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HUMAN-ROBOTIC PARTNERSHIPS AND PERFORMANCE: LESSONS LEARNED FROM ILEWG EUROMOONMARS CAMPAIGNS 2012.

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ABSTRACT

The activities carried out during the EuroMoonMars campaigns include the usage of a Rover (from NASA Ames) and an Unmanned Aerial Vehicle (UAV) for reconnaissance purposes and investigations into system requirements; operator interaction; combined Rover/UAV excursions; human-robotic partnership as EVA assistance/replacement; extension of the RF robotic remote control network as well as the human factors and the living conditions. This paper describes the specific results from two six-members crews taking part in two-week rotations in 2012, with a focus on the experiments and research performed related to the analysis of human robotic partnership, such as: Remote-controlled Rover and/or UAV: their partnerships and efficiency for reconnaissance and EVA support; Efficiency analyses between human-to-human interaction protocols during Rover and/or EVA partnerships as well as during crew rotation; Knowledge transfer towards crew and between crews using tutorials, audio recordings, and motion picture. Acknowledgment: http://sci.esa.int/ilewg - http://mdrs.marssociety.org

Keywords: MDRS, Rover, knowledge transfer, UAV, reconnaissance

1. INTRODUCTION

The International Lunar ExplorationWorking Group (ILEWG) uses the annual and ongoing EuroMoonMars /DOMEX campaigns to investigate the feasibility, limitations, and optimization of human and robotic planetary exploration. Field tests are carried out at the Mars Desert Research Station (MDRS), a space analog environment in Utah. Future locations such as La Reunion are under negotiation. The research performed during the 2012 and 2011 campaigns included tele-presence to assist EVA and joint human/robotic activities. In two-week rotations, crews of six members went to the station to perform new missions and established the knowledge, conditions, systems, and equipment necessary to perform successful and optimized planetary exploration activities.

The MDRS environment forced the crew to work and live together in a closed extreme environment designed on the basis of an early Moon or Mars outpost. This simulation offers a reality where space activities can be experienced first-hand and is therefore essential to increase understanding for human robotic partnership during exploration either on the Moon, on Mars, the

Asteroids or other destinations. The environment allowed additional research to be performed in parallel to Extra-Vehicular Activities (EVA) communication efficiency stress factors and the Moon Mars Habitability Project (environmental aspects of habitat, human factors, food, and sleep study).

During last season, a two crews mission allowed to experiment how to transfer operative knowledge from a crew to the next one. Moreover, a small UAV was available for the second crew which succeeded to perform some terrain reconnaissance to spot some hazardous areas for the use of the rover around the Hab. These two experiments are discussed further.

2. HOW TO LEARN BEST OPERATIVE KNOWLEDGE

2.1 Introduction

Human Extra Vehicular Activities (EVA) are energy expensive, time consuming and risky. Consequently, they should be as limited as possible despite the fact that they are essential for the well being of the crewmembers (to deal with the confinement perception). That is why the presence of rover(s) will be of prime importance (Drake, 1998). They allow to explore wide areas without putting human life at unnecessary risks and can save time optimizing exploration tasks.

The human presence on the surface of Mars will allow *in live* control which is not possible from Earth due to delay in signals transmission. For the remote driver performance, he (or she) must be aware of the rover situation: environment information must be provided to the operator, such as position, autonomy, achievable distance, etc.

In the future, human to Mars crews will follow each other to explore this planet. The scenario in which a departed crew must leave instructions to the next one has been studied during two rotations at MDRS. During the first crew, a tutorial, audio recording and motion picture documents have been edited teaching to the next crew how to drive a rover. With the limited resources, the experiment consisted in highlighting which media is best for transmitting information.

2.2 Situation

The will to transmit a piece of knowledge, particularly regarding how to drive a rover may seems inappropriate since the Earth training should be sufficient for this basic purpose. But, during the six months Earth to Mars transit, the crew can easily lose a part of abilities, including the rover handling, if they cannot keep training themselves. Moreover, the rovers used by the previous crew could be repaired or damaged leading to specific instructions. The software could have been updated and the terrain different from which they have been trained for. There is quite often a latency during which the arriving crew is reaching the same level of situation awareness of the departed one (Sarter & Woods, 1991).

