Experimental System for The Monitoring of Cloud Movements

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Background

Photovoltaic (PV) power generation [1]

Merit
- Renewable energy
- A clean and environmentally-friend source of energy

Demerit
- Depending on weather condition and cloud-cover
- Low conversion efficiency

Renewable energy sources are highly variable, intermittent

It is difficult to maintain the power demand supply balance
The electricity grid must absorb this variability and intermittently

We need to monitor and forecast cloud movements

Outline

- Objective
- Experiment
  - Experimental Environment
  - Application of Potential Game
  - Simple Experiment
- Future Works

Objective

Monitoring

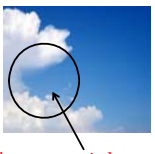
Each camera is controlled such that entropy[2] is maximum

Choose action (Pan, Tilt) such that the entropy is maximized using potential game[3]

Use PIPIP and DISL, PLLL, OSED[4] as a learning algorithm

Network camera

Each camera monitors boundary between cloud and blue sky

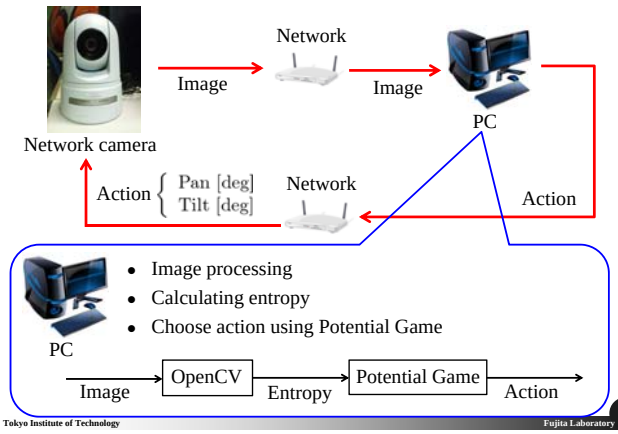


The entropy is large

We can know the size and shape of cloud

Need the experimental environment for the cloud movements

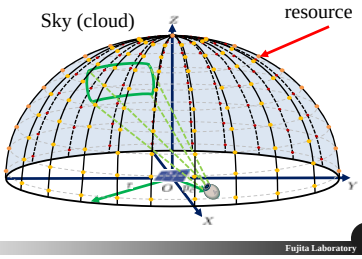
Experimental Environment



Scenario

Approach

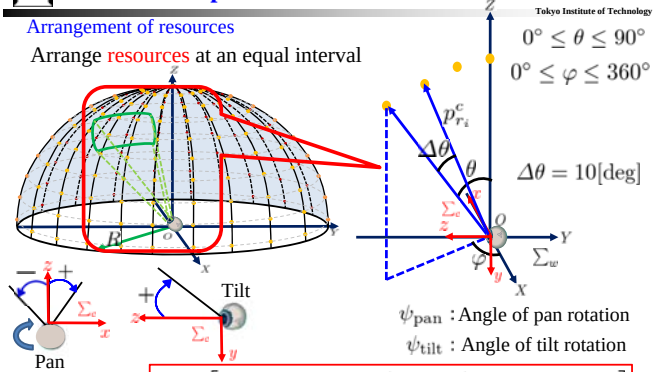
1. Suppose that sky is a curved surface
2. Arrange resources at an equal interval
3. Compute the entropy around resource
4. Move camera such that the entropy is maximized



Experimental Environment

Arrangement of resources

Arrange resources at an equal interval



$0° \leq \theta \leq 90°$

$0° \leq \varphi \leq 360°$

$\Delta\theta = 10[\mathrm{deg}]$

ψ_{pan} : Angle of pan rotation

ψ_{tilt} : Angle of tilt rotation

$$p^c_{r_i} = \begin{bmatrix} -R\cos(\psi_{\mathrm{pan}}+\varphi)\sin\theta \\ -R\{\sin(\psi_{\mathrm{pan}}+\varphi)\sin\psi_{\mathrm{tilt}}\sin\theta+\cos\psi_{\mathrm{tilt}}\cos\theta\} \\ -R\{\sin(\psi_{\mathrm{pan}}+\varphi)\cos\psi_{\mathrm{tilt}}\sin\theta+\sin\psi_{\mathrm{tilt}}\cos\theta\} \end{bmatrix}$$

