MEASURING ENVIRONMENTAL PHYSICS AND CHEMISTRY BY EDUCATIONAL HUNVEYOR AND HUSAR SPACE PROBE MODELS

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ABSTRACT

During the last decade various physical and chemical experiments were built on the Hunveyor lander and Husar rover educational space probe models. We report about several environmental monitoring experiments.

INTRODUCTION

The Hunveyor lander and Husar rover models were introduced to the education of technology- and environment-related courses since the 1997-1998 academic year. In the next years the program have been opened gradually and extended to several universities, colleges and high schools in Hungary. Two main blocks of principles governed the program. One was the scientific achievements in planetary geology [1] [2] [3] [4]. The other was a summary of planetary probe construction and operation [5], and also a summary of measurements and results of The Surveyor Investigator Teams. On the basis of the real operation of the Surveyor, and later the Mars Pathfinder Teams we extracted an educational program by constructing and operating the space probe models from the point of view of measurements carried out on various planetary surfaces and later in the analog terrestrial environment field works.

EDUCATIONAL PURPOSES OF SPACE PROBE CONSTRUCTION

The concept of **Hunveyor** is based on the space probe Surveyor of NASA. The Hunveyor name comes from the **H**ungarian **Un**iversity Sur**veyor**.

The main focus of teaching by construction is a relationship between the technological aspects of modern electronic and information technology machines connected with application in the science field of planetary geology. This focus means not only learning the associated principles (measurements, technologies, instrument systems and computer technology) but the testing of robots under real geographical conditions. In this educational process the student's knowledge gradually increases on physical, chemical, geological characteristics of the surroundings. By placing the space probe models in the terrains another objective rises: application triggers the need in students to develop measuring methods for environmental surface processes. In this educational process measuring technologies reveal interconnections between (interwoven) processes used both in measuring and in nature itself, so students get acquainted with the complexity of the environment. Simultaneously, they learn the benefits of using the complexity of a data processing system (Fig.1.). Working with the experimental space probe is always an interesting challenge because of its complexity.

MEASURING THE PLANETARY SURFACE AND PLANETARY ANALOG TERRESTRIAL ENVIRONMENTS

Stratigraphic works on lunar geology selected and emphasized those principles of terrestrial geology, which can be extended to the Solar System [3][4]. Characteristics of surface rocks were first investigated by their optical properties and morphologies, but later, the lander space probes showed details of the surface. Characteristics of a surface can be determined by mechanical (Fig.2.), optical, thermal, simple chemical property measurements of:

- mechanical properties: strength, rigidity, porosity, depth of regolith, depth of surface powder, roughness of the soil and the largest blocks scattered on the surface, [6] [7] [8] [9];
- optical properties to be studied by a television camera are: relative albedo, roughness, crater density, smoothness, height of the highest elevation in the vicinity of the lander, average inclination of the landscape [10] [11];
- thermal properties are: surface rock temperatures, thermal conductivity [12] [13].

Over these examples we intended to develop simple measuring instruments for soil properties. The planning of measurements on a specific soil property needs detailed understanding of the physics and chemistry behind these characteristics of the soil, and that is one crucial aspect of the space probe experiments as educational tools [14] [15] [16] [17].

Fig.1. The overview of the Hunveyor-4 system [15]

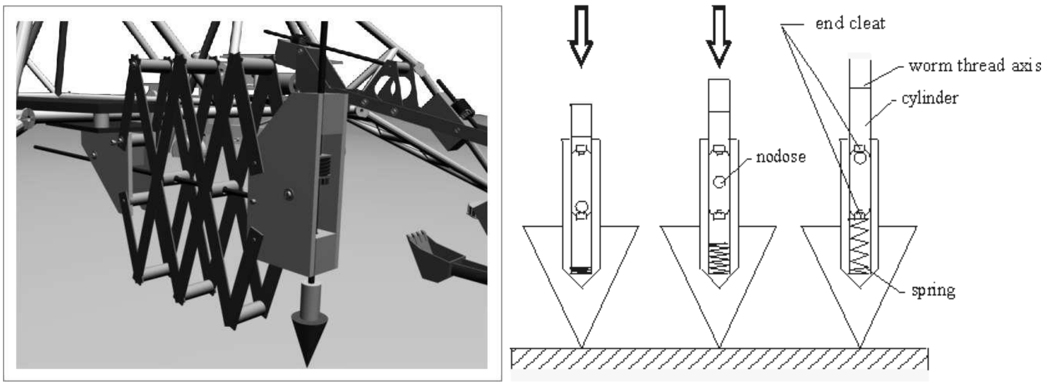

Fig.2. Soil hardness measuring effector on the end of the Hunveyor-2 arm [16] [17]

