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SPA.2013.2.1-01 - Analysis of Mars Multi-Resolution Images using Auto-Coregistration, Data Mining and Crowd Source Techniques

- Collaborative project -

D7.2
New methods and toolkits for the scientific crowd-sourcing of change detection on Mars

WP 7 – Crowd-sourced features for change discovery and validation of data mining

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Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

History table

Version	Date	Released by	Comments
1.0	16/12/15	JS	Converted to iMars template
1.1	18/12/15	PS	Comments to the first version
1.2	22/12/15	JS & JW	Internal review changes
1.3	04/01/16	JS & JW	Internal review changes (2)

Executive Summary

This deliverable is the second within iMars Work Package (WP) 7 *Crowd-sourced features for change discovery and validation of data mining* and is specified in the Description of Work as *D7.2: Improved toolkits in Zooniverse open source repository (GitHub)*. In this document and in the accompanying GitHub repository we report on the development of tools (unique to our knowledge) for the presentation of change within a crowdsourcing environment, an approach to assessing human issues as part of a semi-automated processing chain featuring algorithmic detection, bespoke tools for workflow design and additional coverage of approaches to image preparation for change detection within crowdsourcing.

In doing this, it provides the necessary software for WP7 (Crowd-sourced features for change discovery and validation of data mining), and facilitates the future completion of **T7.3 (Software for crowd-sourcing tools and its validation)**, **T7.4 (Demonstration of crowd-sourcing tools for the scientific community)** and ultimately a deployable Citizen Science project utilising iMars data. This in itself also satisfies **WP8 (Outreach)** as a form of both primary science and outreach. The computer science work in WP7 will link to the iMars GIS (WP5); as such, this deliverable sets out initial image processing parameters that will inform both **T5.2 (Prototype of web-GIS using available data from UCL & DLR)** and **T5.3 (Stress-test of web-GIS with full datasets available from UCL and partners)**. It will also provide validation for algorithmic pipeline development (**WP6, T6.3 – Demonstration of data mining tools with full database**).

Following technological change since the time of preparing the Description of Work and discussion at the time of the project review with the Project Monitoring Officer and the Scientific Advisor, the deliverable has changed slightly; instead of using the original Zooniverse platform which involved developing 'raw' code, we have moved instead to a 'managed service' that has emerged from and is managed by the Zooniverse called Panoptes. This development is positive for the project as it provides both a more sustainable path to the deployment of a working large-scale Citizen Science project (a key request following the review) and also allows us, as early users of Panoptes, to offer feedback to the rest of the Zooniverse community at a key point in its development. Consequently, in addition to the code in the repository we also provide additional commentary on using the Panoptes platform in this report and relevant Panoptes script files in the repository.

Table of contents

Key word list

Citizen Science, Crowdsourcing, Change Detection, Task Design, ICT, Internet Applications, Visual Inspection

Definitions and acronyms

Acronyms	**Definitions**
CSA	Citizen Science Alliance
FAQ	Frequently Asked Questions
ICT	Information Communications Technology
ISIS	Integrated Software for Imagers and Spectrometers
MRO	Mars Reconnaissance Orbiter
PDS	Planetary Data System
SDSS	Sloan Digital Sky Survey
TSV	Tab Separated Values
URL	Uniform Resource Locator
VCS	Virtual Citizen Science

1. Introduction

The Zooniverse was created in 2007 through the release of their first project, Galaxy Zoo. Through this platform over 175,000 people contributed to analysing more than 1 million galaxy images captured by the Sloan Digital Sky Survey (SDSS), with the results subsequently used to produce over 50 publications both on the original science goals and regarding more serendipitous volunteer discoveries (Smith et al. 2013). Due to this success, in 2009 the original project grew to several projects covering a range of scientific disciplines, and to date over 30 projects have been launched with over 1 million participants providing over 300 million classifications.

The success of the Zooniverse resulted in an increasing number of scientists and research teams being interested in using citizen science as a solution to their data analysis issues. To deal with this demand, the Citizen Science Alliance (CSA) - the developers, scientists and educators responsible for the Zooniverse - introduced an online application form where interested scientists could describe their project, the data to be analysed and its potential impact. Such applications were reviewed by the CSA, and the Zooniverse team developed those deemed appropriate. Whilst ultimately this allowed the Zooniverse to have control over the quality of science cases addressed, the downside was the demand put on the developers. Although the more adventurous and technically-savvy scientists could download the codebase locally from the Zooniverse's GitHub repository for editing, it is not possible to set up the platform on the Zooniverse servers and launch the site 'live' without the involvement of the Zooniverse development team at some stage.

Launched in 2015, Panoptes was developed to streamline this process, and perhaps also to make the Zooniverse a more open and collaborative tool. The main component of the Panoptes system is the new online 'Project Builder' interface, which allows users to build the main components of a Citizen Science platform through a simple template system. This document describes the methodology and procedure of utilising the Zoonverse's Panoptes system in order to create the Citizen Science component of the iMars project. It also outlines the code developed and other software used in conjunction, made available as part of this deliverable through an associated online repository.