Experimental Environment

Arrangement of resources

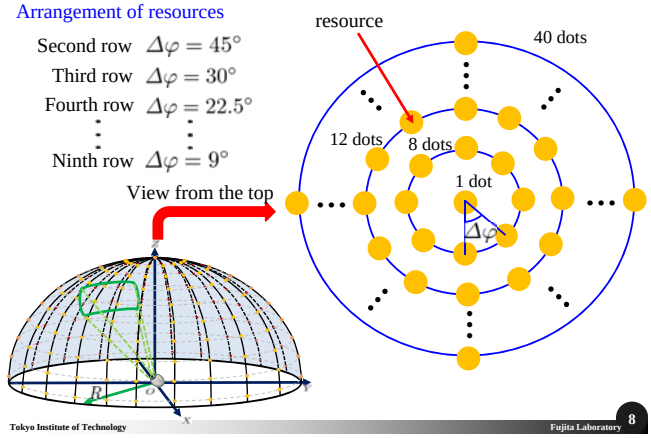
Second row $\Delta\varphi = 45°$

Third row $\Delta\varphi = 30°$

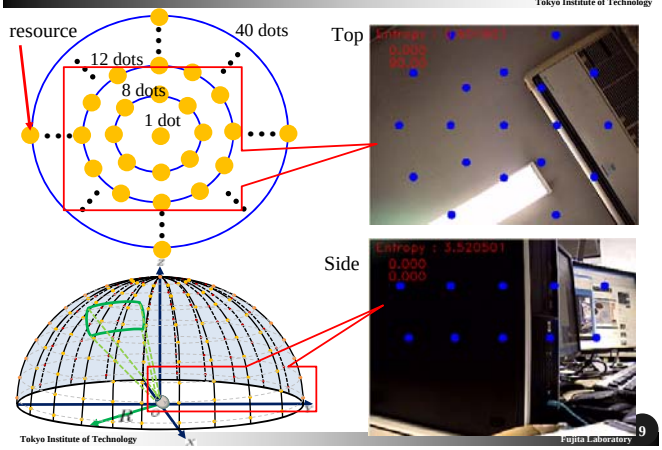
Fourth row $\Delta\varphi = 22.5°$

Ninth row $\Delta\varphi = 9°$

View from the top



Experimental Environment



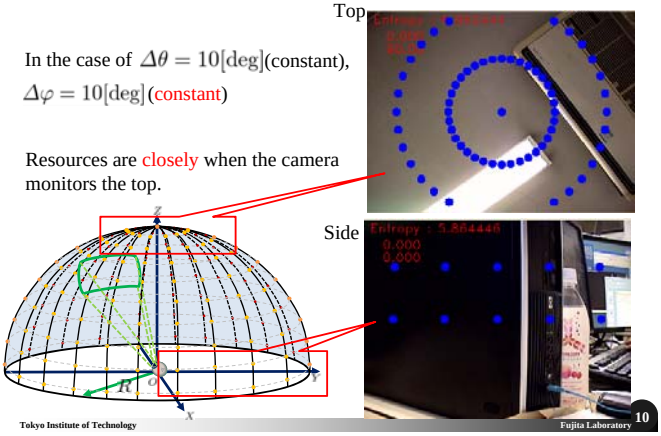
Experimental Environment

Top

In the case of $\Delta\theta = 10[\mathrm{deg}]$(constant),

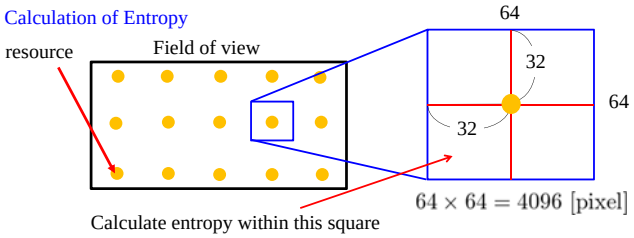
$\Delta\varphi = 10[\mathrm{deg}]$ (constant)

Resources are closely when the camera monitors the top.



