Human-Swarm Interaction through Natural Language Processing

CNIT 581: Project Proposal

Roman Ibrahimov, Yifei Hu

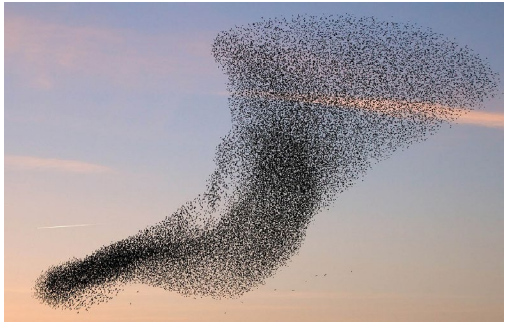
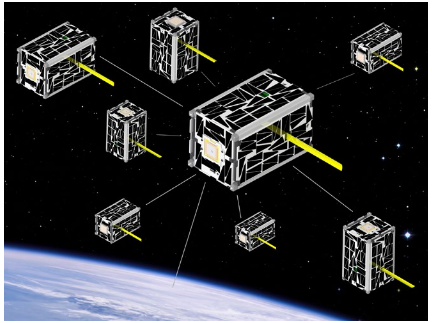
Team Introduction

Roman Ibrahimov
Ph.D. student in CIT

Yifei Hu (胡 翼飞)
Ph.D. student in CIT

Project Introduction

Why multi-agent systems are important?


MAS widely exist in nature and engineering applications. MAS usually offers better autonomy, robustness, flexibility, etc. They are able to achieve sophisticated missions that are well beyond individual system's capability.

