Charles University in Prague

Faculty of Mathematics and Physics

MASTER THESIS

Martin Pecka

Detection of 2D features in MARSIS ionogram pictures

Department of Software Engineering

Supervisor of the master thesis:	RNDr. Jana Štanclová, Ph.D.
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Dedication.

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Název práce: Hledání 2D jevů v ionografických snímcích přístroje MARSIS

Autor: Bc. Martin Pecka

Katedra: Katedra softwarového inženýrství

Vedoucí diplomové práce: RNDr. Jana Štanclová, Ph.D., Katedra softwarového inženýrství

Abstrakt: Práce se zabývá technikami hledání význačných prvků v ionogramech zachycených přístrojem MARSIS umístěným na kosmické sondě Mars Express. Ionogramy jsou reprezentovány jako dvourozměrné obrázky s hodnotou kódovanou pomocí barvy. Vyvíjené techniky se snaží detekovat v takových snímcích různé zajímavé křivky (definované sadou parametrů), případně měřit další parametry nalezených objektů (perioda opakování přímek).

Klíčová slova: rozpoznávání vzorů, detekce, parametrické křivky, Mars Express, vektorizace

Title: Detection of 2D features in MARSIS ionogram pictures

Author: Bc. Martin Pecka

Department: Department of Software Engineering

Supervisor: RNDr. Jana Štanclová, Ph.D., Department of Software Engineering

Abstract: The work focuses on techniques for finding significant features in ionograms captured by the MARSIS instrument onboard the Mars Express spacecraft. Ionograms are 2D images with values represented in color. The developed techniques try to detect interesting curves (parametrically defined) in such images and measure some more parameters of the found objects (like the repetition period of lines).

Keywords: pattern recognition, detection, parametric curves, Mars Express, vectorization

Contents

Introduction

1. Mars Express, MARSIS and ionograms

1.1 Mars Express

First of all, let us briefly introduce the spacecraft carrying all the equipment needed to acquire ionograms. Its name is *Mars Express* (MEX) and it was launched by the *European Space Agency* (ESA) on 2 June 2003.

MEX arrived to Mars at its orbit with periapsis 250 km and apoapsis over 11000 km on 25 December 2003 [19] with seven onboard scientific instruments and a landing module called Beagle 2. We're going to take a look at all of them in the following subsections; just Beagle 2 description is going to be rather short, because the landing sequence failed (for an unknown reason) and the lander didn't establish connection after it landed (if it landed at all)[19, p. 4].

The mission of MEX has several goals like "global studies of the surface, subsurface and atmosphere at unprecedented spatial and spectral resolutions" [19, p. viii]. One of the goals, however, stands out among all the others. It is the search for water (or its traces) on Mars' surface or subsurface.

Why water? There is lots of geological evidence of former water occurrence. But before the MEX mission nobody had proved or refuted presence of water on Mars in the present. Knowing more about water on Mars and its history, the scientists could postulate better hypotheses about the possibility of (former) life on the planet [19, p. ix].

The original mission lifetime of MEX was projected up to the end of 2005 (which would be 1 Martian year = 687 Earth days) [5]. However, overcoming some small problems (as the Solid State Mass Memory anomalies described in [9] or the MARSIS antennas deployment problems in 2004 [6, 7]), MEX has worked on its science goals up to this day and its science mission was extended until 2014 [11] (after 3 preceding similar extensions). Fred Jansen, MEX mission manager, said MEX had enough fuel for another 14 years of operation (at the beginning of 2012) [3]. So there is a hopeful prospect of further and even deeper Mars exploration (eg. [12] discovered an unexpected way of using the MARSIS instrument so that they "added magnetometer functionality" to MARSIS).

In the next subsections you can find out more about particular MEX instruments. The descriptions are based on [19] which you can see for more detailed information.

