2017 Winter Research Focus Period Seminar

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Presentation Overview

- Overview of doctoral thesis
  - Motivation
  - Problem description
  - Challenges
  - Expected contribution
- Related work by Üre
  - Overview
  - Randomized Coordination Discovery (RCD)
  - incremental Feature Dependency Discovery (iFDD)
- Concluding Remark
  - Future plan

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Overview of doctoral thesis

Motivation

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Challenges

Contribution

Cooperative multi-UAV system

Uncertainty

Vehicle dynamics
External disturbance
Resources
Demands

Huge amounts of data

Management of UAVs
UAV itself

Machine learning

Overview of doctoral thesis

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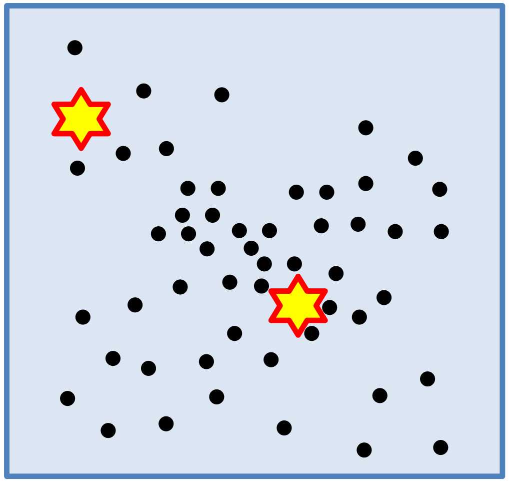
Contribution

- Additional questions

  Q1) Why should **locations of fundamentals** for UAV system be given?



  Q2) What if **goals of cooperative UAVs** are heterogeneous?

  ➔ 3 teams of UAVs for
  - collecting packages and carrying it to stopover
  - transfer it to another stopover
  - aerial refueling

  Q3) What if there is **uncertainty in occurrences of demands?**

  ➔ Heterogeneous types of demands such as *transferring* or *hovering*

  ➔ Uncertainty in occurrences

Overview of doctoral thesis

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Q1) Why should **location of fundamentals** for UAV system be given?
Q2) What if **goal of cooperative UAVs** are heterogeneous?
Q3) What if there is **uncertainty in occurrences of demands?**

- Answers for Q1
  - **Design** the architecture of UAV system
  - Mobility of UAV fundamentals?
- Answer for Q2
  - '**Planning**' algorithms should be more complicated
- Answer for Q3
  - '**Design**' issue + Randomness

- **Stochastic designing problem with cooperative planning algorithms**

Overview of doctoral thesis

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Contribution

- Stochastic designing problem with cooperative planning algorithms
  - Assumption
    - Stochastic & heterogeneous demands
    - Multiple and heterogeneous goals
    - Heterogeneous UAVs
    - Random external disturbance
    - Reward model is known
  - Objective:
    - Achieve a predetermined threshold of value of utility function
      - Maximizing, Max-min
  - Given:
    - Spec. of UAVS
    - Data sets (demand, disturbance, UAV aviation record, etc.)
    - Reward model
  - Output:
    - # of UAVs and fundamentals
    - Location of UAVs and fundamentals
    - Where to go? & how to go?

Overview of doctoral thesis

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- Strong dependency between 'Design' and 'Planning'
  - Solving 'design' problem and 'planning' problem **jointly**

    1) two steps: Planning after design

    2) simultaneously
- 'Design' and 'Planning' are based on 'Learning'
  - Decentralized and autonomous 'learning'
    - Computing resource of a UAV
- Utility function
  - $\frac{\#\ of\ completed\ tasks}{\#\ of\ tasks}$ or $\frac{\#\ of\ completed\ tasks}{fuel\ consumption}$
  - Linear or non-linear
- Multiagent learning
  - The curse of dimension
    - the number of agents enlarged the state space exponentially
    - Heterogeneous agents learn different models even if they have same observation
  - Drawbacks in sharing information among agents
  - How can implement a learning algorithms on an agent

Overview of doctoral thesis

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Contribution

- Scalability
  - Multiagent system
  - Heterogeneous agent
- Practicality
  - Design the architecture of UAV system
  - Randomness in demands

  → How can UAV system replace existing field of industries such as logistics, wireless communication, public safety or disaster management

  - Implementable
    - Computing resource limitation
    - Communication among UAVs

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Related Work by Üre

Overview

RCD (Randomized Coordination Discovery)

iFDD (incremental Feature Dependency Discovery)

- **Multi-agent Planning and Learning Using Random Decompositions and Adaptive Representations** by N.K.Üre (2015)
- ‘Planning’ and ‘Control’ problem
- Develop **planning** and **learning** algorithms that are scalable to large-scale **multi-agent** problems
  - Teams with heterogeneous transition models
  - Meta-optimization layers for self-tuning parameters
- Focus on developing multi-agent learning algorithms

Related Work by Üre

Overview

RCD (Randomized Coordination Discovery)

iFDD (incremental Feature Dependency Discovery)

- Assumption
  - Uncertainty in the environments and UAV dynamics
  - Deterministic & homogeneous demands
  - Given fundamentals for UAV such as stations, # of UAVs
  - Heterogeneous UAVs
  - A common goal of UAVs
  - Reward model is known

Assumption

- *Stochastic & heterogeneous demands*
- *Heterogeneous UAVs*
- *Random external disturbance*
- *Multiple and heterogeneous goals*
- *Reward model is known*

- Approach
  - RCD (Randomized Coordination Discovery)
  - iFDD (incremental Feature Dependency Discovery)
- Output
  - Operation plan of UAVs
  - Controlling UAVs

