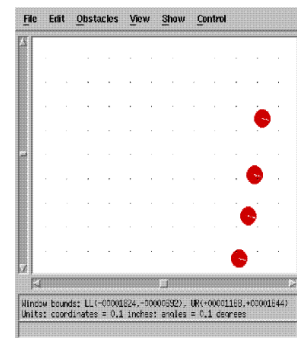
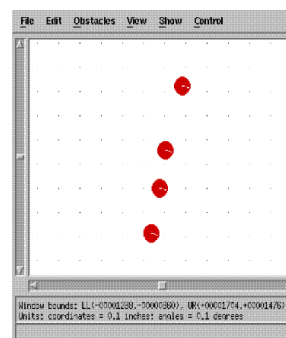
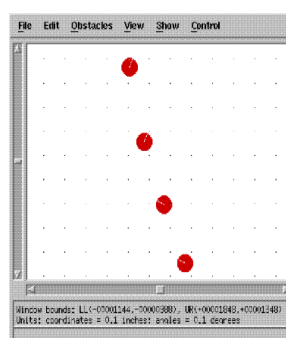
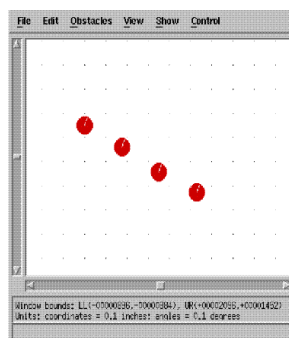
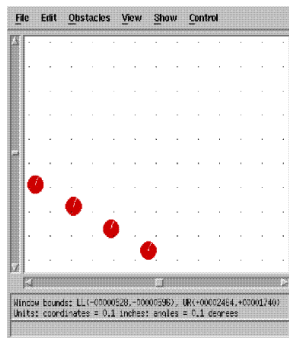


Formations in Multi-Robot Teams

February 18, 2003

Class Meeting 11

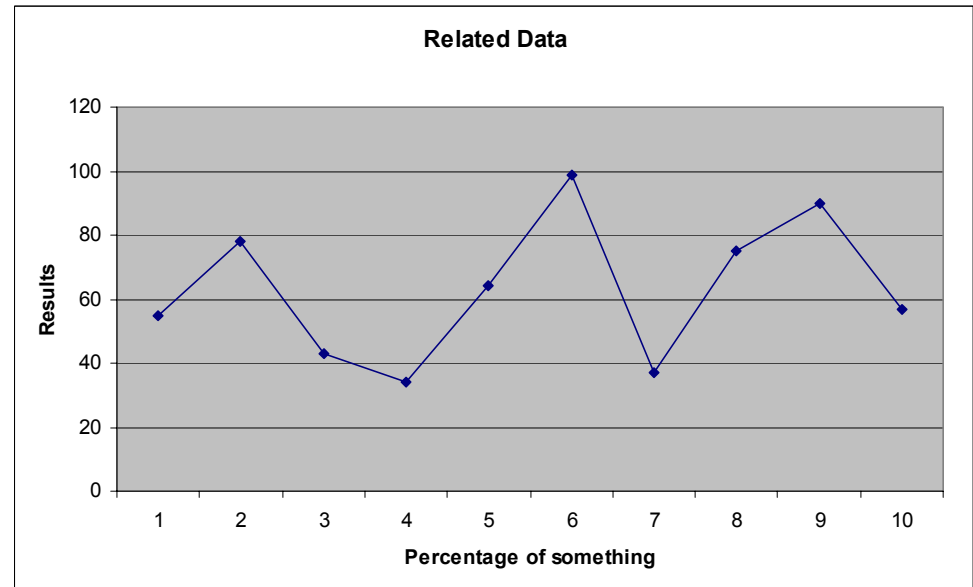
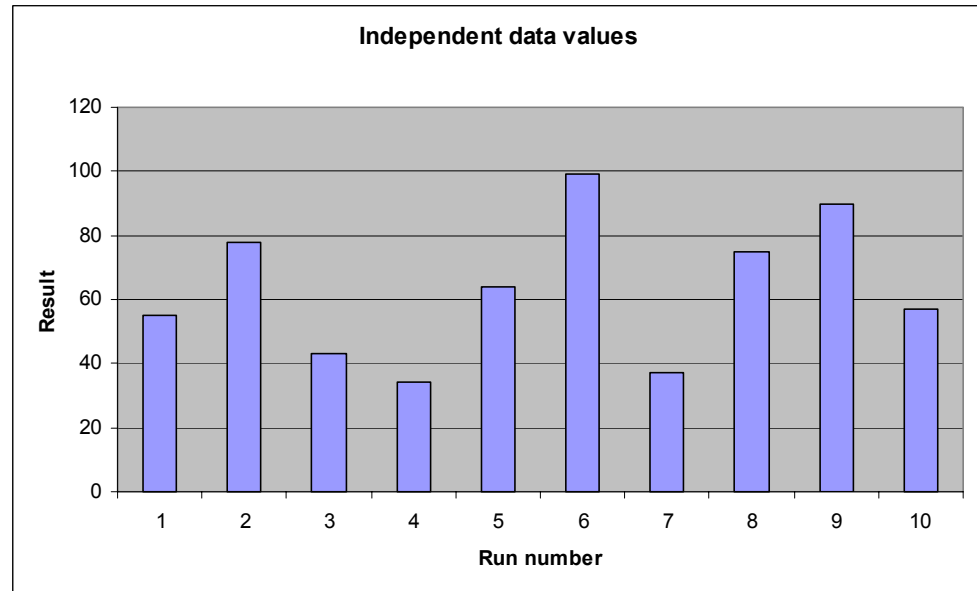