OUR HUSAR ROVER EXPERIMENTS

The basis for the extended works with Husar rover (**H**ungarian **U**niversity **S**urface **A**nalyser **R**over) is a car model based on the Sojourner of Pathfinder.

Experiment for pH measurements for the chemistry of the soil

First step in measuring the chemistry of the surface materials on a planetary soil is the pH. This measurement was constructed by using two arms and a pump on the rover (both from LEGO elements). On the first arm we placed a wireless camera, (being able to rotate around 360°-and could also bend down). The role of the second arm was to place the indicator ribbon to the surface, move it along a distance for contact with the wet soil. The role of the pump was to pour water on the soil surface. The basic technology was the following: (1) Husar-5 pours out water on the soil, (2) water dissolves important chemical components from the soil, (3) the indicator ribbon touches the soil surface and reports the main chemical characteristics of this chemistry by its color changes (Fig.3.) [18].

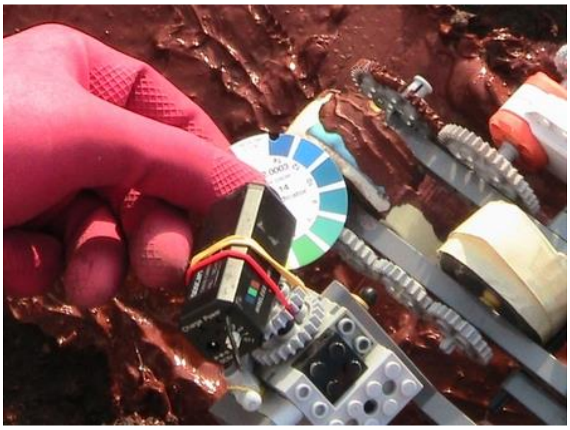

Fig.3. On the front of the rover there is an ultrasonic sensor of the obstacles before the rover. (Upper arm). There is also the camera (right up) and there is the arm moving the indicator ribbon. The ribbon is rolled from one wheel to the other wheel while the arm is contacting the surface and soil. The camera observes the changes on the indicator ribbon colour [18]

Measurement of the gas emission liberated by optical heating

The rover uses an optical lens as a classical heating experiment and uses several gas-sensors for measuring the chemical components liberated by the heating. This experiment demonstrates a classical-style heating combined with a gas sensor application. This way it measures the characteristics of the soil on the surface of a planet [19].

The steps of the measuring process: **Focusing**

1. Basic position: The lens is in resting position exactly a focus distance above the soil. The holding arm is horizontal, the plane of the lens is also horizontal, parallel with the soil.

2. The light sensor measures the intensity of the light and the program decides whether it is enough to begin the measurements.

3. As we shall see, we consider the soil surface as horizontal. The measuring place can be selected by the "terrestrial control". They observe the environment through the camera on the top of the tower on the Husar-5. (We also plan an instrument for making the soil flat and smooth in front of the rover. The ultrasonic sensor considers the larger humps as obstacles and turns back the rover.)

4. After selecting the location of the measurement, the computer program first moves the lens and finds the position (with the help of the light sensor) where the intensity of the light is the highest. This is an angle β with the horizontal plane.

5. The other motor moves the arm up and down and sets the position of the lens plane perpendicular to the solar light. The program takes the measured α angles into the memory.

6. Lifting up the arm is the next step. The height H where the lens collects the sunlight exactly at the focus of the lens reaching the soil surface: $H = h \cos\beta$, where $h = f \cos\alpha$ (see Fig.4. and Fig.5.). From the initial position the lifting motor sets the arm to the necessary position. After lifting the centre of the lens to the height of $y = f + k \sin\alpha$, the arm should be moved through a distance $y – h$. (Using the speed of the movement the program calculates the time of the motion.) This way the focusing was done. By the effect of the solar rays gases are liberated from the soil.