2. Interface design for change detection

2.1 General platform design

A Citizen Science platform for the analysis of iMars data called *Mars in Motion* was developed with the project builder at www.zooniverse.org that launched in 2015. Building a project requires an account on Zooniverse.org. The project builder presents several sections, accessible via a menu on the left hand side (Figure 2.1), which closely correspond to the different pages of the live site (Figure 2.2). The names of these pages are fixed by the project builder and cannot be changed without independently downloading the project builder code from GitHub and then requesting the Zooniverse team to launch the project to the public.

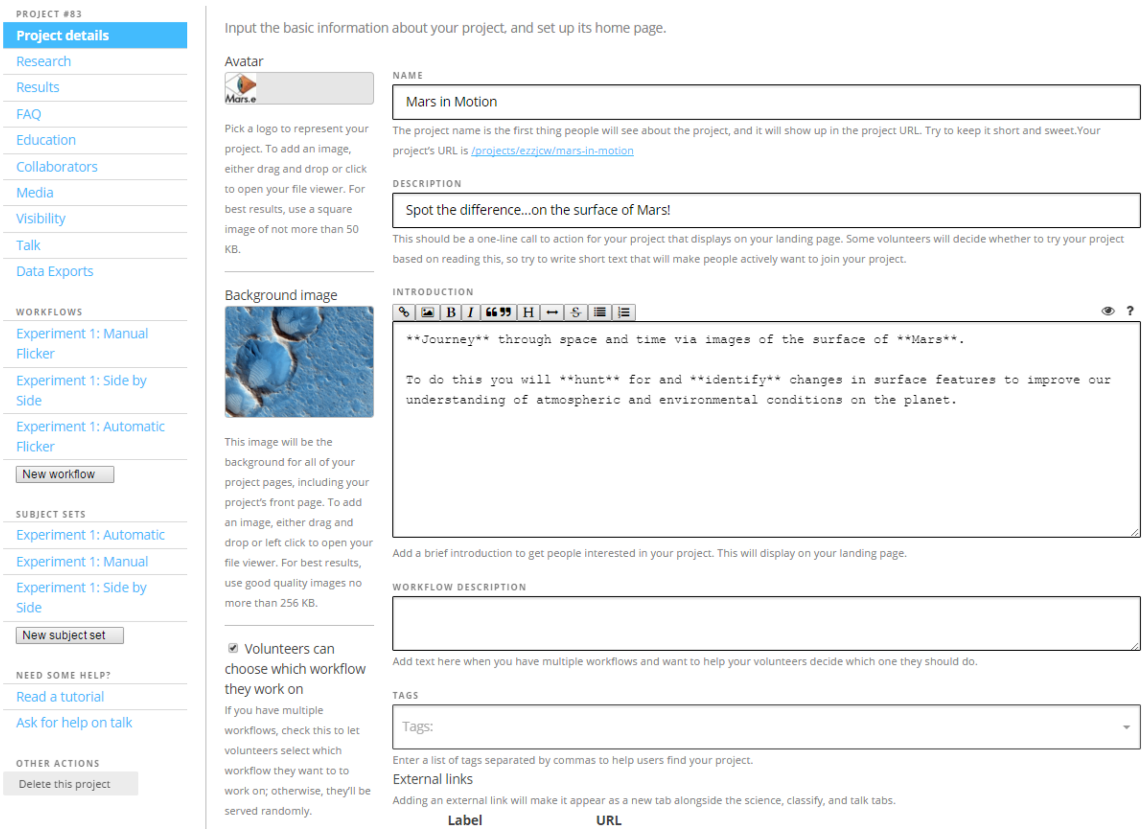

Figure 2.1: Project builder template

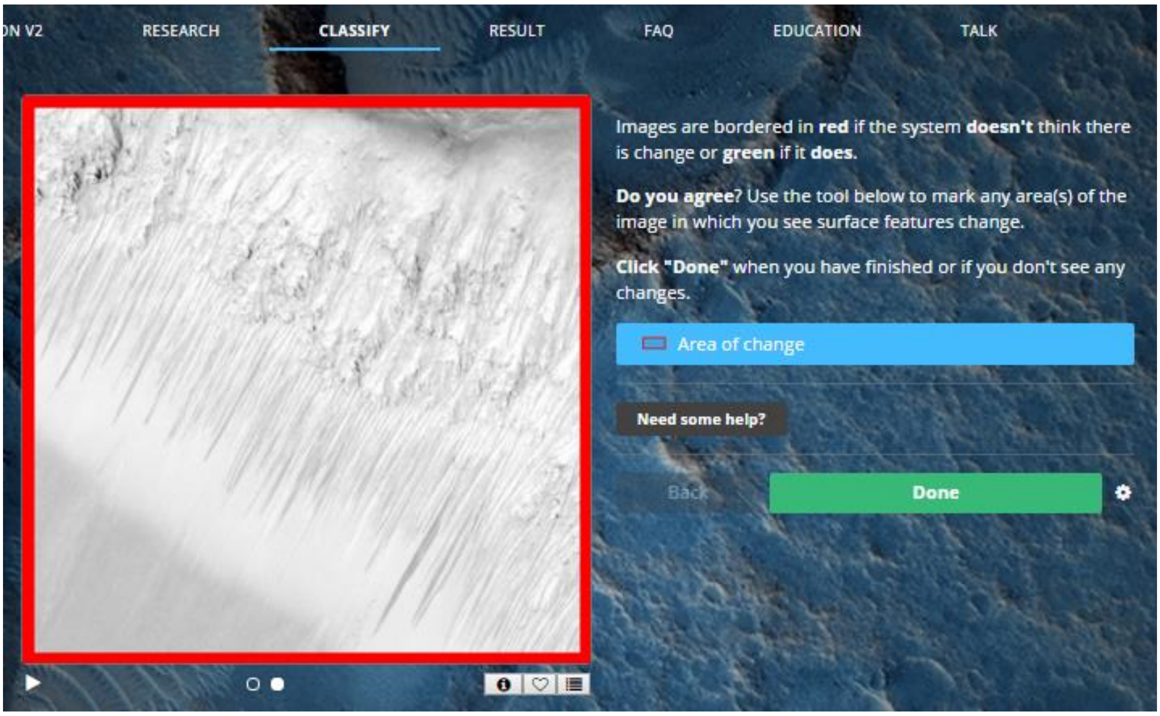

Figure 2.2: Project live site appearance for comparison with the template

2.1.1 Description of pages

The **Science** page describes the project's research motivations and goals to the volunteers and, importantly, is always visible. Whilst ostensibly it only facilitates the presentation of plain text, it renders markdown[1] for the basic formatting of text and facilitates the addition of images via the **Media** Library and links. The site will show the profile photos and roles of team members named on the **Collaborators** page to the side of the text. It is expected that this will be made up of science team members, UNOTT iMars partners and other iMars representatives if requested. The iMars project must pay attention to this page because research has shown that volunteers tend to be more motivated and engaged in a project when their scientific contribution is transparent and the scientists who will use the data have a face (Cox et al. 2015). This has been shown to lead to more classifications for the project overall, which improves the trustworthiness of the volunteers' classifications.

Once the project is established, the **Results** page can display results to the volunteers. This page only displays if the text box contains content. It is important for the iMars team to think about what data is publicised to the volunteers (e.g. publications, stats, graphical interpretations).

[1] Markdown is a lightweight markup language with plain text formatting syntax designed so that it can be converted to HTML and many other formats using a tool by the same name

The **FAQ** page should include additional details about the project, for example how to classify images (i.e. carry out the task), and what scientists plan to do with the classifications. This page can evolve with the project so that any active community members can direct new users towards it; if it is used strategically, and answers the most important and frequent questions that users have about the project, this page can facilitate the engagement of volunteers. Again, this page only displays content if it has any.

The **Education** page is available for researchers to provide educational content for teachers, and describe how teachers might use the platform in the classroom. This page only displays if it contains content and would require the team to update it.