Application of Potential Game (one camera)

Calculation of Entropy



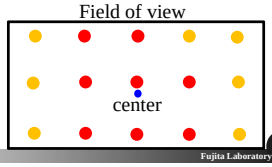
Use eight dots which are near the center as the Utility

● : Use ● : Not use

Utility Function

$$U_i(a_i) = \sum_{j=1}^{8} H_j \quad i = \{1, \cdots, N\}$$

H_j :The entropy of resource j



Application of Potential Game (one camera)

Agent

$N = 1$ (Network camera)

Action

$a_i = (\mathrm{Pan}, \mathrm{Tilt})$ [deg] $i = \{1, \cdots, N\}$

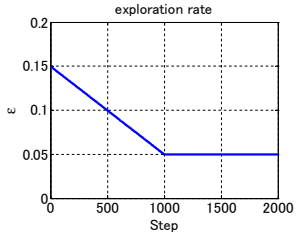
Restricted Action Set

$$\mathcal{R}_i(a_i) = \{a_i + 5(b_1, b_2) | b_1 \in \{-1, 0, 1\}, b_2 \in \{-1, 0, 1\}\}$$

Utility Function

$$U_i(a_i) = \sum_{j=1}^{8} H_j$$

H_j :The entropy of resource j



Learning Algorithm

PIPIP, DISL, PLLL, OSED

Exploration Rate

$$\varepsilon = \begin{cases} 0.15 - 0.0001 \times \mathrm{Step} & (0 \leq \mathrm{Step} < 1000) \\ 0.05 & (1000 \leq \mathrm{Step}) \end{cases}$$

Simple Experiment

A camera monitors black area

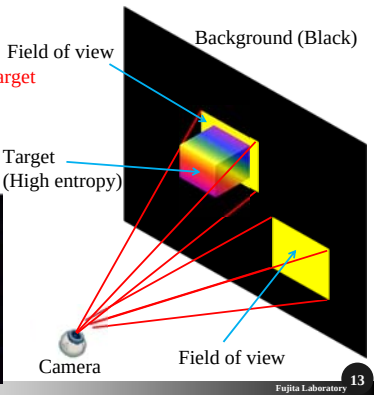
search a target

A camera monitors around the target (High entropy)

Action

$-65° \leq \text{Pan} \leq 35°$

$0° \leq \text{Tilt} \leq 35°$



Simple Experiment

Processing time

640 × 480 [pixel]

320 × 240 [pixel]

Network camera

Processing

PC

2000 step in 19 minutes

Long 0.57[s/step]

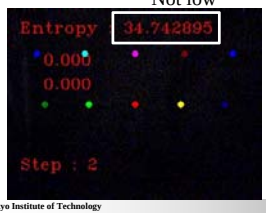
Short 0.38[s/step]

