Sun Sensor and Localization

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Long Range Navigation

- Sun Tracker
  - Design
  - Calibration
  - Performance

- State Estimation
  - Algorithm
  - Sensor models
  - Performance
Motivation

Still used for:

- initializing rover pose
- resetting rover pose during traverse
Requirements

Traverse km distances to science sites
Register position to orbital data
Position error of 5% distance travelled

$3^\circ$ heading error = 5% cross-track error
Sun Tracker

Want a fixed reference

Gyros drift

No magnetic field in Chile
Sun Tracker

- Fisheye lens
- Solar filter
- Camera
- Enclosure
Sensor Model

Solar angles (sensor coordinates)

Image
Sensor Model

Image coordinates ➔ spherical coordinates

Calibrate for points at infinity
Assume symmetry in azimuth
Elevation angle is

\[ r = \sqrt{(u-u_c)^2 + (v-v_c)^2} \]

\[ \beta = p_1 r + p_2 r^2 + p_3 r^3 \ldots \]

Calibration means finding \((u_c, v_c, p_1, p_2, p_3)\)
Geometric constraint

Lines at infinity map to great circles
Lines at infinity
Calibration data
Calibration data
Calibration data
Calibration data
Minimization

Edge data

Initial guess

Optimized value
Result

Initial guess:
  rms: 3.3°
  fov: 120°

Parameter fit:
  rms: 0.1824°
  fov: 187.4°

(Mfg Spec: fov = 190°)

Texture mapped calibration image
Sun spot

Observed az, el given by centroid
Estimating pose

Inclinometer gives roll, pitch
Then suntracker then gives yaw
Estimating pose

Use all data at once

4 measurements: roll, pitch, az, el
3 dof: roll, pitch, yaw
Estimating pose

Model

\[ z_{\text{inc}} = h_{\text{inc}}(r,p) \]

\[ z_{\text{sol}} = h_{\text{sol}}(r,p,y;\alpha,\beta) \]

Minimize

\[ J = (z_{\text{inc}} - h_{\text{inc}}(r,p))^2 + (z_{\text{sol}} - h_{\text{sol}}(r,p,y;\alpha,\beta))^2 \]

to find \((r,p,y)\)
Image location: 4.15.2003

Sun location in 21 images
Derived pose: 4.15.2003
Image location: 4.16.2003

Sun location in 100 (68) images
Derived pose: 4.16.2003

roll

pitch

yaw
Sun location in 219 images
Derived pose: 4.18.2003

- Roll
- Pitch
- Yaw
Image location: 4.24.2003

Sun location in 128 images

roll

pitch

yaw
Results

Accuracy: $\sigma \sim 4^\circ$

Some systematic errors, possibly from:
  - rover accelerations
  - unknown sensor orientation
  - synchronization
  - incorrect time (clock skew)
  - incorrect location
  - calibration of optics
Conclusions

New method for calibrating wide fov lens

Feasible method for absolute orientation
  – Accuracy: $\sigma \sim 4^\circ$
  – No drift
  – No GPS*

May be best used
  – infrequently
  – while motionless
  – in conjunction with a gyro

*still need georeferenced position

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Conclusions

Use onboard rover
  – infrequently
  – while motionless
  – in tandem with a gyro

Initialization:
  – may be able to bootstrap
Future work

Georeferenced orientation is possible

Georeferenced position not yet addressed