A planetary landing device inspired by gliding cockroaches

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Demands for autonomous planetary landing

Figure: Visualisation of ESA's ExoMars rover. (Launch: 2013)

Unmanned exploratory missions to e.g. Mars involve a landing phase, where the spacecraft descends vertically to the planetary surface.
In order to minimize the impact during landing a breaking system of parachutes and airbags is employed. This system is uncontrolled and hence not able to adapt to unforeseeable situations. Indeed, landing spacecraft may easily hit a stone, slide down crater rims or be dragged along by strong winds on the planetary surface. In all these events, the costly mission is highly endangered as failures in landing systems in the near past have proven. Due to the communication round-trip delay time between the spacecraft and ground control, external supervision of the descent is impossible.

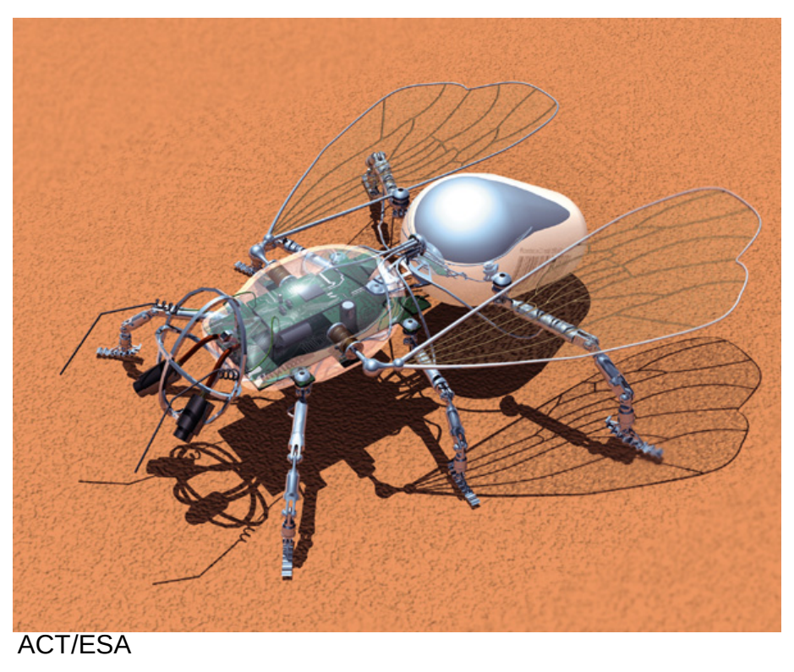

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Figure: Artistic visualisation of a bio-inspired exploratory rover.

A landing device is desired that can autonomously stabilize the descent and visually guide the spacecraft to a safe landing place.
Auto-piloting systems as known from modern aircrafts are capable of landing safely. However, such systems cannot be employed for planetary landing for several obvious reasons such as the lack of predefined and properly equipped runways. Besides, a system with rigid wings and complex control architecture would require a too large fraction of the highly restricted and costly payload during launch.
As a consequence ESA's Advanced Concepts Team ventures into biology and explores the potential of natures landing concepts.