Outline

- Exam #1 solutions
- Assignment #2 solutions/discussion
- Assignment #3 discussion
- Introduction to Formations
- Student Presentation: Daisy Tang
- Discussion of Formations

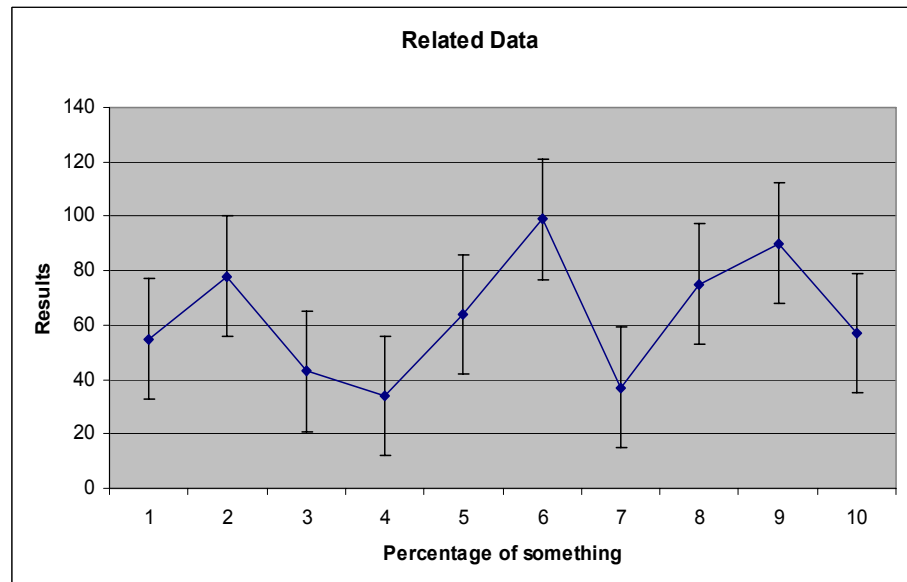
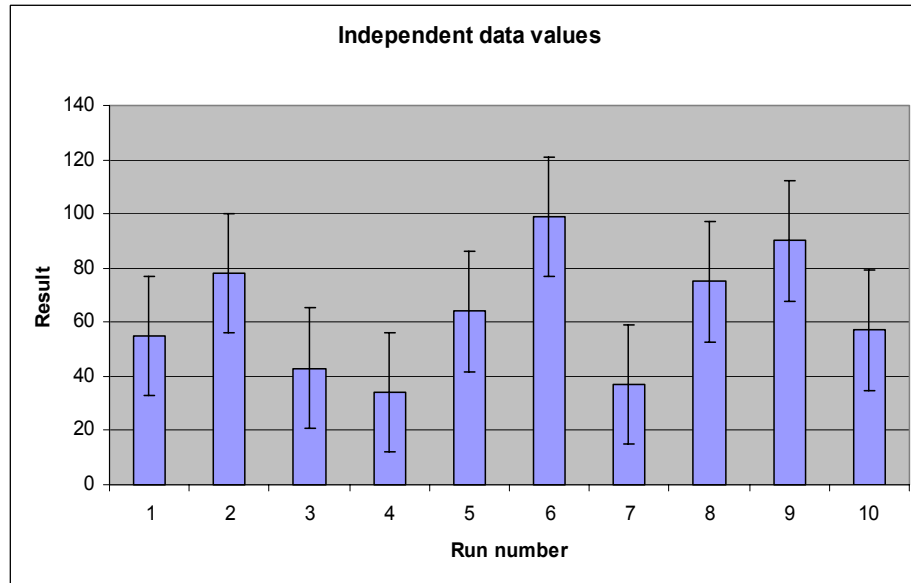
Discussion: Data Presentation