2.1.2 Administration pages

Zooniverse account holders can have access to projects as **Collaborators**, even before they are public. A project owner can allocate team members with one or many of the roles below.

- *Owner* only applies to the original project creator;
- *Collaborators* have full access to edit workflows and project content;
- *Experts* can enter "gold mode" to make classifications that will be used to validate data quality;
- Members of the research team will be marked as *researchers* on **Talk**;
- *Moderators* are named and have extra privileges in the **Talk** community discussion area to moderate discussions;
- *Testers* can view projects and classify subjects to give feedback while the project's still private but cannot access the project builder;
- *Translators* can access the project builder and a translation site, to translate a project's text into a different language.

The iMars team has not yet discussed this aspect of the project but it is proposed that, as the developers of the Citizen Science platform, the WP7 team at the University of Nottingham is in the best position for this.

The **Media** page is where the project team can upload image files to use within the website. For example, iMars might store its logo and any examples that will help volunteers to detect change. Whilst the markdown code *`![title](URL)`* can be typed into any free text box in the project builder to display images from external websites, uploading them here provides a permanent and stable link.

Project owners can assign a project *public* or *private* status on the **Visibility** page. Anyone can access a public project with its URL but only named collaborators can view a private project. A project can also be in *development* or *live*. During *development*, workflows can be edited, and subjects will never retire. When a project is *live*, workflows are locked for editing, and the number of classifications count toward subject retirement. Projects can *apply for review* by the

Zooniverse community if they wish the Zooniverse to promote them; whilst this would be of significant benefit for the profile of our project, projects may launch independently.

Finally, **Talk** is the Zooniverse name for the forum, or discussion boards, attached to a project, where volunteers discuss the project and subjects with each other and researchers. Previous projects have engaged volunteers by maintaining a vibrant and active Talk area (Raddick et al. 2013), and made additional research discoveries within Talk conversations. The default is set to subject-specific discussion boards, which host a single dedicated conversation for each topic. Additional boards might host conversations about a general topic such as “Announcements,” “Project Discussion,” “Questions for the Research Team,” or “Technical Support.” User groups (administrators, moderators, teams or all volunteers) define who can read content of a board, or write a message within a board.