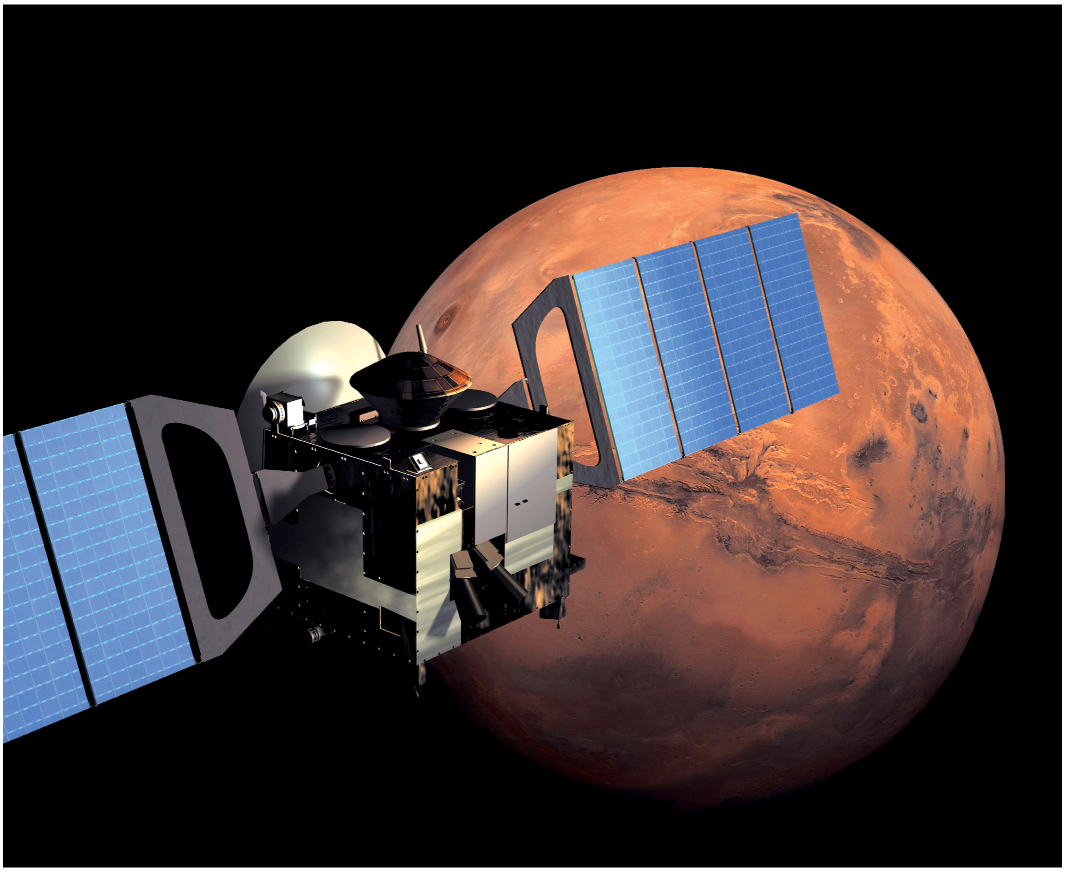

Figure 1.1: Mars Express spacecraft. Credit: ESA [8]

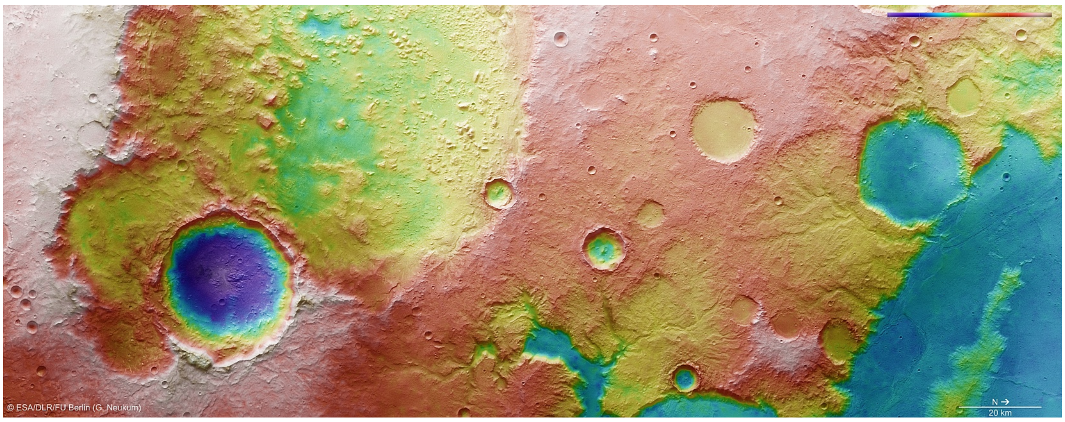

Figure 1.2: Example image taken by HRSC. Credit: ESA/DLR/FU Berlin (G. Neukum) [18]

