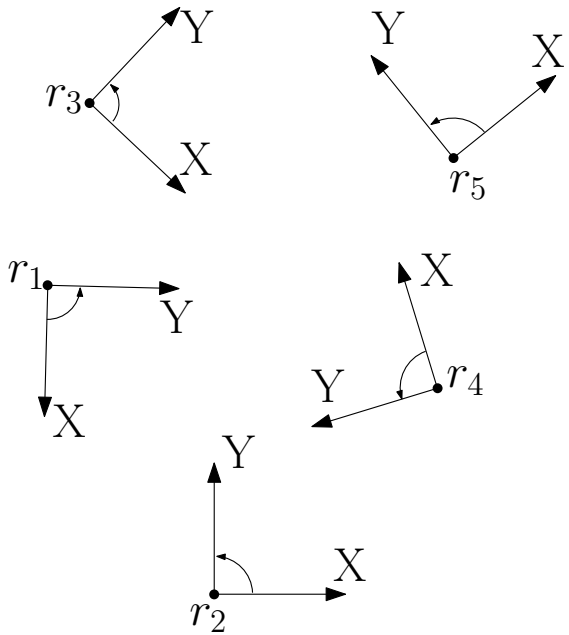
- Agreement on co-ordinate system.



- Robots having same SoD but different chirality

Computational Model of Swarm Robots

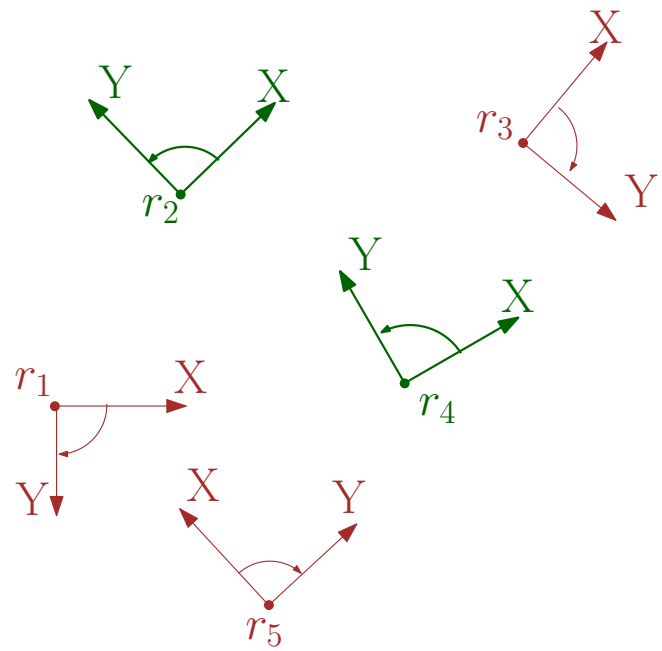
- Agreement on co-ordinate system.



- Robots having different SoD but same chirality

Computational Model of Swarm Robots

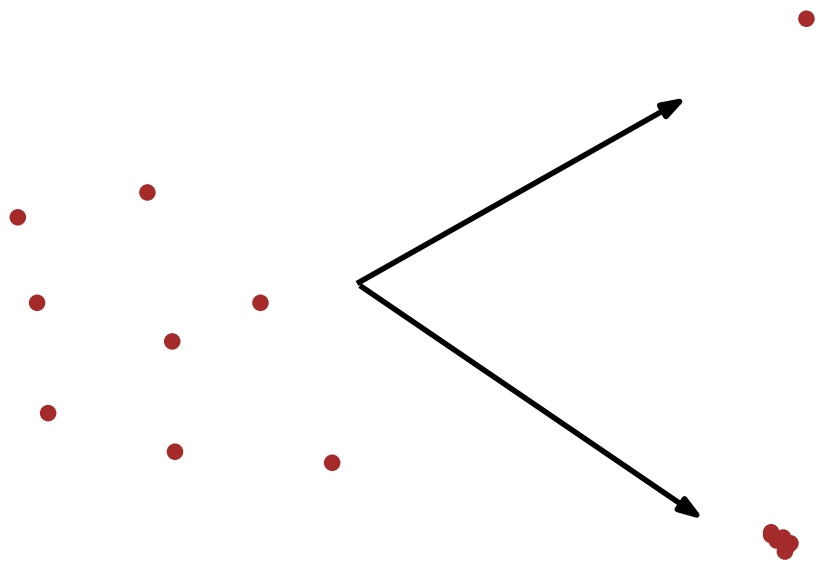
- Agreement on co-ordinate system.