We *strongly* recommend that the iMars team agrees how the discussion boards will be administered some time before launch because an active community will be a significant ingredient of the project’s overall success. It is anticipated that UNOTT will administer the discussion boards, while encouraging other members of the iMars and science teams to contribute and participate directly with queries where their specialist knowledge is relevant.

2.1.3 Workflow

We now pay special attention to ***workflow***, which refers to the sequence of tasks that volunteers perform, because they demand an understanding of several concepts that are unique to Zooniverse.org, which come with constraints, which the project team needs to understand in order to have realistic expectations of what volunteers can ultimately contribute. The project builder’s *workflow* page defines those tasks and sets the order in which volunteers will do them on the **Classify** page of the main website.

To fully understand how a task is built on the Zooniverse, it is important to understand a few basic concepts: *subject*, *manifest* and *retirement*. A ***subject*** is a unit of data to be analysed; this can include one or more images that will be analysed simultaneously by volunteers. A *subject set* consists of a list of subjects (the “***manifest***”) defining their attributes (*metadata*), and the images themselves. Manifests must be a .CSV or .TSV file. The first row of this file should define the headers of the image metadata, and one must correspond to the filenames of the images within the same folder on the computer to present to volunteers; the Headers that begin with “#” or “//” denote private fields that will not be visible to classifiers in the main classification interface or in the Talk discussion tool. Subject images must be no more than 600KB in size and be one of the following file types: .JPG, .JPEG, .PNG, .GIF, .SVG. Table 2.1 shows the approximate size limit in terms of pixels for each file type. Note: Although the files are uploaded in the *Subject Set* section, the number of times each subject should be viewed and classified by volunteers is set within the *Workflow*; this is known as subject ***retirement***. Once a subject has reached the retirement limit it will no longer be shown to any volunteers.

File Type	Size limit (pixels)
JPG	1000x1000
PNG	500x500
GIF	500x500
SVG	500x500

Table 2.1: Pixel size limits for each image file type

Once the subject set and manifest are uploaded, they can be selected for volunteers to analyse in the ***Workflow*** section (Figure 2.3), which we now explain. A *Workflow Title* is required and useful if the project contains multiple workflows. When volunteers can choose which workflow to work on, this name will appear on a button on the homepage; the default otherwise is "Get started". The *Main Text* box should contain an instruction to volunteers, or a question, that is clear to a non-expert and captures the data the project requires.