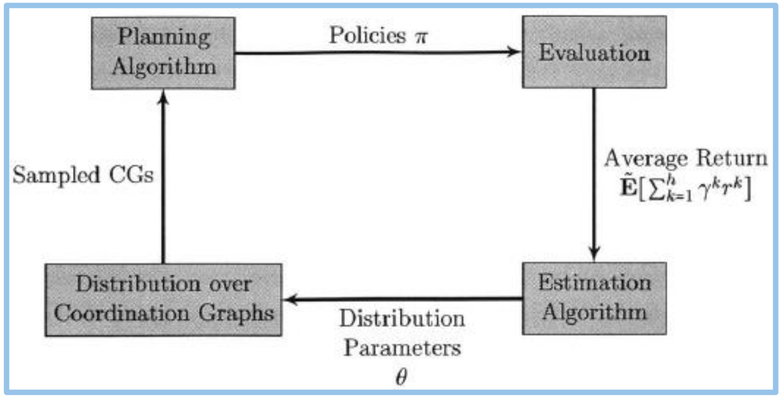
Related Work by Üre

Overview

RCD (Randomized Coordination Discovery)

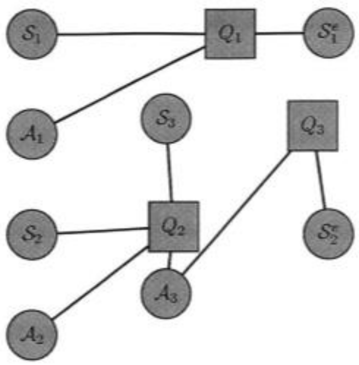
iFDD (incremental Feature Dependency Discovery)

- A **multi-agent planning algorithms** that performs coordination structure search for solving large-scale MMDPs



  - The discovery of useful coordination structures through a **randomized** search process
  - Assuming the full knowledge of the transition model

- CFG (Coordination Factor Graph)
  - factor graphs where the state-action variables are shared across different factors



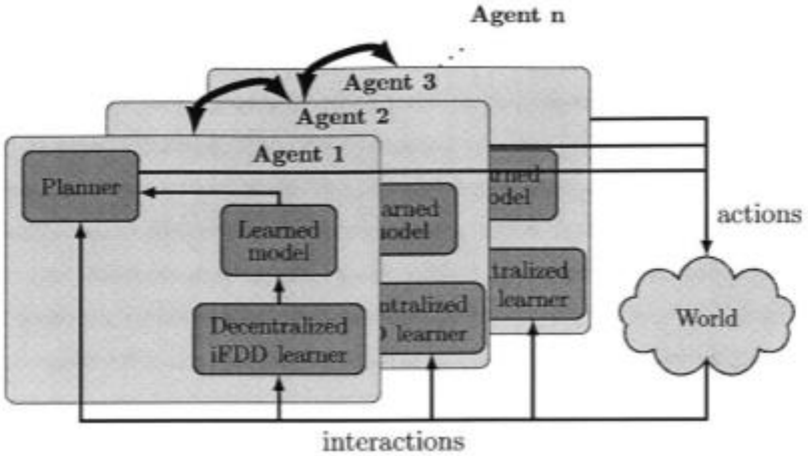
Related Work by Üre

Overview

RCD (Randomized Coordination Discovery)

iFDD (incremental Feature Dependency Discovery)

- Multi-agent learning with approximate representation
- incremental Feature Dependency Discovery (iFDD)
  - not fixing the model structure
  - allowing the model complexity grow based on the estimation error
- Focus on estimation/learning of transition models using multiple measurements/observations obtained by the agents
  - Multiple single agent learning algorithm



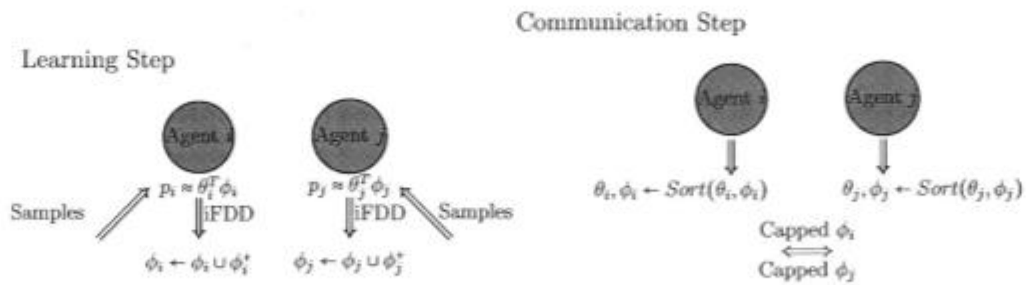
Related Work by Üre

Overview

RCD (Randomized Coordination Discovery)

iFDD (incremental Feature Dependency Discovery)

- State based uncertainty
  - Representation
    - P doesn't necessarily map each state to the same probability value
      - MDP with state-correlated uncertainty
    - $p(s) = P(\langle s, a, s' \rangle \in E | s)$
  - Learning
    - Linear function approximation
    - $p(s) \approx \hat{p}^k(s) = \phi^{\mathrm{T}}(s)\theta^k$
    - Stochastic Gradient Descent (SGD)
    - With iFDD



(a) Each agent maintains and updates an independent iFDD representation during individual learning steps

(b) Each agent ranks their features based on the corresponding weight and broadcast a capped number of top ranked features. Weight updates are handled individually for transferred features

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Concluding Remark

Future plan

- Completion of assumption and model
  - Formulate problems
- Derive necessary mathematical tools
  - Appropriate utility function
  - Necessary parameter to make models
- Approach method
  - Which algorithms of machine learning can be applicable
  - At first, devise algorithms without any additional assumptions
    - If possible, find global optimal
  - Within acceptable boundary, revise the first algorithms in order to make faster
- Based on the algorithms, the UAV system can be applied to practical domain

Q & A

Thank you!