- Robots having different SoD and different chirality

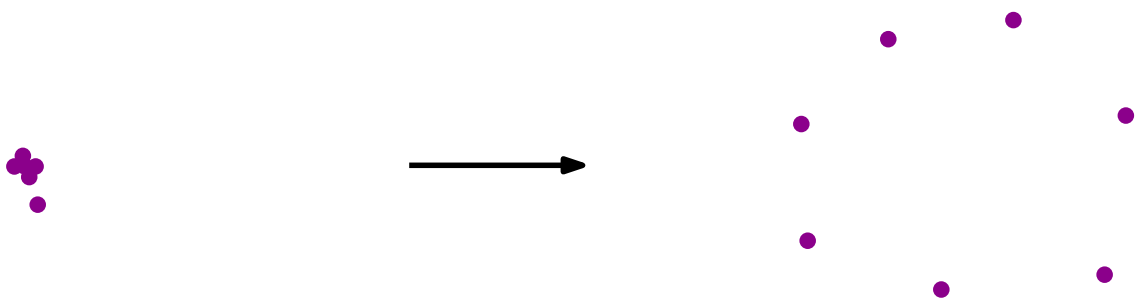
Example of Some Geometric Problems on Swarm Robots

- Gathering [Prencipe2007] or Convergence [Cohen2006]



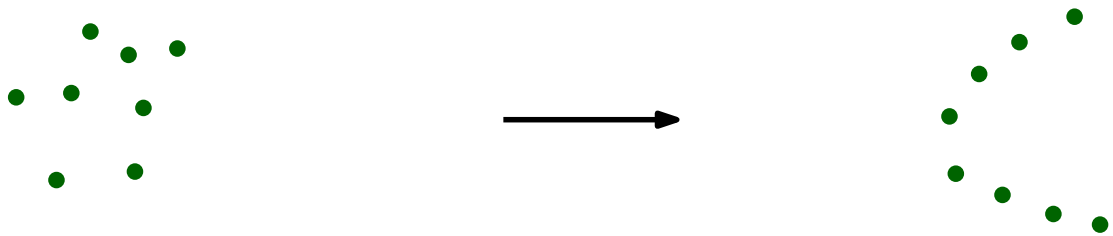
Example of Some Geometric Problems on Swarm Robots

- Scattering [Lali2011]



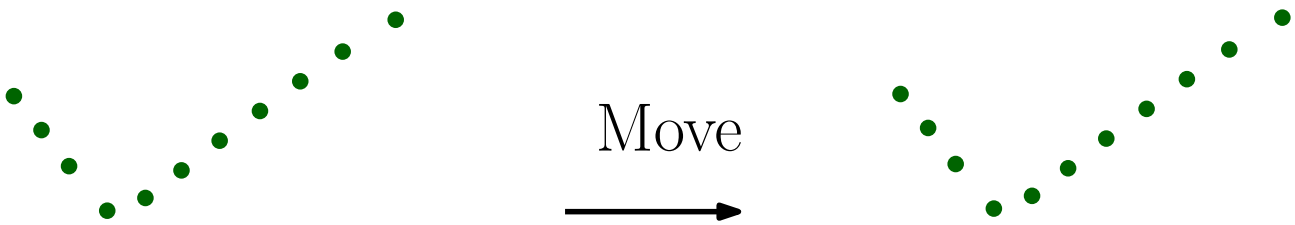
Example of Some Geometric Problems on Swarm Robots

- Pattern formation [Flocchini2008]



Example of Some Geometric Problems on Swarm Robots

- Flocking [Canepa2007]