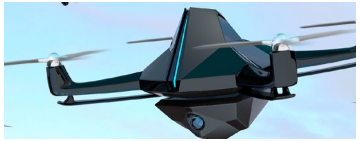
Project Introduction

Advantage

Individual Limits

Food Survival

Migration

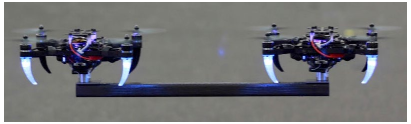


Search and Rescue Coverage

Sophisticated Tasks

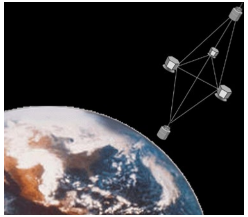
Swarm Intelligence

Applications



Cooperative Lifting

Search and Rescue



Satellite Formation

Project Introduction

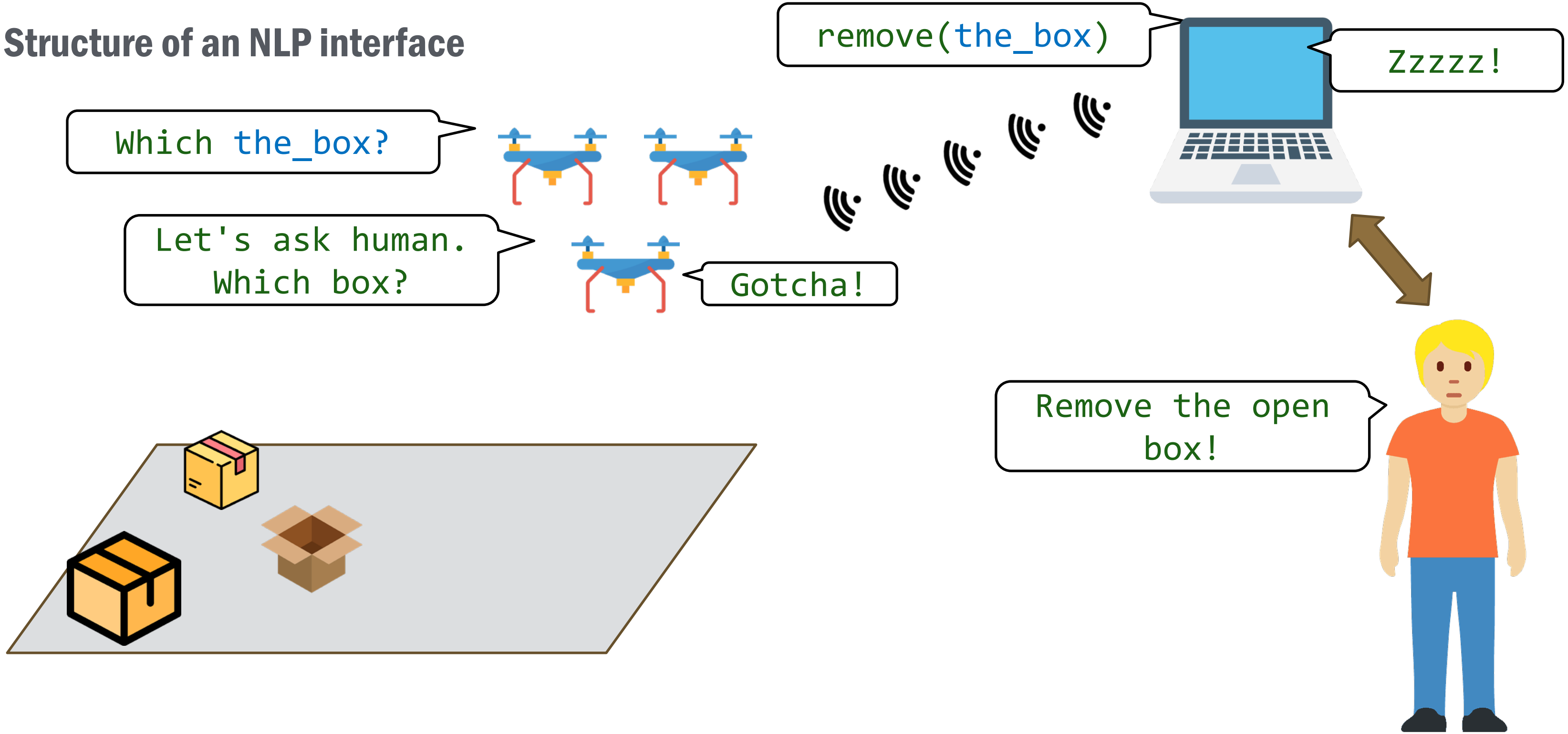
Project Introduction

Importance of Human Presence in Swarm

- recognize and mitigate shortcomings of the autonomy;
- have available “out-of-band” information not accessible to the autonomy and that can be utilized to increase performance;
- convey changes in intent as mission goals change;