1.1.1 HRSC (*High–Resolution Stereo Camera*)

HRSC is a high–resolution pushbroom[1] camera for surface imaging. Its goals are to characterize surface structure and morphology at resolution 10 m px^{-1} (regions of interest at 2 m px^{-1}), surface topology at high vertical resolution, atmospheric phenomena, physical properties of the surface and to classify terrain and to refine the martian cartographic base. It is also intended to observe Mars' moons Phobos and Deimos during their approaches.

HRSC is able to capture the surface at resolution up to 10 m px^{-1} with field of view 11.9°, covering a 52.2 km wide strip of surface at height 250 km (which is the periapsis of MEX). The camera consists of 9 CCD sensors allowing it to acquire triple stereo images in 4 colors and 5 phase angles. What is a very useful property of these images, is that they are taken nearly simultaneously and thus having the same illumination and other observational conditions (which further helps in photogrammetric processing of the images).

HRSC also contains a super–high–resolution camera called SRC (*Super–Resolution Channel*) aimed at targeted observations of particular surface details. With image resolution 2.3 m px^{-1} and field of view 0.54° it provides a detailed view of a 2.3x2.35 km large surface. Its main purpose is to take details of places of interest, eg. future landing sites for other landing modules.

Up to November 2011 HRSC had covered about 88% of the martian surface [10, pp. 72–73] and still continues to gather new data. The scientific results of HRSC are for example better exploration of fluviatile valleys [15], dicovery of numerous glacial landforms, investigating lava flows, dicovery of "dust devils" (fast moving dust storms) or providing data to derive a detailed topographic model of more than 20% of Phobos [13, pp. 945–949].

1.1.2 OMEGA (*Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité*)

OMEGA is a medium– and high–resolution spectrometer operating in visible and near–IR spectra (0.38–5.1 μm wavelength). Its medium–resolution operating mode (from heights of 1500 to 4000 km) can measure with the resolution 2–5 km targeting at global surface coverage, while the high–resolution mode (from the close vicinity of periapsis) brings resolution 350 m or better, but will cover only a small fraction of the surface.

As stated in [19, pp. 38–39], the main goals are to study the evolution of Mars, to detect minerals hidden to lower resolutions, to map mineralogical boundaries between geological units, to reveal gradients in hydration minerals related to fossil

[1] A camera that scans the image by rows perpendicular to the flight direction. See `http://earthobservatory.nasa.gov/Features/EO1/eo1_2.php` for more details.

water flows and to monitor features associated with wind transportation. In particular, it is intended to find carbonates (not found on martian surface until the launch of MEX) and water ice. It is also able to measure atmospheric pressure, CO and H_2O column densities and surface temperature.

Recent contributions of the OMEGA payload are e.g. confirmation of liquid water on the surface when the planet was young [14], discovery of infrared and ultraviolet glows in the atmosphere [1], proving that Mars had a hot and wet period [2], analyzing the south polar cap and finding out it is formed mainly of water ice [4], observation of CO_2 ice clouds [17] or finding ferric oxides near the equator [16].

1.1.3 MARSIS (*Mars Advanced Radar for Subsurface and Ionosphere Sounding*)

1.1.4 PFS (*Planetary Fourier Spectrometer*)

1.1.5 SPICAM (*SPectroscopy for the Investigation of the Characteristics of the Atmosphere of Mars*)

1.1.6 ASPERA (*Analyser of Space Plasmas and EneRgetic Atoms*)

1.1.7 MaRS (*Mars Express Orbiter Radio Science*)

1.1.8 Beagle 2

2. Title of the second chapter

2.1 Title of the first subchapter of the second chapter

2.2 Title of the second subchapter of the second chapter

Conclusion

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