Autonomous navigation of lunar rover based on stereo –vision

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• The future work
Introduction of China’s Chang’èe Project

- In order to solve Earth’s energy problem in the future, China declared the **Chang’èe Project** in 2004, which includes three steps:
  - Circle the moon (2007, lunar orbit stage)
  - Land on the moon (lander-rover stage)
  - Back from the moon (sample return stage)

- Lunar rover will be landed at about 2012, its objectives:
  - In-situ exploration of lunar regolith and crustal thickness, deep structure of lunar mantle, etc.
  - Origin & location of shallow moonquakes, record little collisions, etc.
  - Data collection for lunar base selection
Our Development: Prototype Design

- mast
- solar array
- manipulator
- high gain antenna
- low gain antenna
- CCD camera
Prototype of Lunar rover
Prototype of Lunar rover
Main performance

1500mm × 1200mm × 1000mm ;
200 kilograms ;
6-wheel rocker suspension;
10~50mm/s;
1024*768 pixels;
The structure of system

- I/O Board
- CPU Board
- CPU
- RAM
- DOC
- RS422 Interface
- PC104 BUS
- Hazd cam
- Navcam
- Arm/Mast/Antenna
- Drive/Steering
- Robot/Grinder
- IMU
Stereo-vision navigation

Theory of stereo-vision

\[ Z = \frac{fB}{x_r - x_L} = \frac{fB}{d} \]
Stereo-vision navigation

• Merit
  • Untouched sensor
  • Passive sensor
  • Low power

• Disadvantage
  - Mass data
  - Complicated algorithm
  - Sun light influenced
# Hardware

## Technical Specifications

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>FUNCTIONS</th>
</tr>
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<tbody>
<tr>
<td>Function</td>
<td>FireWire PC/104+</td>
</tr>
<tr>
<td>Controller</td>
<td>TSB43AB22</td>
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<tr>
<td>Connector</td>
<td>2x Molex 534-62-6011</td>
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<tr>
<td>Bus</td>
<td>PC/104+ (PCI)</td>
</tr>
<tr>
<td>Onboard Flash</td>
<td>–</td>
</tr>
<tr>
<td>Remarks</td>
<td>–</td>
</tr>
<tr>
<td>Power Supply</td>
<td>–</td>
</tr>
<tr>
<td>PCI Bus Voltage</td>
<td>3.3 &amp; 5V</td>
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<tr>
<td>Operating Temperature</td>
<td>-25°C to +70°C</td>
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<tr>
<td>Extended Temperature</td>
<td>-25°C to +65°C</td>
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<tr>
<td>Weight (gr)</td>
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<tr>
<td>MTBF</td>
<td>&gt;100 000h</td>
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</table>

1394 Image card
Hardware

Dual Camera
Stereo vision algorithm

Matching algorithm

SAD algorithm

\[
\min_{d = d_{\text{min}}} \sum_{i=\frac{-N}{2}}^{\frac{N}{2}} \sum_{j=\frac{-N}{2}}^{\frac{N}{2}} |I_{\text{right}}[x+i][y+j] - I_{\text{left}}[x+i+d][y+j]|
\]
Stereo vision algorithm

Camera calibration
Stereo vision algorithm

Left image

Right image

Environment

Path-planning
Prototype Testing
Prototype Testing

- Trafficicability
  - Climbing obstacles
  - Climbing slopes
  - Cross over craters
  - Turn/turn in place

- Navigation and control system testing
  - Path planning testing
  - Autonomous control testing
Prototype Testing

• Related technologies mainly include:
  - Autonomous vision-based navigation + remote control
  - Stereo vision algorithm is adopted for autonomous controlling
  - IMU system is used to inspect the prototype’s orientation
  - Local path-planning
  - Rebuild the three-dimension of terrain
The future works

• Key technologies of lunar rover: In-depth research
  - Comprehensive testing of the prototype in lunar-simulating labs
  - Visual Odometry

• Deep space exploration
  - Mars exploration
  - ……

• Collaborate with international organizations
Thanks !