The Monitoring of Cloud Movements with Visual Sensor Networks

Akihiro Sugiyama
FL12-1-2
16th, April, 2012

Background
Photovoltaic (PV) power generation [1]
The installation of PV generation systems is rapidly growing due to concerns related to environment.

Merit
- Renewable energy
- A clean and environmentally-friendly 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
However the electricity grid must absorb this variability and intermittently
We need to monitor and forecast cloud movement

Objective

Monitoring [2]
Satellite and ground-based sky imaging tools can be used to monitor and forecast cloud movements.
Forecast of PV energy production is available in advance.

All-sky imaging [3]
- The system includes a camera and wide-angle lens or hemispheric mirror.
- Analysis of image is based on the red-to-blue ratio.
- lens distortion is large

Visual sensor networks
- Surveillance
- Tracking
- Catching speeding drivers
- Gathering scientific data

Scenario

Characteristics
- Monitor cloud using network camera
- Choose action (Pan, Tilt) such that the entropy is maximized using potential game[4]
- Use PIPIP(Payoff based Inhomogeneous Partially Irrational Play)[4] as a learning algorithm

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

Entropy[5,6]

The pip of a dice : $X = \{1, 2, 3, 4, 5, 6\}$

The probability of $x : p(x)$

$H(X) = -\sum_{x \in X} p(x) \log p(x)$

Probability distribution

Entropy

Converting a image to a gray scale image

pixel value $[0 - 255]$ brightness

Red
Green
Blue

ex $[0, 0, 0]$ Black
$[255, 255, 255]$ White
$[255, 0, 0]$ Red
$[0, 255, 0]$ Blue
$[255, 255, 0]$ Yellow
**Entropy[5,6]**

Calculation of the probability $p(x)$

<table>
<thead>
<tr>
<th>$x$</th>
<th>$p(x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

Total pixels $600 \times 600 = 400000$

Entropy

$$H(X) = -\sum_{x \in X} p(x) \log p(x)$$

Probability $p(x)$:

- $p(0)$: The number of pixel value 0
- $p(1)$: The number of pixel value 1
- $p(255)$: The number of pixel value 255

Total pixels $800 \times 800 = 640000$

**Scenario**

- Each camera is controlled such that entropy is maximum.
- Each camera monitors boundary between cloud and sky.
- We can know the size and shape of cloud.

**Experiment Settings**

*Experimental system [7]*

- Projecting movie of the sky on the ceiling
- Control commands (C++ program)
- Network camera
- Images
Future Works

Compose experimental system
- Display the camera image
- Pan and Tilt control with network camera (one camera)
- Calculating the entropy (one camera)
- Pan and Tilt control with network camera (multiple cameras)
- Calculating the entropy (multiple cameras)
- Application of Potential Game

The analysis and evaluation of experimentation
- Sunlight
- The color of the cloud
- The overlap of the field of view
- Using bearing angle [8]

References


