AUTOMATIC POINTING AND IMAGE CAPTURE (APIC): A FIELD STUDY

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The input image is passed to APIC along with a threshold value. APIC outputs pixel coordinates indicating the centroids of discovered regions. These pixel locations are converted into 3D coordinates. PTU angles are calculated.

HRC images are captured.
Why do it?

WAC images provide a low resolution of the target when compared to a HRC image.

Having this level of data richness prior to target selection could influence sampling decisions.

- APIC provides a selection of HRC images to accompany the initial WAC images
- Without APIC someone will have to manually select targets in both left and right images, calculate the location of the rock and the required PTU angles, and then upload this onto the timeline.
- APIC could be initiated during periods of rover inactivity to ensure that the downlink bandwidth is always fully utilised by scientifically valuable data.
Key points of APIC

- APIC uses a single WAC image.
- APIC is able to capture useful HRC images in an unknown environment.
- It is possible to specify a maximum number of HRC images to return.
- APIC can simplify the upload command sequence, as one APIC command could result in the capture of several HRC images.
- If APIC was initiated on the first day the initial panorama could be joined by a selection of HRC images, thus increasing the quality and richness of data available to scientists during their initial assessment.
- APIC could be initiated at intervals during long autonomous traverses, in order to gather HRC images of targets as they are passed, these could be down-linked if sufficient bandwidth is available.
- APIC would increase science data return during the nominal mission as HRC images can be returned along with the initial WAC images. This could in some situations save a sol of operations as once the WAC images are assessed on Earth, HRC images are requested during the next sol. APIC may have already captured those images.
The Platform. Idris

Idris is a 4 wheel drive, 4 wheel steering, electric vehicle, weighing about 350kg. It has a maximum driving at speed of around 10km/h. Its maximum payload is 150kg and it is comparable in size to a small car. It was initially based on a robuCAR TT design but with some notable additions.

Idris is equipped with:

- A 6DOF lightweight arm with a gripper.
- A Panoramic camera mounted on a stabilized 2-axes platform.
- A selection of additional sensors such as a GPS receiver, an inclinometer and a digital compass.
Site 1, Rocky site.
Site 2, Sandy site.
Unstructured Testing: MER Images
Problems encountered during the transition into the field

1. PTU Pointing Accuracy

Old PTU
• Accuracy +/- 2 deg.
• Low stability.
• Limited range of motion (180 deg).

New PTU
• Accuracy +/- 0.1 deg.
• Rigid Aluminum design.
• Full range of motion (360 deg).
2. Pointing Heuristic to improve pointing accuracy.

APIC uses the pixel location of the target to approximate the distance to the target. In some situations it is possible APIC could over-estimate the distance to the target. This is particularly the case with targets that stand well proud of the ground plane.

In order to alleviate this problem a heuristic correction was put in place.

Aiming at the lower quartile of the target alleviates this problem by reducing the estimated distance to the target.

The more the target stands proud of the ground plane the more this correction corrects its distance.
3. Filter Selection.

The images produced by the three broadband filters in the AU filter wheel represent the three primary colour channels (R G B).

The Green filter was selected as it allows the most light through, and generally produces the best images.
4. Suitable User Interface.

Outdoor use required a robust and simple user interface.

It was essential that experiment could be initiated with as little computer interaction as possible.

It was also important that along with the results the software logged all inputs and generated intermediate products, as this information is very valuable for debugging.

ERICA – developed in Python so is platform independent. It also provides easy integration with other AU image processing products.
5. Automatic Parameter Generation.

Region threshold is generated through manipulation of the image’s standard deviation. $Sd \times 2.5$. 

[Diagram showing the process flow with labeled nodes like WAC, HRC, Rock Id, APIC, PTU Controller, PTU Kinematics model, and capture image nodes.]

Original code was developed and tested using the JAVA programming language. As developmental software a limited amount of attention was given to efficiency or suitability to a target platform.

APIC has now been coded in C. Significant effort has been expended to keep this implementation as simple and as efficient as possible.

APIC has been designed to be as deterministic as possible. However, in situations where this is not possible in advance, constraints are in place to limit processing time. APIC’s region growing algorithm uses no floating point variables or operations.
SOME CODE METRICS

Our test machine
• Pentium 1 133MHz processor
• 80 Mb of Ram
• Running openSUSE 10.2

APIC is generally run on a half scaled WAC image. This reduces the processing requirements and also inherently smoothes the image.

Running times | Scale image 512 x 384 pixels | Full size image 1024 x 768 pixels
--- | --- | ---
Region detection | 2.663 s | 13.304 s
3D coordinate calculation | 0.033 s | 0.033 s
Pan Tilt calculations | 0.032 s | 0.032 s
Peak data memory usage (including Input image) | 700 KB | 2.7 MB
SOME MORE STATS

In order to give a better indication of the processing requirements of APIC, a number of normal APIC scenes were processed along with some very difficult scene's. The resulting times can be seen below.

Average times achieved when processing 10 Standard images taken in AU Mars Yard

<table>
<thead>
<tr>
<th>Region detection</th>
<th>Scaled image</th>
<th>Full size image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running times</td>
<td>512 x 384 pixels</td>
<td>1024 x 768 pixels</td>
</tr>
<tr>
<td>Average</td>
<td>2.235 s</td>
<td>14.527 s</td>
</tr>
<tr>
<td>Shortest</td>
<td>2.17 s</td>
<td>11.81 s</td>
</tr>
<tr>
<td>Longest</td>
<td>2.92 s</td>
<td>18.02 s</td>
</tr>
</tbody>
</table>
Next we experimented with the most challenging images we could find. AMASE data. We ran APIC on two example images.

### Region detection

#### Running times

<table>
<thead>
<tr>
<th></th>
<th>Scaled image</th>
<th>Full size image</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image 1</strong></td>
<td>7.32 s</td>
<td>44.64 s</td>
</tr>
<tr>
<td><strong>Image 2</strong></td>
<td>12.42 s</td>
<td>68.64 s</td>
</tr>
</tbody>
</table>

Finally we exercised a constraint placed within APIC to constrain processing time. APIC is currently limited to creating 4095 regions. So inputs were generated using the 2nd AMASE image to artificially hit that target.

### Region detection

#### Running times

<table>
<thead>
<tr>
<th></th>
<th>Scaled image</th>
<th>Full size image</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image 2</strong></td>
<td>25.27 s</td>
<td>168.62 s</td>
</tr>
</tbody>
</table>

If a very complex image such as this one does cause too many regions to be generated, APIC will just ignore the remainder of the image, HRC images are still returned.
Site 1, Rocky site.

Challenging environment containing hundreds of possible targets

HRC images output
From APIC

12 – 14th April 2011
Site 2, Sandy site.

Less Challenging environment containing few possible targets

HRC images output
From APIC

12 – 14th April 2011
Unstructured Testing: MER Images
Future Developments

• APIC be integrated with other none contact instruments, for example CLUPI.
• Use of multi-spectral images. Providing mineralogy indicators.
• Mineral prioritization based upon a predefined criteria.
• Opportunistic survey for a valuable mineral. Only drawing attention to rocks that match certain spectral signatures. (e.g. carbon)
KSTIS Integration

Quality → External Input e.g. Micro Spectrometer

Image Captured → Image Processed For Target Regions

Target Region Fuzzy Input Parameter Assessment → Fuzzy Structure Rule Base → Fuzzy Texture Rule Base → Fuzzy Composition Rule Base

+ × × → Bias

Output Science Value
Any Questions?

EADS Astrium’s Bridget rover on AU Field trials in Clarach Bay near Aberystwyth.