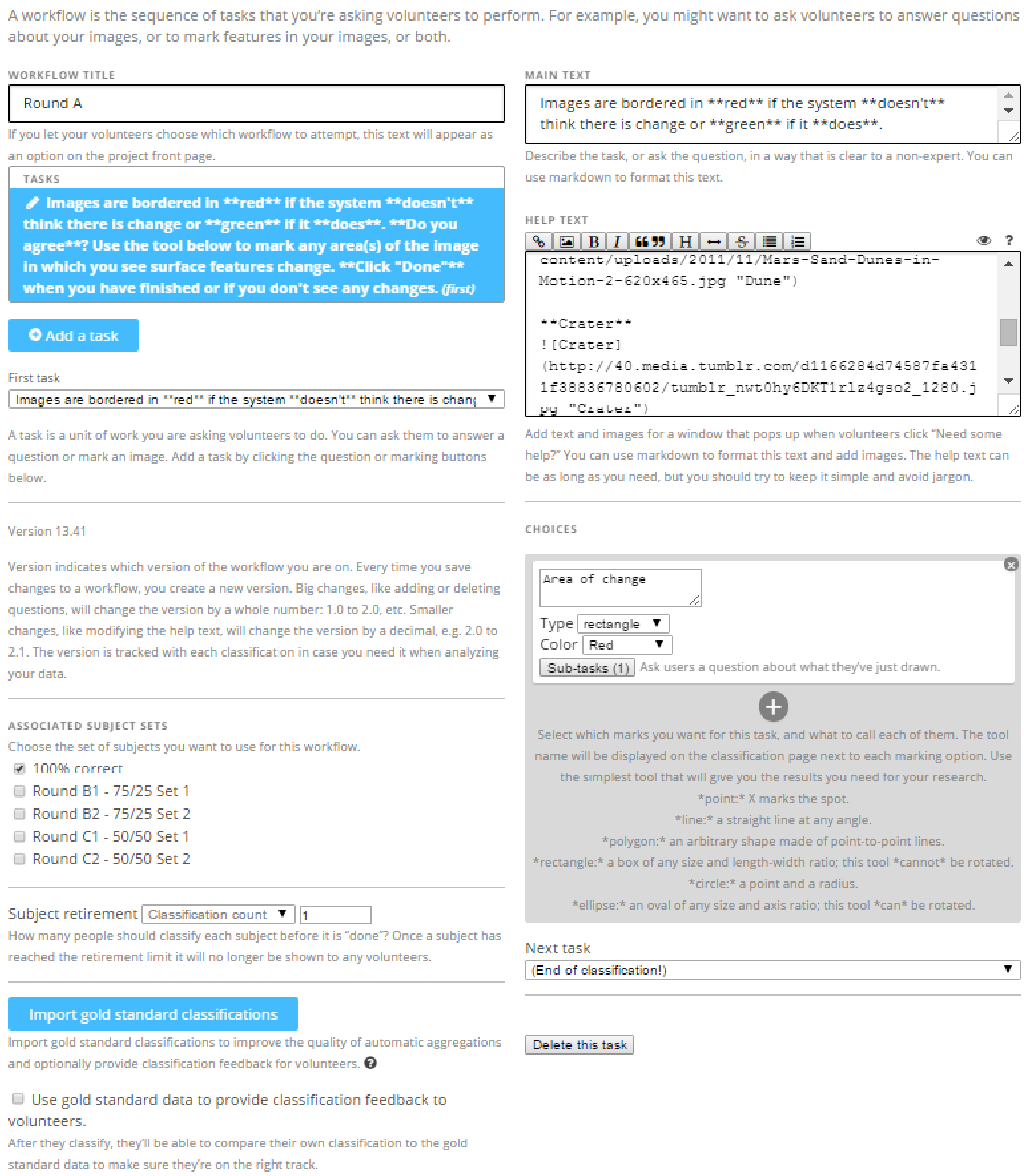

Figure 2.3: Panoptes workflow creation template

In the *Main Text*, volunteers may answer questions about images, or mark features in the data, or both, which correspond to the two key types of *tasks*: *questions* and *drawing*. For *questions*, a volunteer can choose from a list of possible answers to a question about an image e.g. 'What type of surface feature does this image contain?'. In drawing tasks, volunteers annotate images using drawing tools that the project builder specifies. The tools currently available are: points, lines, polygons, rectangles, circles and ellipses. The iMars project can provide these tools within *Mars in Motion* for volunteers to annotate surface features, which will be discussed in more detail in sections 2.3 and 2.4.

Volunteers may also carry out a *subtask*, for example answer a follow on question about their answer e.g. 'How confident are you with your answer?'. Note that the project builder can define the order in which tasks appear.

Help Text enables the placement of text and images for a pop-up help window, to appear next to the main text of the task in the main classification interface, when the volunteer clicks a button '*Need some help?'* Markdown can format this text, and link to other images to help explain the text, whether it describes the motivation for the question or explains each answer option.

2.1.4 Data exports

This is the final section of the project builder before the volunteers' 'workflow' is defined. The project owner can export data according to classification, subject, workflow and workflow contents once within a 24-hour period. An email signals when the data is available. The iMars team has not yet discussed the administration of volunteers' classifications, and how frequently, and this will depend heavily on the science teams' needs.

2.2 Presentation of change

Previous Zooniverse projects have not directly asked volunteers to look for change. Panoptes does not therefore ostensibly offer a mechanism for presenting more than one image. We consider that there are three options available to us to address this limitation:

1. Stitch images together before the volunteers see them, to create a side-by-side view of a 'Spot the difference' task. This requires processing images prior to their upload to Panoptes and consideration of the resolution of the screen that volunteers will be using;
2. Provide users with an element on the interface to switch between the two images. At the moment Panoptes currently provides a play/pause button, which triggers a flickering of the images at a fixed speed three times, and a small circle underneath the images as a link (Figure 2.2). The play button appears when there is more than one column with an image file name in the *manifest* file and use of the arrow keys as keyboard shortcuts is not permitted;
3. Process the images so that the two images continually alternate automatically. For this to work, the images must be very well co-registered and saved as a .gif file to flicker at a fixed speed.

2.3 Incorporation with algorithmic detection

An emerging concern is where the volunteers can ultimately contribute within the project's overall image analysis pipeline. Put simply we see three alternatives, on a spectrum from *validation* to *discovery* of change on the Martian surface:

1. Annotation of imagery, e.g. border images with a line coloured according to whether the algorithm's found change or not, so that the volunteers are *visually and immediately aware* if they are looking at an area in which the change detection algorithm has found change;
2. The algorithm's decision is *hidden* in the image's attributes for the volunteer to consult if and when they wish;
3. The system *does not* tell the volunteers whether the algorithm thinks the area they are looking at has changed.

The answer to this question will determine how we design the task workflow to provide useful scientific data. As an example, the task of detecting change could be **conceptually** broken down as follows:

1. Can you see a change on the surface? (Yes/no)
2. Mark on the image where you see a change
3. What feature do you think you have marked?
    a. Crater (Daubar et al. 2013)
    b. Sand dune (Hayward, Fenton, and Titus 2014)
    c. Gully (Hobbs, Paull, and Clarke 2014)
    d. Slope streak (Grimm, Harrison, and Stillman 2014)
    e. Recurring Slope Lineae (McEwen et al. 2014)

Such a task can evolve incrementally during our experiments to assess the usefulness of the data elicited by responses to each sub-task, but should not change once the site is live. We suggest that the iMars team need to agree on this by **March 2016**, on the completion of WP7 experiments, before *Mars in Motion* goes live.