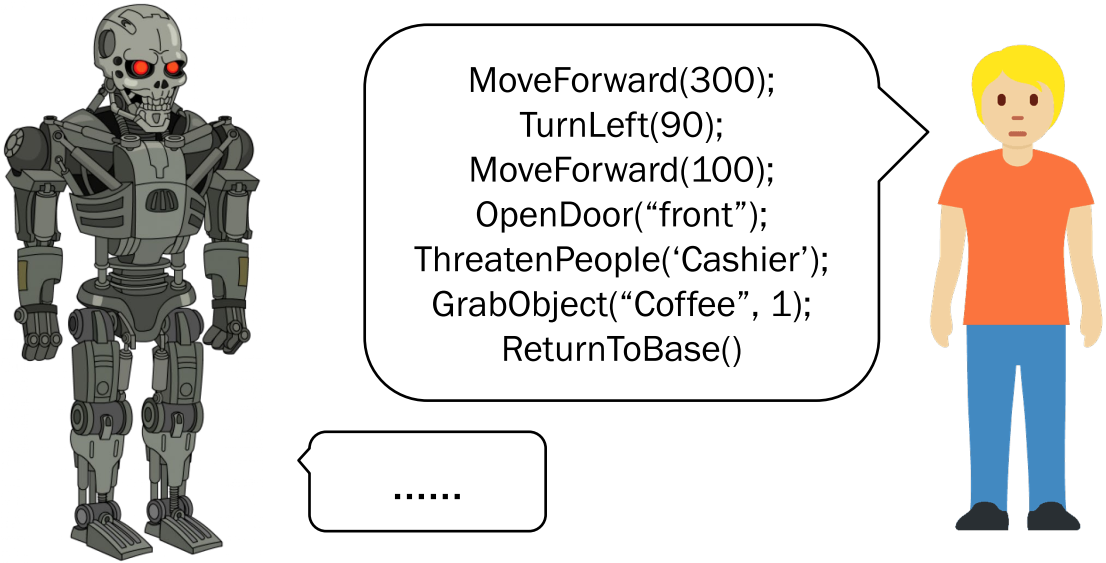
Project Introduction

Structure of an NLP interface



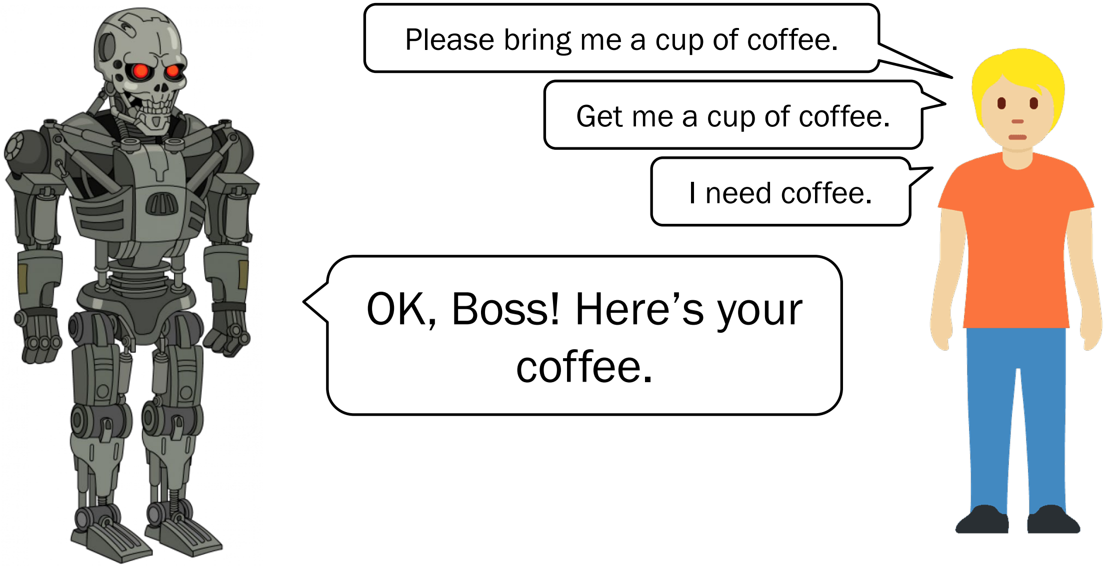
Project Introduction

Decompose the NLP interface



Project Introduction

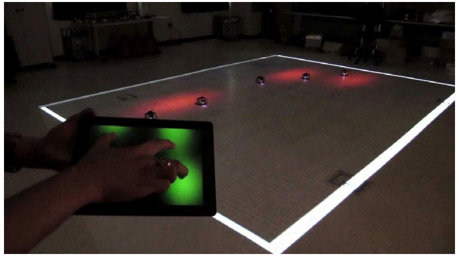
Decompose the NLP interface



Literature review

Human-swarm Interaction

- Human-swarm interaction based on augmented reality tablet application [1]
- An inherently collaborative task: collective transport [1]
- Human-swarm interaction based on tablet application [2]
- Quick manipulation of the swarm [2]



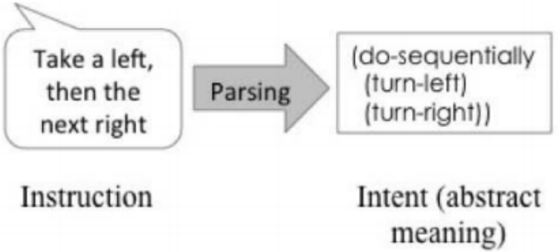
[1] Diaz-Mercado, Yancy, Sung G. Lee, and Magnus Egerstedt. "Human–swarm interactions via coverage of time-varying densities." *Trends in Control and Decision-Making for Human–Robot Collaboration Systems* (2017): 357-385.

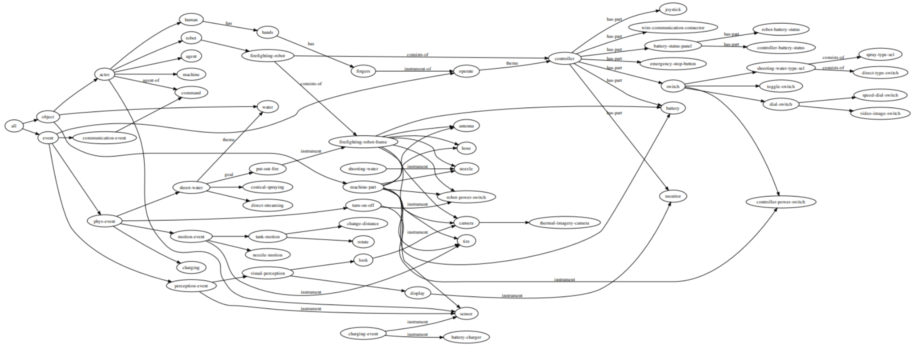
[2] Patel, Jayam, Yicong Xu, and Carlo Pinciroli. "Mixed-granularity human-swarm interaction." *2019 International Conference on Robotics and Automation (ICRA)*. IEEE, 2019.