Anyway, there will be a probability that operative instructions (Pierre Falzon 1991) must be passed from a crew to another. Even if these instructions may not as basic as how to drive the rover, this exercise is appropriate for this simulation when crewmembers had no idea how to drive it. With care taken the results can be extrapolated to other situations more relevant to a manned mission to Mars.

Three medias have been edited to perform the transmission of instructions:

- The textual tutorial contains what the first operator learn from the rover. It contains a set of instructions that should help the arriving operator to handle the rover. The text takes a small amount of data and increased the possibility of mentalization. In the other hand, there is a lack of visualization of the task to be performed.
- The audio recording transcribed the same thing as the text, only the media has changed. The advantage is the possibility that the operator have to see the subject of what he is listening.
- Finally the motion picture shot at the first person allows the watcher to immerged himself into the situation. The advantages seems to be the cognitive relief and the mimesis possibility, but the counter part is a higher amount of data and the lack of detachment regarding the situation.

1.1. Hardware

The rover *Senseta* from NASA (Fig. 1) in carbon fiber is controlled by Wi-Fi. It can reach the speed of 18 km/h and it is equipped two stereo cameras which can be oriented in different directions (left/right and up/down).

Fig. 1: Rover Senseta with dimension (cm) 46 x 38 x 42.

A D-link Ethernet router powered by a Hawkey technology Wi-Fi antenna make a dual channel connection between the rover and the computer. The computer is a laptop with the software MaxConnect Groundstation and a Logitech joystick (Fig. 2). The view from onboard cameras are displayed on the screen for steering the rover.

Fig. 2: Laptop and joystick for controlling the rover.

2.3 Protocol and results

A test lap has been settled (by the operator named as *Builder*) around the MDRS (see Fig. 3) with three phases: general handling, dexterity and emergency return to base.

During the exercise, the operator stays inside the habitat (Hab), since in real condition, the rover replace a human EVA. The operator have the image from the rover, the GPS signal, and can also see through the windows of the Hab.

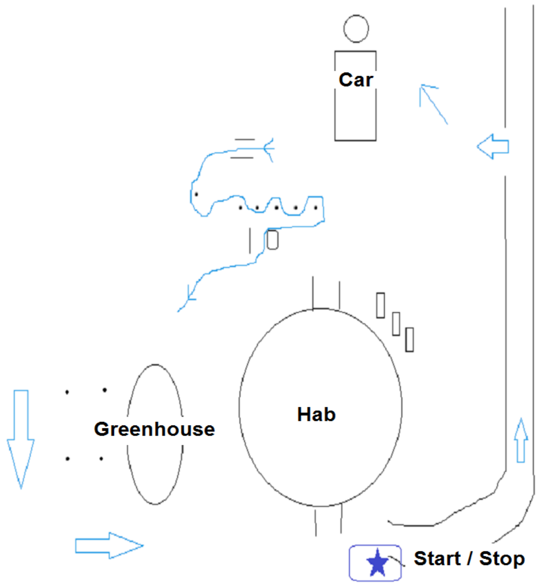

Fig. 3: Lap around the Hab.

Each operator performed the first try with only the description of the lap. For the next lap performed the operators had learnt thanks their respective tutorials. Only the neutral operator performed its laps with only the lap description shown in Fig. 3. Their time laps are recorded and shown in Fig. 4.

The neutral operator drove the rover during the first rotation. At that time, the rover had a steering problem (it went to the right while the joystick is at its neutral position) which forced the operator to strongly compensate, affecting his performance. During the second crew rotation, the rover specialist succeeded to repair this failure, which occurred again during the test #5 affecting the performance of all operators.

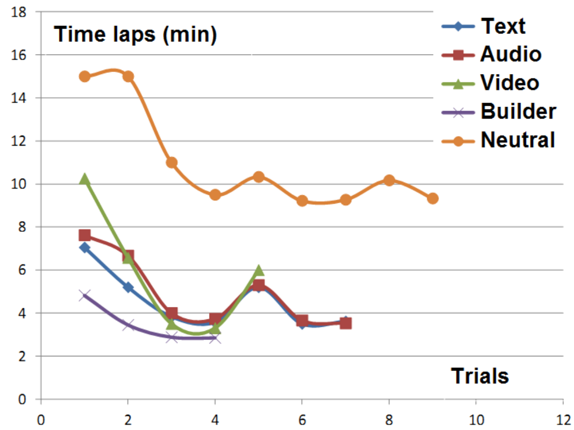

Fig. 4 : Raw results from the experiment.