- Select right graph type for the data!
- Don't interpolate lines unless they are meaningful!



Data Presentation (con't.)

- Here's how to show standard deviation:



Clarifications to Assignment #3

Your Assignment #3 solution must adhere to the following:

1. Include a Makefile with your code
 - “make all” should compile all of your code
2. Use a revised version of the script handed out today so that all 6 copies of the robot code can be run from one xterm window
 - OR: You can fork off separate processes
3. “Style” counts!
 - “Jerky” or excessively slow robot motions won’t get full credit
4. Submit your code so that it uses Nserver port # 7019.
5. Provide at least minimal documentation for the “meat” of your code (i.e., at least clearly defining the starting point of subroutines and describing what they do)
6. Remove all debugging print statements from your code. Only print out informative statements that are helpful to the casual user (me and the TAs!) to indicate the status of the program run.
7. Plot data correctly!

Formations in Multi-Robot Teams: Objectives

- Understand key issues in formation-keeping
- Understand various formations studied by Balch and Arkin and their advantages/disadvantages
- Be able to determine best formation for given circumstances

Key Issues in Formation-Keeping

- What is **desired formation**?
- How do robots determine their **desired position** in the formation?
- How do robots determine their **actual position** in the formation?
- How do robots move to ensure that **formation is maintained**?
- What should robots do if there are **obstacles**?
- How do we **evaluate** robot formation performance?

Example Movies of Column Formation-Keeping



Parker, 1995



Parker et al., 2001

Student Paper Presentation

- “Behavior-based Formation Control for Multi-Robot Teams”, by Balch and Arkin, *IEEE Transactions on Robotics and Automation*, December 1998.
- Presented by Fang (Daisy) Tang



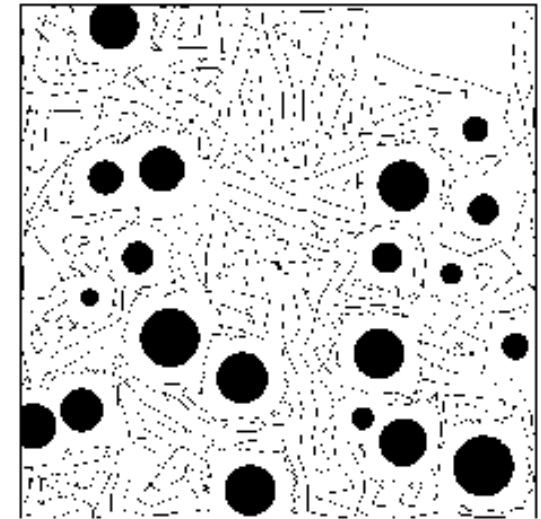
What is **desired formation**?