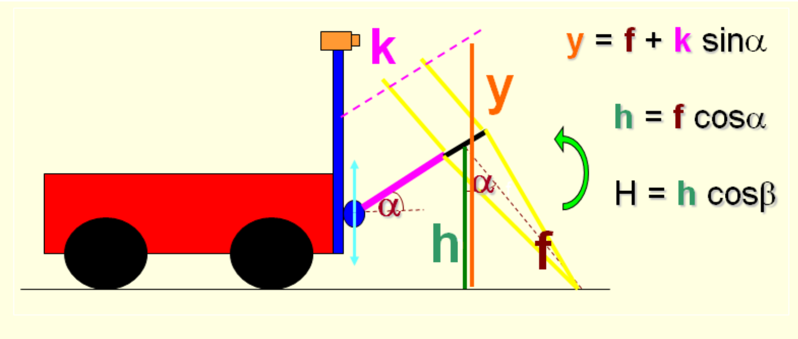

Fig.4. The lens at resting position on the front arm of the Husar-5 rover (right) and the steps in positioning the lens [19]. The height "H" and the angle "β" is not visible in this picture, because they are outside, in the perpendicular plane.

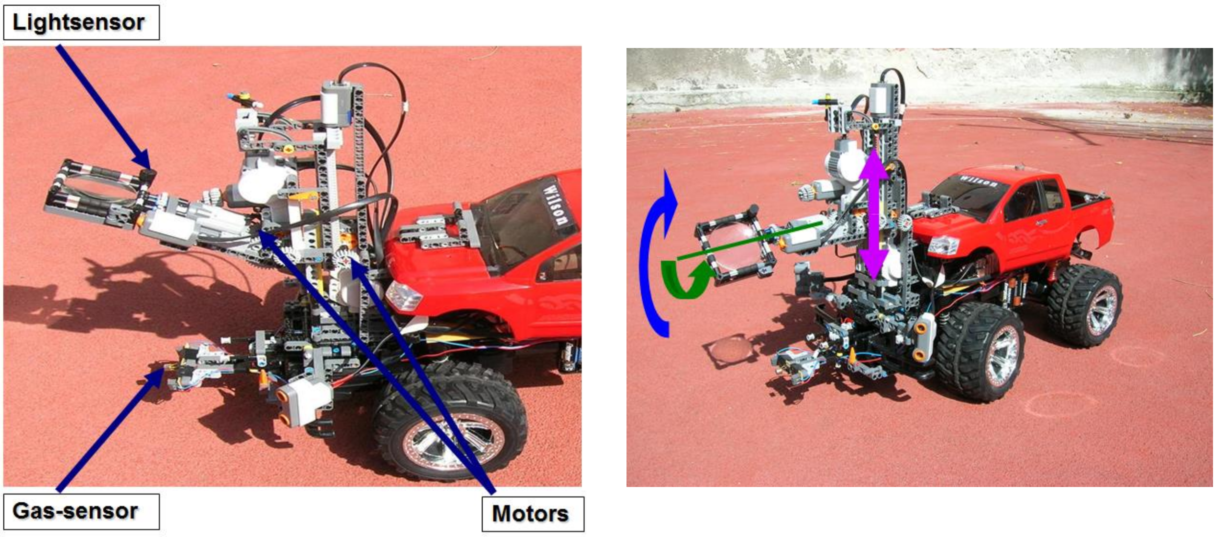

Fig.5. Movement possibilities: One motor makes the arm move up and down along an arc from the horizontal plane to about 40-45°. The lens can be rotated around its axis of symmetry. If that is the basic position shown on the figure (0°-angle), then the computer program moves it from -90° to +90° position. The whole system - consisting of two motors and the lens - can be moved together in a perpendicular direction, too. (This is called lifting.)

Identification of a carbonate rock specimen of a planetary surface

It is known that dropping acids produces rather quick reactions with carbonate rocks. This is the first robotic work to be realized by electronics. The CO_2 gas produced will be observed by gas sensors. This is the second act to be robotized. Of the carbonates some are paramagnetic, especially siderite (iron-carbonate). This results in a third step: magnetic contact and attraction of siderite by the magnet. So the main steps to get a robotic realization for finding carbonate specimens among the rocks on the field are the following: (1) identification of a carbonate by acid test, (2) measuring the gases liberated by acid, and (3) the magnetic test identifies the existence of an iron component (Fig.6.) [20].