Finally, the learning rate is computed in each case (see Tab. 1). It shows that learning with the video is the better way to improve performance. Comparing text and audio recording, the same improvement rate is found. And without any help, the rate is the lowest.

Media	Learning rate (min/trial)	Data amount
Video	-3.38	304 MB
Audio	-1.81	1.19 MB
Text	-1.61	17.7 kB
Nothing	-0.68	0

Tab. 1: Learning rate computed from lap time recording.

Since the audio and text enable roughly the same learning rate, but with an audio recording 100 times larger than the text, the audio recording is not the media that should be considered. In order to select, video or text, a compromise must be found between learning rate and data storage free space available.

3. AERIAL RECONNAISSANCE MISSION

3.1 Introduction

Due to the characteristics of a rover, it cannot go in every type of terrain. The rover used at MDRS was a 5 cm in diameter wheels and therefore enable to overcome every obstacles like big rocks or climb every slopes. In a real mission to Mars, rovers will have more dexterity, but this kind of event would also occur at a different scale.

To avoid putting the rover in such situation, aerial terrain reconnaissance could help. Indeed, it is nowadays currently use on Earth for different types of mission. At MDRS, an Unmanned Aerial Vehicle (UAV) has been used to spot obstacles around the Hab that the rover Senseta could not overcome.

3.2 Hardware

The drone Parrot (see Fig. 5) is a four rotors helicopter with two onboard cameras (one front, one ventral). Thanks to a Wi-Fi network it is controlled by an Android smartphone. Moreover, its two gyroscopes and one accelerometer it can sustain a stationary flight.

It can flight during 15 minutes and goes up to 50 meters (depending of the environment) from the operator.

Fig. 5: UAV Parrot used during MDRS experiment to spot hazardous areas for the Senseta rover.

On the smartphone side, the view of the cameras are presented in four modes: only front view, mainly front view (ventral view is reduced in a corner), mainly ventral view, only ventral view. Moreover, the smartphone software allows to record every picture or video that is required.

3.3 Protocol

A first operator pilot the UAV around the Hab performing four paths. During these flights, the operator records video and picture mainly regardless of any pertinent obstacles for the rover. It is not the work of the pilot to decide whether or not if an obstacle is pertinent. But, at his discretion, he can decide to document further any site he spot which he judge necessary for the tasks of the intelligent cell.

The intelligent cell have the task to analyze the pictures and videos taken during the reconnaissance mission. These analyses determine the potential risk of obstacles for the rover and their locations. This task has not been easy since there is not any size reference in the terrain to be compared with in order to evaluate the size of an obstacle. And it was not easy either to establish the location of the obstacles spotted.

Then the intelligent cell brief the rover specialist about the obstacles found between the Hab and the rover target. During this briefing they agreed on the best route to drive on and the operator watch the pictures and motion pictures related to the route that will be taken. This part of the work increase the situation awareness of the operator, which ease a quick decision in case of trouble and minimize its consequences.

1.2. Results

The UAV have been used on four paths around the Hab as it is show on Fig. 6.a. Thanks to the documents brought by the flights campaign, the intelligent cell have succeeded to report hazardous areas for the rover, in red on the Fig. 6.b.

Sadly, the rover had a major failure (the rear shock absorber broke during the first experiment about tutorial on how to drive the rover) before conducting the last part of the experiment.