Literature review

Robot Control with NLP

- Natural Language Processing technology is used to extract explicit command(s) from natural language.
- Ontology-based NL control system [1][2]
- Pre-defined Syntax [3]
- Robots can also use NL to respond [4]

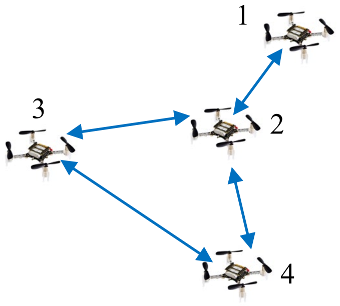




[1] Hong, J. H., Min, B. C., Taylor, J. M., Raskin, V., & Matson, E. T. (2012, October). NL-based communication with firefighting robots. In 2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC) (pp. 1461-1466). IEEE.
[2] Matson, E. T., Taylor, J., Raskin, V., Min, B. C., & Wilson, E. C. (2011, December). A natural language exchange model for enabling human, agent, robot and machine interaction. In *The 5th International Conference on Automation, Robotics and Applications* (pp. 340-345). IEEE.
[3] Matuszek, C., Herbst, E., Zettlemoyer, L., & Fox, D. (2013). Learning to parse natural language commands to a robot control system. In *Experimental robotics* (pp. 403-415). Springer, Heidelberg.
[4] Raman, V., Lignos, C., Finucane, C., Lee, K. C., Marcus, M. P., & Kress-Gazit, H. (2013, June). Sorry Dave, I'm Afraid I Can't Do That: Explaining Unachievable Robot Tasks Using Natural Language. In Robotics: Science and Systems (Vol. 2, No. 1, pp. 2-1).

Approaches

Distributed Consensus



$x_i(t) \in \mathbb{R}$: heading direction of UAV *i*.

$\mathcal{N}_i$: the set of UAV *i*’s ***neighbors*** including itself.
those agents in agent *i’s sensing range*

What are $\mathcal{N}_1, \mathcal{N}_2, \mathcal{N}_3, \mathcal{N}_4$?

$\mathcal{N}_1 = \{1, 2\}$ $\mathcal{N}_2 = \{1, 2, 3, 4\}$ $\mathcal{N}_3 = \{2, 3, 4\}$ $\mathcal{N}_4 = \{2, 3, 4\}$

Problem:
Develop an iterative update for each UAV’s state (i.e. control input) by only using its neighbors states

$$x_i(t+1) = u_i$$

$$u_i = f_i(x_j(t), j \in \mathcal{N}_i)$$

such that all states converge to reach a ***consensus***, namely

$$x_1(t) = x_2(t) = \cdots = x_m(t) = x^*$$

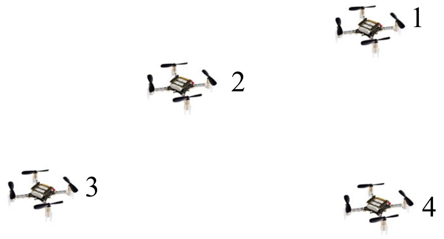
Consensus is the basis for a large number of autonomous agents to work as a cohesive whole, is the key to understand collective behaviors and swarm intelligence.