2.4 Fine tuning for Martian features

Section 2 of **Deliverable 6.1 (Algorithm Theoretical Basis Document for data mining tools)** identified different types of Martian surface features of interest and emphasised their variation in size and spatial distribution. Another aspect in which they vary is shape; volunteers would require tools to draw shapes appropriate to the various features. Panoptes currently permits annotations of the following shapes:

- Point
- Line
- Polygon
- Rectangle
- Circle

- Ellipse

These tools are suitable for the annotation of the surface features in which the project is interested because their shape corresponds to the shape of different features; for example, craters can be marked with a circle and slope streaks can be marked with an axial line and/or polygon for their outer boundary. The shapes can be coloured red, yellow, blue, green, cyan, magenta, black or white, which is useful if the same shape is used for the annotation of more than one feature type.

2.5 Bespoke tools and workflow design

The Zooniverse Panoptes platform provides a number of standard tools for image analysis, from classification-type question tasks to annotation-type drawing tools for simple measurements, which have been understandably developed to cover as wide a range of scientific questions and disciplines as feasible. As such, they might not be appropriate for the measurement of more complex features as those found on the surface of Mars. To address this issue, the Zooniverse has made their code available through the GitHub source code hosting service. From here, any scientist or science team can download and create their own instance of the Zooniverse locally, and therefore have complete access to edit and adapt code as required. This means that not only can bespoke tools tailored to the specific science case be developed, but also the workflow itself (the way the tools and tasks are presented) can be adapted - for instance changing the task after a set number of images, or having different citizen scientist groups do different tasks etc. Once created this platform can then be tested or launched on the local machine or a configured server, however to be included on the Zooniverse server as an endorsed project any adaptations of the code have to be approved by the Zooniverse development team.

An example of this process, created as part of WP7 of the iMars project, has been uploaded to the GitHub system (see 5.1). Specifically a new version of the Zooniverse's Planet Four has been adapted to analyse craters on the surface of Mars, with a new 'elliptical' tool developed to mark secondary impacts and 3 different workflows created to investigate the effect on volunteer performance and engagement of differing tools and tasks. As this work was completed towards the beginning of the iMars project (mid-2014), the Panoptes predecessor, Ouroboros, was used but the procedure has not changed significantly (a link to the GitHub repository for Panoptes including installation instructions can be found in 5.1).

3. Image Processing

As described in section 2.1, the data to be analysed by the public is uploaded to Panoptes by way of a folder of images (referred to as *subjects*), with a manifest file describing the contents and associated metadata. In order to be compatible with this procedure and to fulfil the change detection goals of the project, the imagery produced by iMars will have to go through a number of processes beforehand.

3.1 General processing for Panoptes platform

For an image to be uploaded to the Panoptes platform as a subject to be analysed, it has to fulfil specific size and type requirements (see 2.1). The types of Martian imagery being used and produced by iMars are generally several hundred MB in size, and of various geo-referenced formats (Geotiff, JPG/JGW, and JP2). To address this, The ISIS 3 software package has been used to convert the imagery into the more standard JPG format, and ImageMagick to 'slice' the imagery into a number of smaller partitions (installation and commands detailed in the outputs, 5.1). This process chain, or an adaption of it, will need to be utilised for the data produced by **WP6 (Change detection from data mining and validation)**, and reversed when converting volunteer data from a pixel position to a geo-referenced data-point for display on the iMars **web-GIS (WP5)**, as long as the Panoptes system is restricted to these image file types. In order to achieve this, the UNOTT team will require the raw imagery with sufficient time to process the imagery for display on the Citizen Science platform and iMars WebGIS.

In order to detect changes on the Martian surface, it is better to think in terms of image 'pairs' or 'sets' as two or more images will need to be compared. Therefore each image slice created by the process described above has to have at least one corresponding image of the same area taken at a different time. In order to achieve this, it is important not only that the two original 'full size' images are co-registered, but that they also cover the same extent (upper-left pixel in same location and so on) so that the same number of image slices are created for each which are aligned. An example of two sliced image sets is available through the iMars GitHub repository (see 5.1).

3.2 Processing for change presentation

As described in section 2.2, we have developed three interfaces for presenting changes on the Martian surface to the citizen scientist. Panoptes already has the functionality for one of these (manual flicker by button click - controlled via the manifest file), but for the other two we have developed programme code to process the imagery beforehand. As before, the code relies on ImageMagick tools, and can be accessed via the iMars GitHub repository (5.1). There is also included an example of the image slices the code creates (both side-by-side, and .GIF files for automatic flickering).

3.3 Processing for validation / algorithm incorporation

One of the key research areas of Citizen Science, and Virtual Citizen Science (VCS) in particular, is the role of the volunteer when working in conjunction with an automated process. As such, it is of high interest to the Zooniverse development team, and as explained in section 2.3 there are several ways in which we can explore the issue. Panoptes already facilitates two of these (not informing the volunteer, and giving algorithmic results via the manifest file) but for the direct annotation of imagery code has been developed to process the imagery beforehand. Again the code relies on ImageMagick commands, and can be accessed via the iMars GitHub repository (5.1). An example of the resulting annotated imagery is also included (Figure 3.1). The datasets produced by **WP6 (Change detection from data mining and validation)** will help inform how best to utilise volunteer work in the pipeline, and indeed what is feasible to achieve in terms of the amount of volunteer analysis is required.