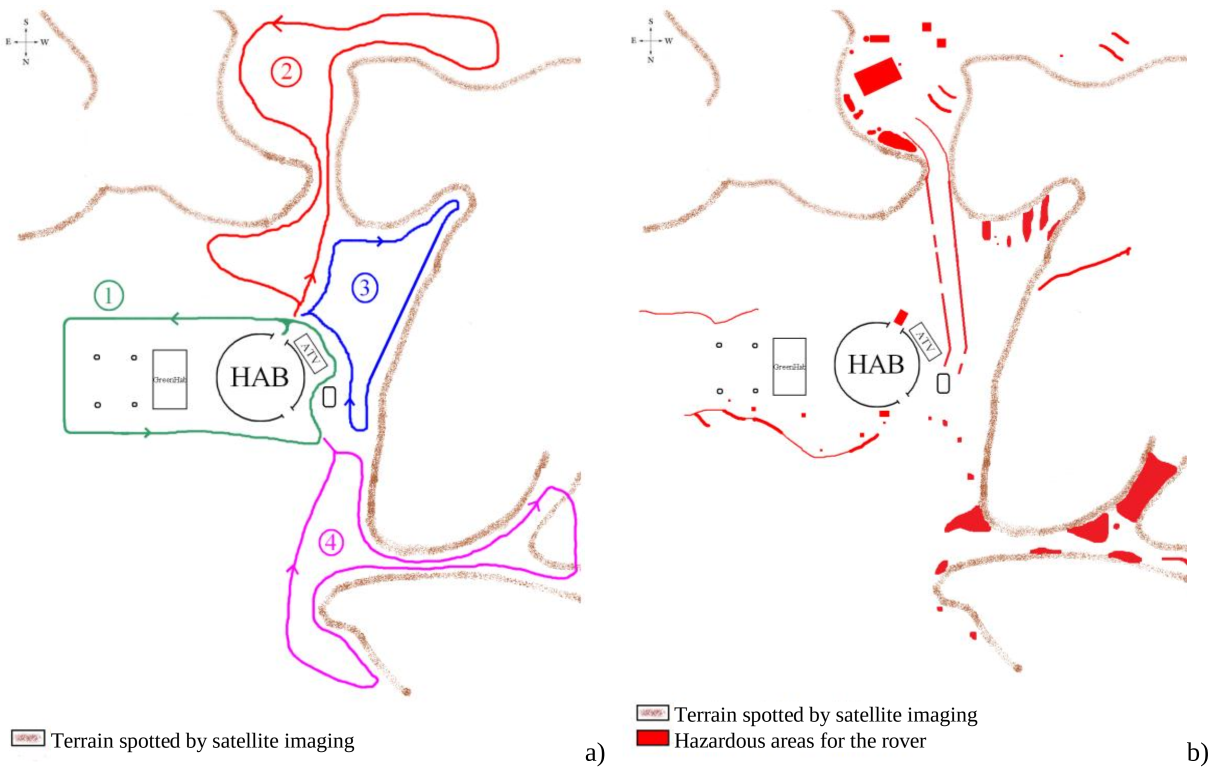

Fig. 6: Map of the paths undertook by the drone (a) and hazardous areas spotted by the intelligent cell.

As a backup experiment, a crewmember performed an EVA taking the path #4 of the drone and make his own map of the hazardous areas for the rover. By comparing what he has spotted and the map build previously shown in Fig. 6.b, the quality of the conjunction work of the terrain reconnaissance and the intelligence cell has been evaluated.

Between the two, 10 over 17 areas are in common. During the EVA, the volunteer spotted two additional areas while missing or minimizing five areas noted as hazardous from the materials brought by drone observations. These discrepancies can be attributed to the fact that on the pictures and video from UAV flights, it is impossible to determine the size of obstacles. Consequently, some of them are overestimated, others underestimated.

4. CONCLUSION

At this point it is good to recall that the first experiment has been conducted during two rotation of six members crew. Thus few people have participated leading to a few amount of statistic data and results must be carefully considered.

The knowledge transmitted is an operative one because it consist in how to *operate* the rover and differ from general knowledge. The limited experiment conducted cannot conclude if the video media is the best one for every operative knowledge to be transmitted from a crew to another neither if it is the best one to every type of personality. Indeed strong variation of the learning rates are expected regarding the task and the background (general knowledge) of the operators.

The study do not address either the time required to edit these documents and therefore the time *lost* by the first crew. Indeed, the gain is measured for the learning crew, but in the overall, it is not possible to show if time has been saved particularly if making the video is longer than recording audio or writing a tutorial (which still remains unlikely).

During the second experiment, even if the final part of could not be performed, the two first ones have been rich teaching. The crewmembers had the opportunity to prepare rover activities, involving multiple UAV flights and analyzes of pictures and videos. The EVA performed to check these analyses shown a fair agreement regarding the hardware.

For missions to Mars, it is no doubt that hardware will be much more sophisticated and will enhance analyses. Nevertheless, this simulation begun to show the potential of UAV terrain reconnaissance as an asset for preparing exploration missions, for rover activities and for EVA as well.

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