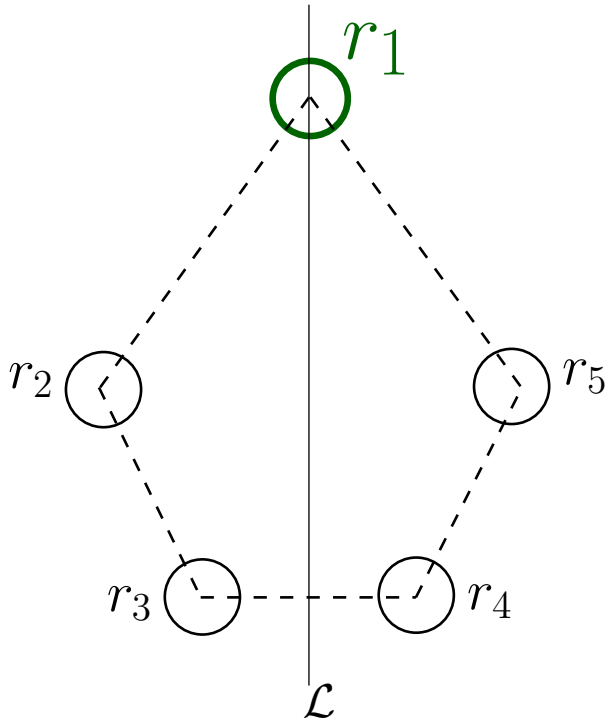


Scope of the Lecture

- Leader Election
- Gathering
- Arbitrary Pattern Formation
- Circle Formation

Scope of the Lecture

- Leader Election.



- The robots elect r_1 as their leader.

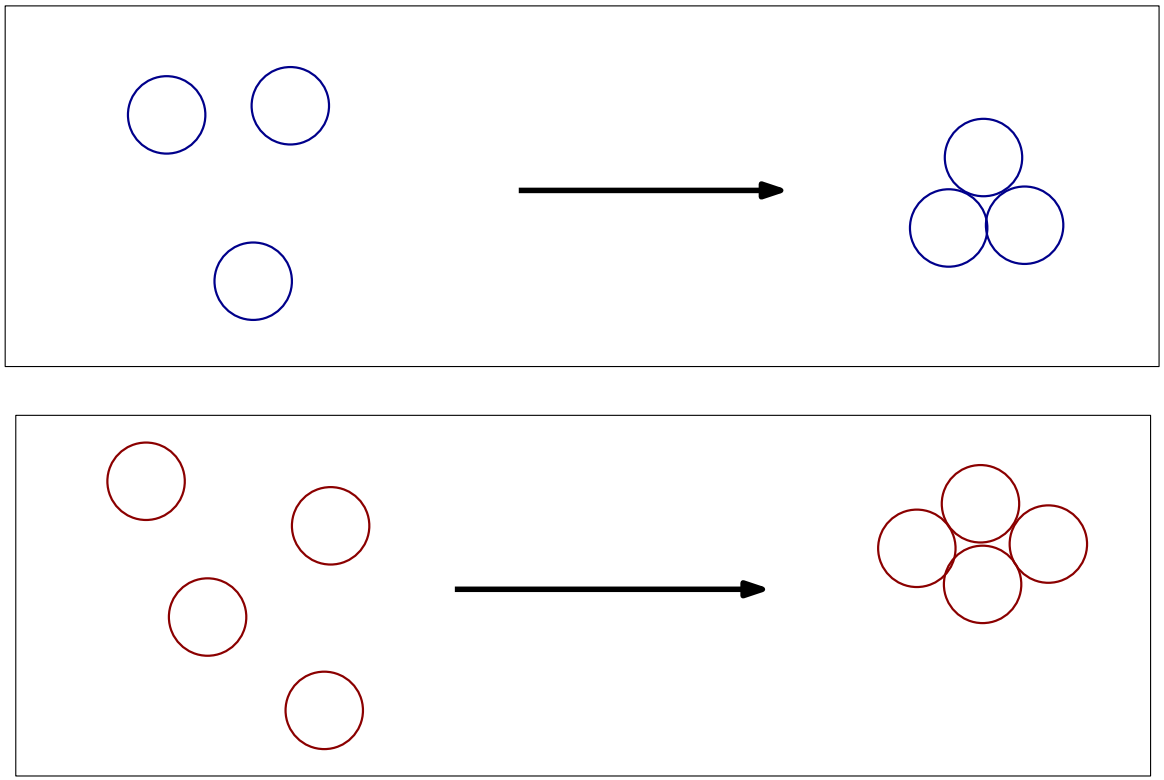
Scope on the Lecture

Some Works for Leader Election

SoD	*Chirality*	*# of robots*	**Earlier results**
Yes	Yes	Any	Leader election possible [Flocchini1999].
Yes	No	Odd	Leader election possible [Flocchini2001].
No	Yes/No	Any	Leader election not possible [Flocchini2001].
No	**Yes**	**Any**	**characterization of all geometric positions [DieudonneL2007].**
No	**No**	**Odd**	**characterization of all geometric positions [DieudonneL2007].**
No	**No**	**Any**	**Characterization of all geometric positions where iterative leader election (total ordering of robots) is possible. [Gan Chaudhuri2010]**

Scope of the Lecture

- Gathering Fat Robots [Czyzowicz2009].