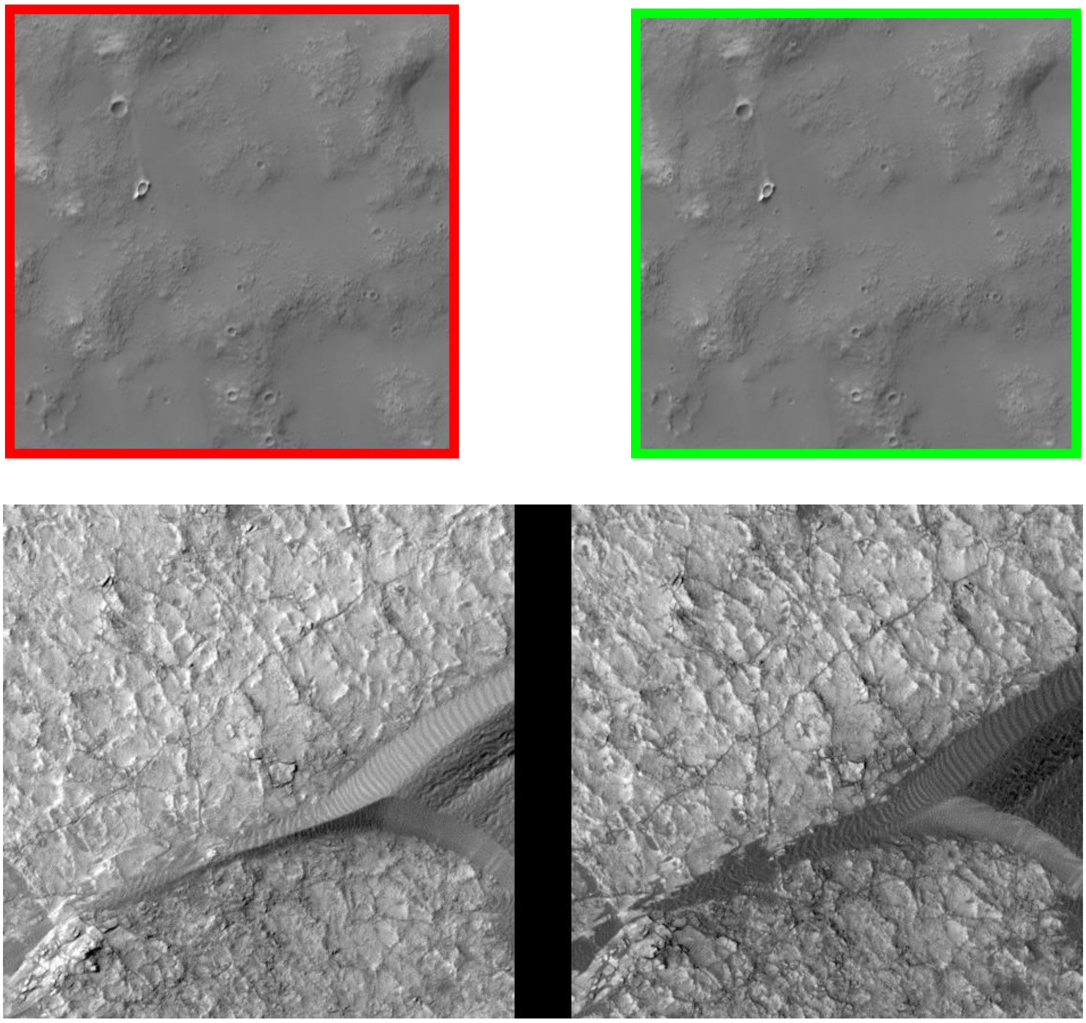

Figure 3.1: Images annotated with algorithm result (top, red – no change, green - change) and processed for side by side comparison (bottom)

4. Consequences for iMars and future steps

In both using the Panoptes project builder system to create a change detection VCS project for iMars, and processing the Martian imagery for its use, a number of considerations and issues have arisen that will have consequences for the iMars project. Table 4.1 below describes these issues, along with suggested future steps to address them during the remainder of the project.

