Mars Express 2003 Carries Beagle2: A European Lander on Mars

Development of the Vision System

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JOANNEUM RESEARCH

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Contents

— Whoami
— Quick Overview of Mars Express
— Quick Overview of Beagle2 Mission (incl. Video)
— History of Beagle2 DEM: How to Propose for Research
— Elevation Modeling & Calibration Concept
— Examples
Institute of Digital Image Processing

Short Profile
JOANNEUM RESEARCH

— Located at Graz (2nd Largest City in Austria, 200 km SW of Vienna)
— 350 Employees
— Non- University
— Owned by Federal State of Styria
— 20 Research Institutes
  — Largest: Institute of Digital Image Processing (45 People)
— Link Between Industry and Universities
  — R&D for Industry
  — Own – Funded Research
  — Research for Public Organizations (EU, ESA, Austrian Gov., ....)
— 75% of Budget from Contracts
Dpt. of Remote Sensing
- Environmental Remote Sensing
- Geometric Processing (RSG: SW Package within ERDAS)
- Interferometry
- Laserscanning
- Mobile Mapping
- ...........

- Process Control
  - Real – Time
- Optical 3D Measurement
  - Steel Industry
  - Mining
  - Disaster Management
- .......

Institute of Digital Image Processing (DIB)
Mars Express

- One of Six Int. Mars Missions 2003 – 2004
- Low – Cost (< 150 Mio €)
- European – Only
- Search for Water
- Launch June 1, 2003 (+11d)
  - Soyuz Carrier
- Arrival 26th Dec, 2003
  - Polar Orbit, 250-11000 km
- 7 Instruments
  - Incl. Stereo Camera
- UK Lander: Beagle2
Beagle2 Journey

— Atmospheric Entry by Aeroshell
— Parachute Descent
— Landing at Maja Vallis
  — 52°West, 19.5°North
  — Spring – Summer
— Touchdown by Airbags
Beagle2 Lander

- 60 kg
- 70 cm Diameter
- 4 Solar Cells
- Robotic Arm
- Primary Goal:
  - 180 d Operation
Beagle2 Mission

... Video
Main Tool: Robotic Arm
Robotic Arm: Just the Wires......
The PAW Subsystem

The PAW is an integrated collection of scientific instruments, sample preparation and acquisition tools, deployed by the Robotic Arm for in-situ investigation of the Martian surface. Samples of “solid” material acquired by the PAW are returned to the GAP for detailed isotopic and chemical analysis. The majority of subsystems on the PAW are serviced by the PAW electronics.

Mandate

- Multi-spectral stereo imaging of the immediate area around the lander
- DEM construction of the landing site (including the 1m² working zone)
- Multi-instrument in-situ rock/“soil” analysis
- Wind measurements at various heights about the Martian surface
- Acquisition of “core” samples from rocks
- Acquisition of “soil” samples (Mole or spoon) from the sub-surface
- Delivery of solid samples (“core” or “soil”) to the GAP via the inlet port
- Pre PAW deployment hazard mitigation via the WAM
- Deposition of “soil” samples onto ESOS for angle of repose experiment
- Analysis of “soil” samples (acquired by the Mole or spoon) with in-situ instruments
- Analysis of uncovered “soil” surfaces with spectrometers (after top layer scraped off with PAW)
- Imaging of “Mole-hole”
Beagle2 Instruments & Tools on Robotic Arm

1. Stereo Camera (x2)
2. Microscope
3. Mößbauer Spectrometer
4. Rock Corer Grinder
5. Sampling Mole
6. X-Ray Spectrometer
7. Wind Sensor
8. Spoon

Electronics (BB)
WAM
Electronics Torch
MIC focusing mechanism
Stand off “thumb”
PLUTO winch
Shutter
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Austrian Contribution: The Beagle2 DEM History

- June 98: Tests at DIB with Pathfinder Stereo Pairs (Provided by MPAE Lindau, D)
  - ESA Provides Info About 2 Potential Lander - Teams (Linkin/Moskau, Pillinger/London)
- ASA Informed → „Carry On“
- 27.11.98: Beagle2 Camera Meeting in London: DIB Contribution Consolidated. No Funding Yet
- Jan 1999: Work Started (Own Risk by JR)
- March 2000: Budget Fixed
Beagle2 DEM: How to Reach the Goal
Beagle2 DEM: Stereo Reconstruction

Example Data: Mars Pathfinder

- Left / Right Image
- Stereo Matching
- Disparity Map
- 3D Reconstruction
- Digital Elevation Model (DEM)

Left / Right Exterior Orientation
Merging Several Stereo Reconstructions to „World“ DEM

Accurate Calibration → Each Individual DEM Correct

Ortho Image  DEM

1/4 of Pathfinder Landing Site Ring:
Merging 4 Reconstruction Areas
Some Examples of Real Work

@Leicester University

@Aberystwyth University of Wales
Interior Calibration (Focal Length etc.)

1. Viewing Calibration Target with Camera

2. Making N Images

3. Analyse Point Positions

4. Evaluation

Pressure & Temperature Chamber
Test Procedure on Various Filters

1. Viewing Calibration Target with Camera

2. Making N Images

3. Analyse Point Positions

4. Evaluation
Effect of Lens Distortion Compensation

Without Compensation

With Compensation

1 Pixel
Example: Temperature Dependence
(Only Right Camera, x-component)
Wide Angle Mirror (WAM) Rectification

- Heuristic Approach as First Attempt
- Calibration Image Necessary
Robot Arm Calibration

Marker

Calibration ‘L’
RA Calibration: Calibration Step

View Calibration Target with Camera

Position of Calibration Target Known in RA Coordinate System

Fixed Relation

Virtual Points: P00, P01, P02
Exterior Orientation

View Scene with Camera

Virtual Points: P10, P11, P12

Rotation Matrix R
Translation Vector t

Pos1 (CAM)
Examples for DEM Generation

Left Camera
Right Camera

Incl. Calibration Images
Disparity Image

Column Disparities
Row Disparities
Resulting DEM

DEM

Ortho Image
Visualization:
Measuring Within DEM
Visualization: VRML2.0
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Last DEM Generation Test

Robot & Mockup

Mounting Cameras & Calibration Targets
Last DEM Generation Test

Result of 10 Overlapping Reconstructions

Detail

Robot & Mockup Simulation
Conclusion

— Low Cost Mission to Mars is Possible
  — (in Case of Success.....)
— Austrian Contribution Beagle2 DEM
  — Modeling the Environment of the Lander by Photogrammetry
  — Support for Vision System on Lander
— Co-operation with British Team Excellent
— Awaiting Boxing Day 2003......
  — + 10d: Waking Up Beagle2