Scope of the Lecture

Earlier Works on Gathering Point Robots

Scheduling	*Visibility range*	*Agreement in co-ordinate*	*Multiplicity detection*	*Earlier results*
Sync	unlimited	No	No	Solved [Ando1999].
ASync	Any	Yes	No	Solved[Flocchini2001].
ASync	unlimited	No	Yes	Not solvable for two robots [Prencipe2007].
ASync	unlimited	No	Yes	Solved for three and four robots [Cieliebak2002]. Solved for more than four robots initially (a) in bi-angular configuration. (b) not in any regular n gon
ASync	**unlimited**	**No**	**No**	**Not solvable [Prencipe2007].**

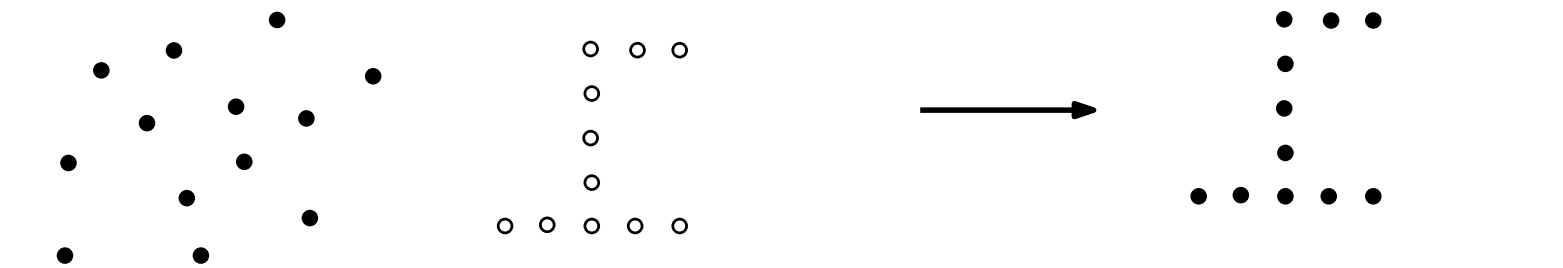
Scope of the Lecture

Some Works for Gathering Fat Robots

Scheduling	*Agreement in* co-ordinate	**Earlier results**
ASync	No	Solved for up to four robots [Czyzowicz2009].
Sync	No	Solved for any number of robots [CordLandwehr2011]. (randomized / considering. robots with identification and communication power).
Sync	No	Solved by simulation [Bolla2012].
ASync	**Chirality**	**Solved for any number of robots [Agathangelou2012].**
Async	**No**	**Gathering any number of transparent fat robots. without collission. [Gan Chaudhuri2010].**

Scope of the Lecture

- Arbitrary Pattern formation[Flocchini2008]