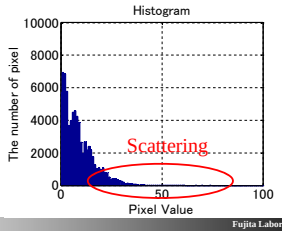
Display

2000 step in 12 minutes

Noise

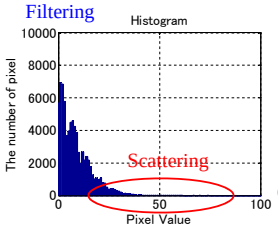
Not low



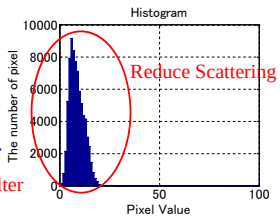


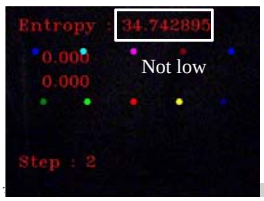
Simple Experiment

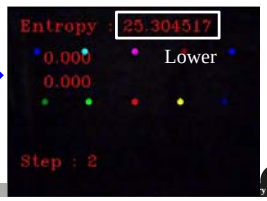
Filtering



Gaussian filter



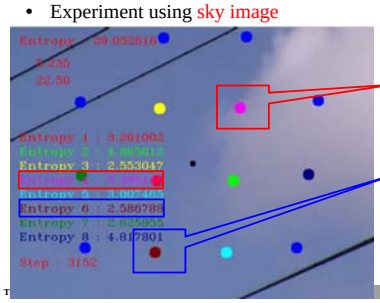




Future Works

Experiment

- Experiment using multiple targets
- Experiment using multiple cameras
- Application of Potential Game (multiple cameras)
- Experiment using sky image



Entropy is high (about 5.3) boundary between cloud and blue sky

Entropy is low (about 2.5) in the sky

References

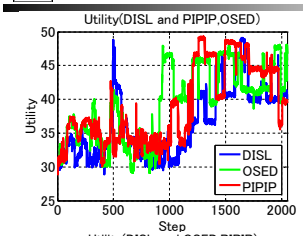
[1] T. T. N. Khatib, A. Mohamed and N. Amin, “A New Controller Scheme for Photovoltaics Power Generation Systems,” *European Journal of Scientific Research ISSN*, Vol. 33, No. 3, pp.515-524, 2009.

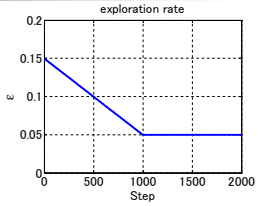
[2] Y. Zhang, M. Rotea, N. Gans, “Sensors Searching for Interesting Things: Extremum Seeking Control on Entropy Maps,” *the 50th IEEE Conference on Decision and Control and European Control Conference*, Orlando, Florida, USA, Dec. 14th, 2011.

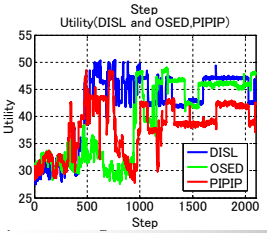
[3] T. Goto, T. Hatanaka and M. Fujita, ”Payoff-based Inhomogeneous Partially Irrational Play for Potential Game Theoretic Cooperative Control of Multi-agent Systems,” (available at arXiv:1107.4838), 2011.

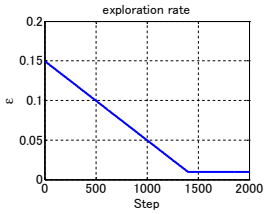
[4] 後藤,”ポテンシャルゲーム理論的協調制御における学習アルゴリズムの提案,” 東京工業大学 修士論文, 2011.

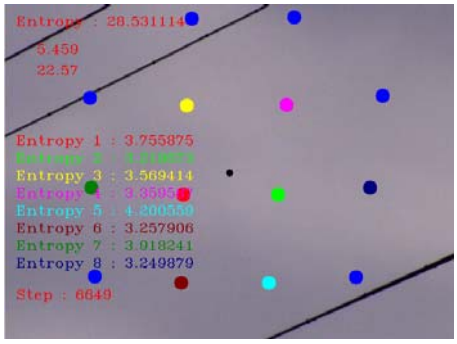
Appendix


Utility(DISL and PIPIP,OSED)
Utility
Step
DISL
OSED
PIPIP


exploration rate
ε
Step


Utility(DISL and OSED,PIPIP)
Utility
Step
DISL
OSED
PIPIP


exploration rate
ε
Step


Entropy : 28.531114
5.459
22.57
Entropy 1 : 3.755875
Entropy 3 : 3.569414
Entropy 6 : 3.257906
Entropy 7 : 3.018241
Entropy 8 : 3.249879
Step : 6649