Approaches

Randezvous

N: number of agents

$x_i \in \mathbb{R}^2,\ i = 1, \ldots, N$: the state of each agent

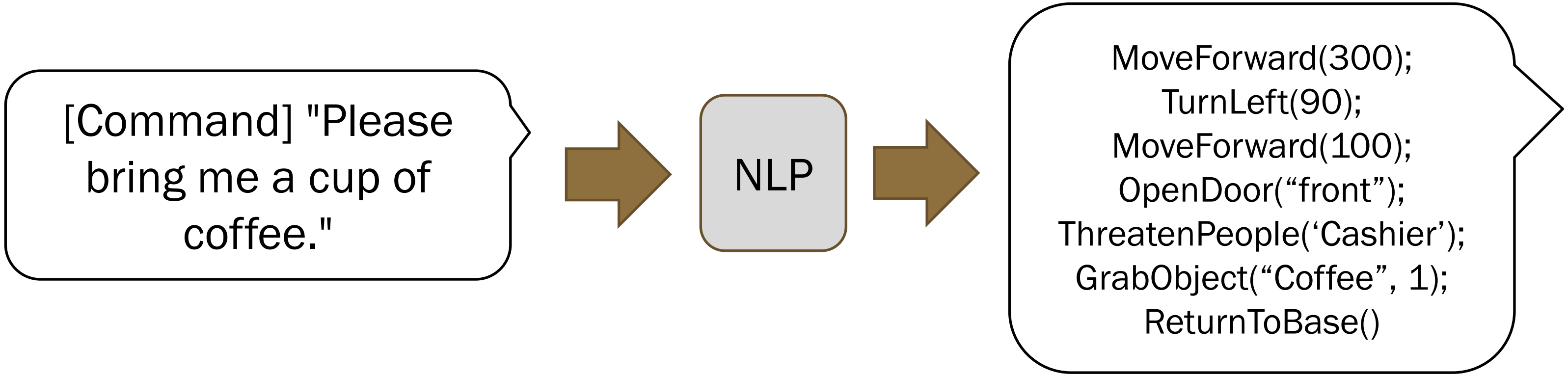


Problem:
Model each agent with the single-integrator dynamics $\dot{x}_i = u_i$ where $u_i \in \mathbb{R}^2$ is the control input to agent i such that:

$$\lim_{t \to \infty} (x_i - x_j) = 0,\ \forall\, i, j = 1, \ldots, N$$

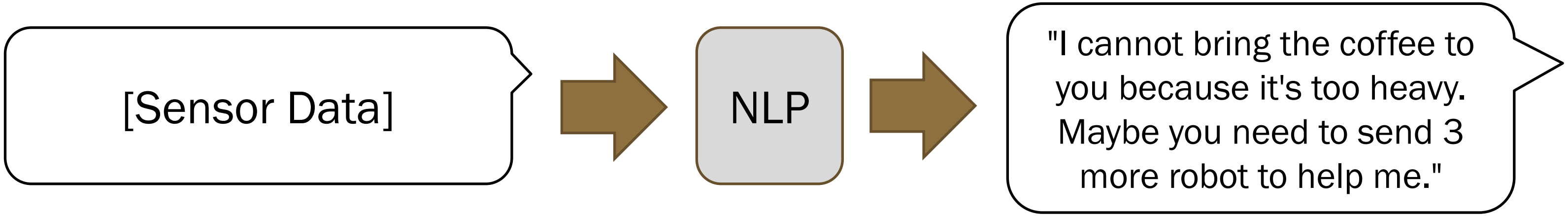
Approaches

Decompose the NLP interface



Approaches

Decompose the NLP interface



Plan

NLP algorithm with basic commands

Swarm in simulation

Partial interaction with the swarm in simulation

Full NLP algorithm

Full interaction with the swarm in simulation

Test cases on real drone swarm

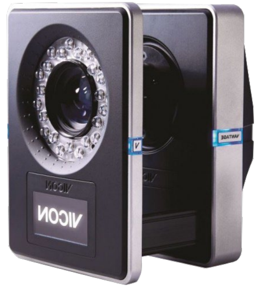
Phase 1

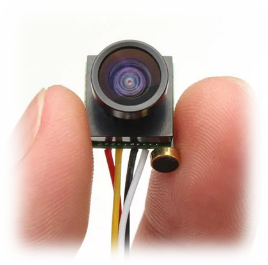
Phase 2

Phase 3

Equipment list

- Crazyflie 2.1 nano-quadcopters
- Vicon MoCap System
- Camera
- Computer with Robot Operating System (ROS)
- A remote server to reside NLP models





Roman Ibrahimov
Ph.D. student
Computer and Information Technology
ibrahir@purdue.edu

Yifei Hu
Ph.D. student
Computer and Information Technology
hu381@purdue.edu

polytechnic.purdue.edu

/ TechPurdue

PURDUE UNIVERSITY | Polytechnic Institute