(a) Set of robots (b) Given pattern (c) Robots move to form the pattern

- A set of robots form a given pattern

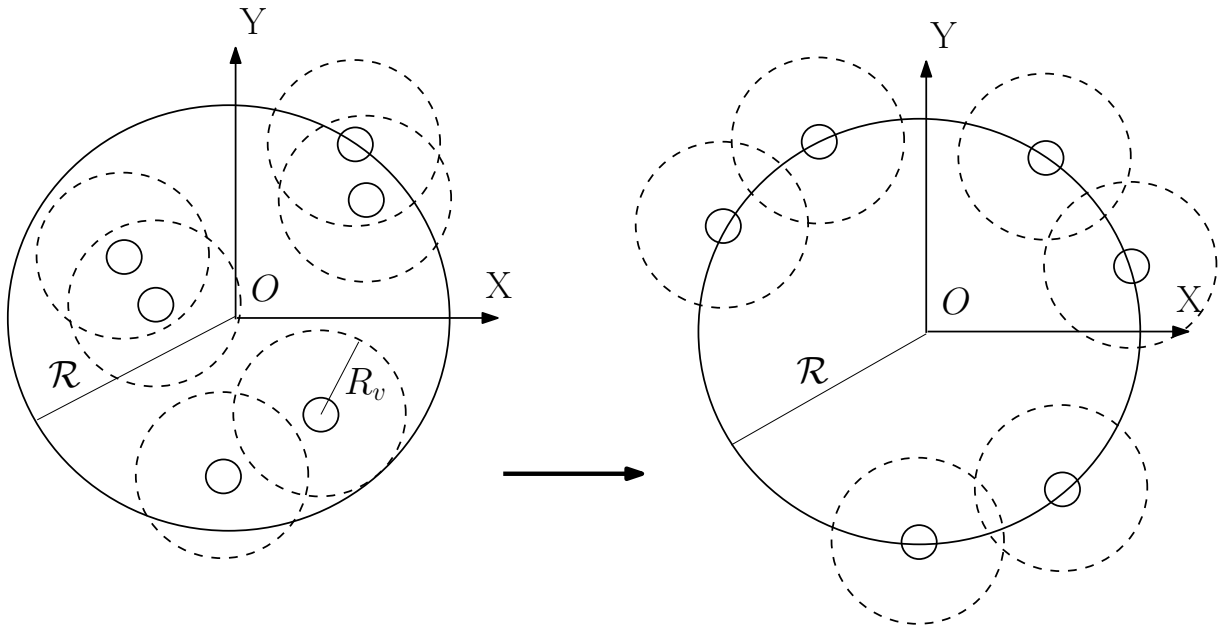
Scope of the Lecture

Some Works for Arbitrary Pattern Formation for Point Robots

Scheduling	SoD	Chirality	**Earlier results**
Async	Yes	No	Any pattern formable with odd no. of robots and *Symmetric pattern* is formable for even no. of robots [Flocchini1999].
Async	Yes	Yes	Arbitrary pattern is formable for any no. of robots [Flocchini2001].
ASync	**No**	**Yes**	**Arbitrary pattern formation not possible [Flocchini2008].**
ASync	**No**	**No**	**Asymmetric pattern formation is possible without collision [Ghike2010].**

Scope of the Lecture

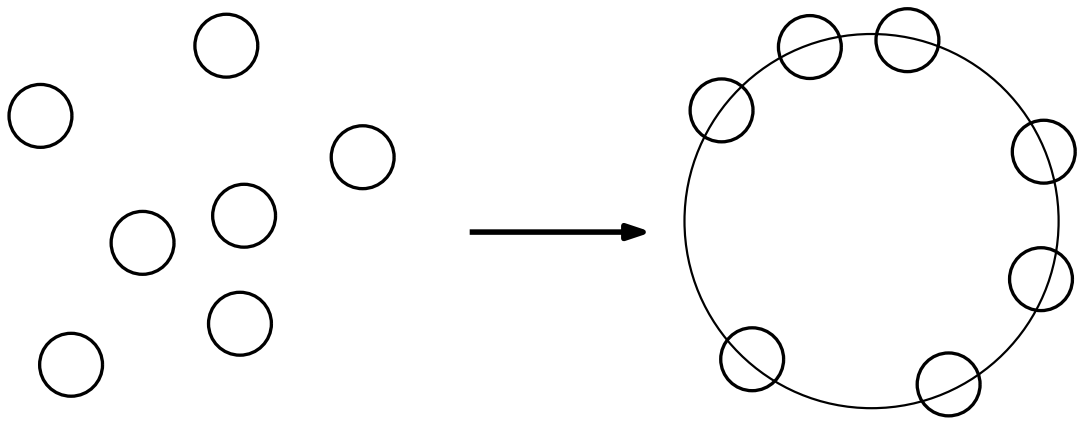
- Circle formation [Defago2008].



- Circle formation in limited visibility range ($\mathcal{R}_v$) and agreement in co-ordinate system

Scope of the Lecture

- Circle formation [Defago2008]



- Circle formation in unlimited visibility range and no agreement in co-ordinate system

Scope of the Lecture

Some Works on Circle Formation for Fat Robots

Scheduling	*Visibility range*	*Agreement in co-ordinate*	*Reported results*
Sync	Limited	No	Heuristic of approximate circle formation [Sugihara1990].
Ssync	Unlimited	No	Circle formation [Defago2002].
ASync	Unlimited	No	Bi-angular Circle formation [Katreniak2005].
ASync	Unlimited	No	Circle formation [Defago2008].

No reported result on fat robots.

Organization

Problem	Shape	Visibility range	Co-ordinate system
Leader election	Point or transparent fat robots	Unlimited visibility range	Local co-ordinate systems with no chirality
Gathering	Transparent fat robots	Unlimited visibility range	Local co-ordinate systems with no chirality
Pattern formation	Point robots	Unlimited visibility range	Local co-ordinate systems with no chirality
Circle formation	Transparent fat robots	Limited visibility range	Global co-ordinate systems
Circle formation	Transparent fat robots	Unlimited visibility range	Local co-ordinate systems with no chirality

Conclusion

- Solid Fat Robots: Visibility Block model.
- Unequal visibility range.
- Optimal/efficient Algorithms.