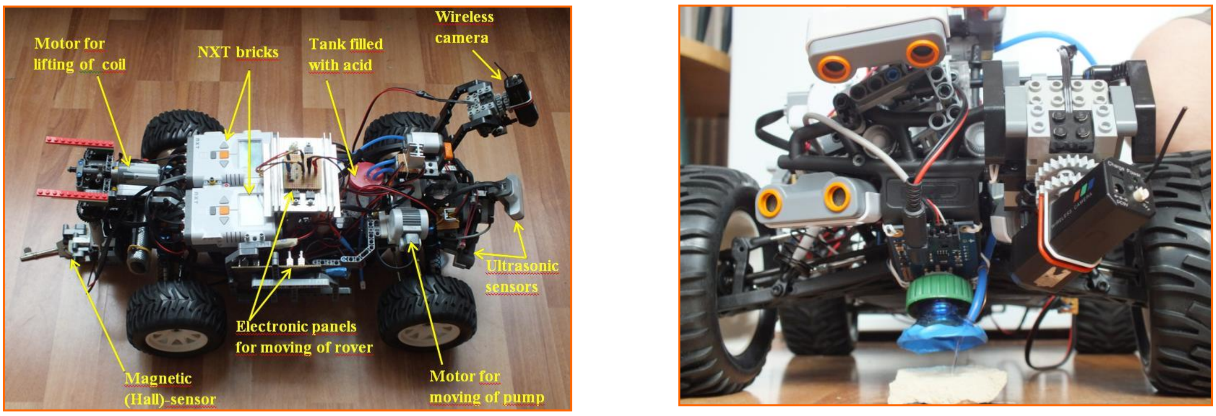

Fig.6. The Husar-5 rover with the Carbonate experiment instruments [20]

Magnetic soil dispersing experiment onto an invisible magnetic patterned carpet

We imagined a Martian environment where the wind transports dust particles and the magnetic ones are trapped by small magnetic discs which were sewed into the carpet. In this experiment the adhesion of magnetic dust particles made the magnetic disc pattern fixed inside the carpet visible [21].

In preparing the experiment various composition of the sand + iron grains were mixed previously. Such dust mixtures were poured onto the unrolled magnetic carpet placed on Hunveyor. The magnetic discs between the two sheets caused magnetic adhesion of the magnetic component of the dust. Adhered grains made the pattern visible by coloring the surface of the sheet above the magnetic discs (Fig.7.). Similar experiment was carried out on Mars Pathfinder [22, 23].

Changing parameters in the dispersing experiment

There were two changing parameters in the previous stage of the experiment planning: the mixing ratio between iron and sand, and the slope of the carpet. In the experiments we used 4 sand+iron grain mixtures and 3 different positions of the carpet depending on the conditions how it is rolled out and sloped out from the Hunveyor frame: 1) on smooth flat carpet, 2) a small-angle (gentle) aslope carpet, 3) a high-angle aslope carpet (Fig.7.).

Fig.7. Experiment arrangement with various slope declinations of the magnetic carpet (a white sheet with invisible patterned magnet squares fixed inside). Left: the carpet is at a small angle, almost horizontal slope. Middle: dispersion and adhesion when the carpet is in position of a more elevated gentle slope position. Right: dispersion and adhesion onto a high-angle slope carpet [21]

Students enjoyed the experiment and gradually recognized the role of the two parameters in determining the real mixing ratio of a real distant dust. In carrying out experiments with an unknown (Martian) mixture, the mixing ratio was determined by interpolating the produced pattern between the previous experimental cases.

The students proposed the following questions:

– Almost perpendicular slope cannot show the magnetic content, only in the case of very strong magnetic particle content. Therefore somehow we must stabilize the rolling down in a gentle slope position.

– Magnetic particles adhere and form small clusters before they fall down from winds.

SUMMARY

Such robotic realization of basic experiments triggers enthusiasm in students for measurements both in physics and chemistry, and also helps physics and chemistry education to make learning the basic concepts and laws of these disciplines enjoyable.

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