Targeting the landing site

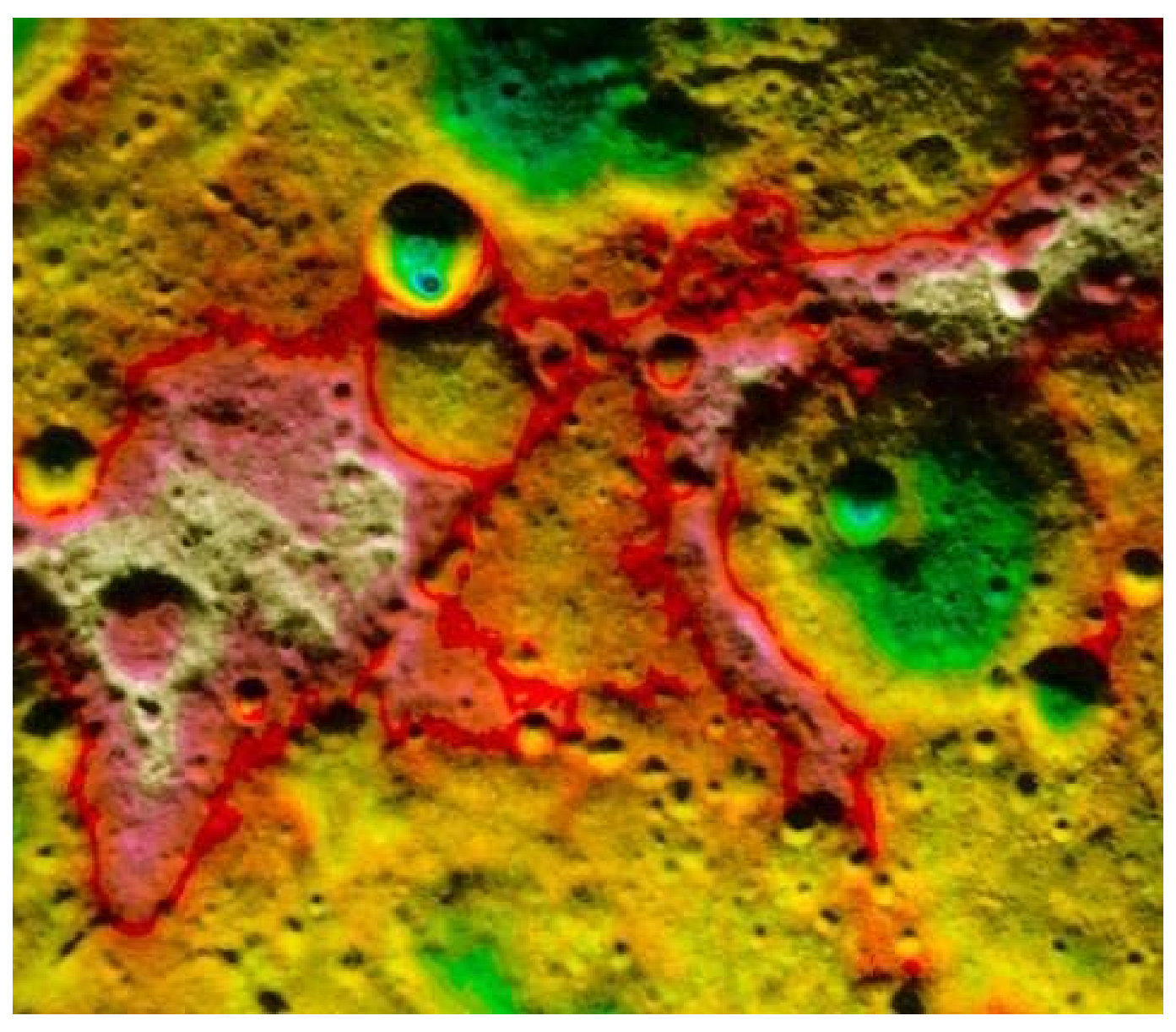
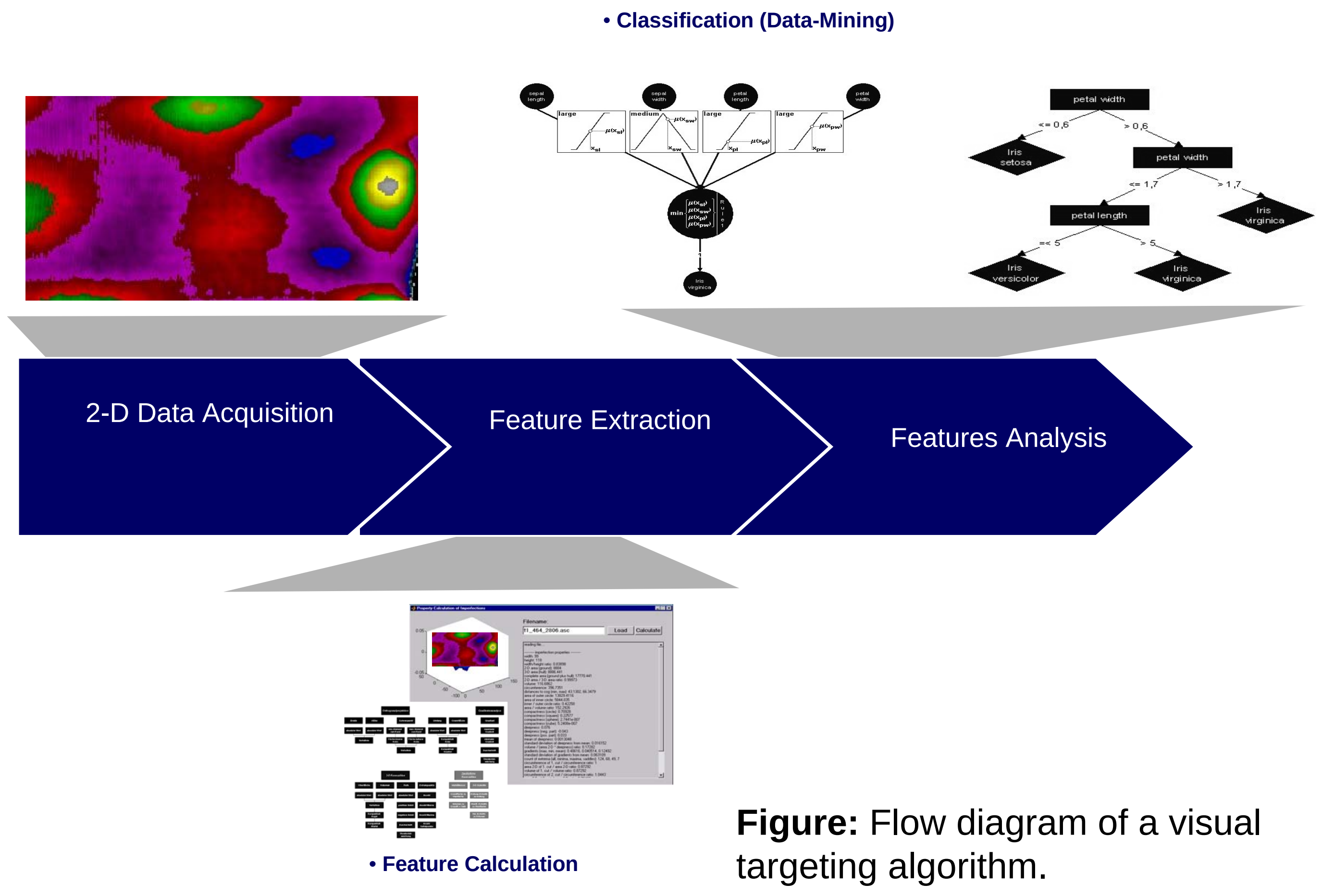