- Dependent upon **mission objectives**, e.g.:

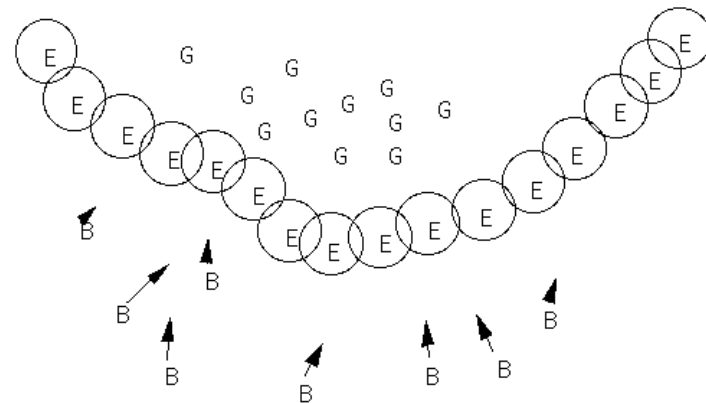
- Minimize penetration through barrier
- Maximize surface area coverage (e.g., “Graze”)
- Maintain certain constraints
 - E.g., Maintain convex hull area less than specified amount
- Stay together while getting to goal
- Moving object through environment

Maximize surface area coverage

Graze



Staying together on way to goal



Minimize barrier penetration

What is **desired formation**? (con't.)

- Dependent upon **environment**:

- Obstacle-free
- A few obstacles
- Cluttered

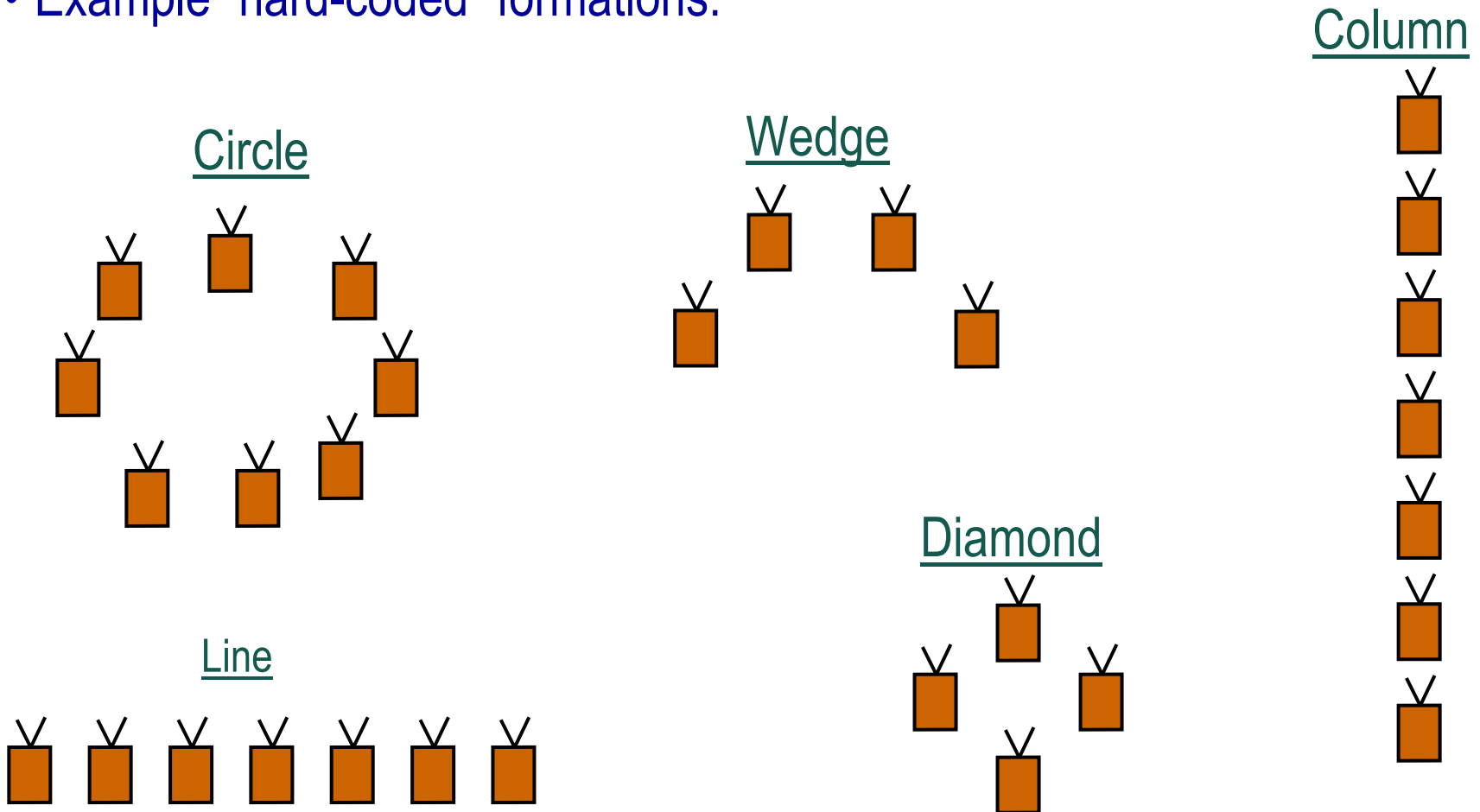


- Dependent upon **sensing/communication capabilities and requirements**:

- Ability to detect other robot positions
- Ability to communicate with each other
- Ability to sense effect of formation-keeping “through the world”

Possible formations

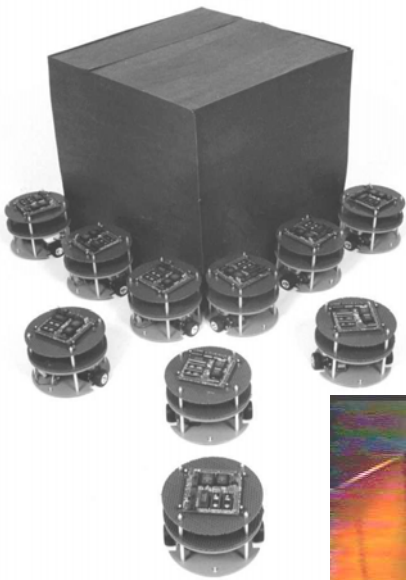
- Formations can be “hard-coded”, in the sense that they specify Cartesian positions for all robots.
- Example “hard-coded” formations:



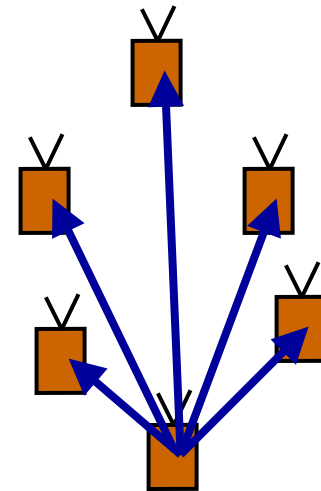
Possible formations (con't.)

- Or, formations can be **defined by constraints**, which allow variation in Cartesian positions for robots

E.g., Move object across room



E.g., Maintain LOS (line-of-sight) visibility



Next Time...

- Wrap-up Formations
- Pursuit/Herding