Figure: Picture of a typical Martian surface. Height information is colour coded.



- Classification (Data-Mining)

2-D Data Acquisition

Feature Extraction

Features Analysis

- Feature Calculation

Figure: Flow diagram of a visual targeting algorithm.

Task: Autonomous approach to an unknown planetary surface and choosing a landing site that is both safe and scientifically interesting.

Extraction of features from the image of the potential landing site acquired by a low resolution onboard camera. these features are fed to a machine learning algorithm (pre-trained) that is able to classify the nature of the landing site. This information is used as input of the GNC system.

Guidance algorithms and Hazard Avoidance techniques can be tested at ESA's Precision Landing Test Facility on their ability to precision landing and pinpointing capabilities. (Guizzo et al. (2007). Testing GNC technologies for planetary landing on Mars and Moon analogues. *2° International Workshop on Exploring Mars and its Earth Analogues*.)

Gliding cockroaches

ESA Design Workshop 2006 for an Unmanned Aerial Vehicle proposed a conventional propeller driven aeroplane: 65 kg (incl. 4-12 kg payload).

The layer of the Martian atmosphere is 3 km thick and resembles that of the Earth in 30 km height. Gliding flight proves to be extremely difficult, even with motor power. Gravity on Mars is 1/3 of that on Earth.

Active flapping flight would be a desirable means of locomotion for a Martian explorer but also faces great energetic demands.

In some cockroach species (e.g. *Balatta orientalis*, right) only the male have very rudimentary flying abilities. If such a male cockroach falls off from an elevated point, it can be watched using its rigid and small wings to obtain control over their descent and hence minimize the impact on the ground [personal observations].

Autonomous and robust control

Sensors for detecting optic flow, position of the horizon and polarization compass derived from various insects are biologically well examined and subject of studies on Martian landers (JPL/NASA).

The recent progresses in both analyzing biological piloting strategies and transferring them to technical design has opened new perspectives for mission design.

Conclusions and outlook

Targeting Current state of the art CNG technologies may be sufficient for choosing an appropriate landing site in our concept.

Navigation Bio-inspired visual auto-piloting systems have reached a high level of sophistication and are under close examination. Latest findings in the field need to be assessed and incorporated.

Gliding The escape behaviour of non-flying cockroaches is poorly examined. However, the principle wing design and the observed behaviour seem promising for our demands.

How we work

ESA's Advanced Concepts Team (ACT) is a think-tank located within the European Space Agency (ESA). We identify research areas that appear to be promising for application in future space missions and develop projects on conceptual research.

These projects are made public in calls promoted on our website and in the Ariadna Newsletters. Research groups from universities of all ESA member states are invited to tender by submitting research proposals.

Proposals are then evaluated by the team and usually one proposal will be chosen for a study lasting two to six months.

Studies are conducted jointly by the university research team and the responsible ACT-member. Each study is financially supported by the Ariadna scheme with a lump sum.

This scheme is especially attractive for research groups to perform a pilot study venturing in new fields and also to establish new contacts.

The ACT explicitly encourages non-space-related research groups to participate!

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