Subject	Description	Consequences	Future Steps
Change Detection	Panoptes not primarily designed for change detection tasks	Limited presentation techniques of multiple imagery	Downloading and direct editing of Panoptes code to suit needs - will require Zooniverse approval for live site
Volunteer Role	The contribution of volunteers to the overall project pipeline	The strengths and weaknesses of both the volunteers and the algorithm require definition and means of assessment	Experiments to understand how to optimise volunteers' contribution when collaborating with machine detection
Science Case	Panoptes (and all VCS platforms) require a clearly defined science aim as a key motivation to take part	Science target (i.e. feature types) need choosing and invested stakeholders identified who will use the data	Experiments to investigate volunteer performance in relation to feature type & metric specification
iMars Imagery	Maximum file size Panoptes allows - 600KB	Martian imagery has to be sliced into smaller chunks. This requires images to be not only co-registered but also same extent/size	Either implementing a workflow that cuts the co-registered images to the same extent, or a script that slices the image based on geo-referenced data rather than pixel position
iMars Imagery	Panoptes does not accept any raster geo-referenced image format	Any annotated results are returned with a pixel position rather than location (latitude/ longitude) will be an issue for displaying volunteer data on WebGIS.	Implementing a workflow/script that can convert from pixel position to geographic position, either on the fly for live upload or via a batch procedure

Table 4.1: Issues and considerations in adapting Panoptes for the iMars project

In this deliverable we have identified a range of issues that require consultation with the wider iMars team and principally concern the governance of the Citizen Science project. The issues we outline below were not considered explicitly in the Description of Work and also reflect the changing nature of Citizen Science projects:

1. Roles and responsibilities within the Citizen Science project.
Initial proposal: By default UNOTT will take responsibility for the administration of the platform but other project partners will be invited to contribute as they see fit. A primary form of participation would be to be (a) identified in the Science page and (b) to participate in answering scientific queries referred to them by UNOTT from the public/writing short blog posts or sharing details (e.g., abstract) of new publications that show how the data is being used in order to 'complete the circle' between citizen scientist and the science they help create. In the event that users of the Citizen Science outputs lie outside the iMars team, this extended science team would be required to contribute content.

2. Image pre/post-processing.
Initial proposal: The Zooniverse platform does not currently permit the retention of geo-referencing metadata tied to images and works in terms of pixel locations rather than latitude and longitude. In order to make the Citizen Science products useful to the wider scientific community and integrate them into the iMars WebGIS, it is necessary to carry out pre- and post-processing to allow the re-translation of Citizen Science products back into geo-referenced data. UNOTT will take primary responsibility for this and are in a good position to do so as Dr Giordano has been added to our staffing. We will however seek advice and input from knowledgeable project partners. Our understanding from discussion with the scientific community within the Zooniverse is that there would also be significant wider interest in a demonstrated solution for translating pixel coordinates from and back into schemes of geo-referencing.

5. Outputs and publications

5.1 Table of deliverable outputs

Table 5.1 below lists the outputs that have been produced during this deliverable, along with the section of this document to which they contribute and their format. They are available on an iMars repository in GitHub (https://GitHub.com/sprinklebum/iMars-eu.git).

Document Section	Filename	Description	File Type
2.5: Bespoke tools & taskflow creation	https://GitHub.com/zooniverse/NottMarsZoo.git	GitHub repository containing code for Planet Four: Craters	Download link
2.5: Bespoke tools & taskflow creation	https://GitHub.com/zooniverse/Panoptes.git	GitHub repository containing Panoptes code	Download link
3.1: General image processing for Panoptes platform	General Image Processing.md	Installation and commands for image conversion and slicing	Markdown text file
3.1 General image processing for Panoptes platform	ImageSetA & ImageSetB	Example of image slices (pairs)	Folder - containing jpg image files
3.2: Image processing for change presentation	sidebyside.sh	Code for creating 'side by side' image pairs	Shell script
3.2: Image processing for change presentation	autoflicker.sh	Code for creating automatic flicker gif's	Shell script
3.2: Image processing for change presentation	sidebyside & autoflicker	Example of image slices	Folder - containing jpg and gif image files
3.3: Processing for validation / algorithm incorporation	algorithm.sh	Code for annotating imagery to display algorithm result	Shell script
3.3: Processing for validation / algorithm incorporation	algorithmchangeA & algorithmchangeB	Example of image slices	Folder - containing jpg image files

Table 5.1: Table of contents of iMars WP7 GitHub repository

5.2 Conferences and demonstrations

J. Sprinks, R. Houghton, S. Bamford, J. G. Morley, J. Wardlaw (2015). Is that a Crater? Designing Citizen Science Platforms for the Volunteer and to Improve Results, *European Planetary Science Congress 2015,* EPSC2015-694, Vol. 10

J. Wardlaw, J. Sprinks, R. Houghton, S. Bamford, S. Marsh (2015). Demonstration - Zooming in-and-out of Mars: new tools to interact with multi-resolution Mars datasets (public), *European Planetary Science Congress 2015,* Oct 2015, Nantes, France

J. Wardlaw, J. Sprinks, R. Houghton, S. Bamford, J. G. Morley, S. Marsh (2015). iMars: Crowd-sourced Analysis of Imagery for Geological Change on Mars, *Geological Remote Sensing Group 26th Annual Conference 'Challenges in Remote Sensing',* Dec 2015, ESA ESRIN, Frascati, Italy

6. Relevant links

Citizen Science Alliance website and application, available at: www.citizensciencealliance.org

iMars GitHub Repository, available at: https://GitHub.com/sprinklebum/iMars-eu.git

Mars in Motion Citizen Science Platform, available at:

www.zooniverse.org/projects/ezzjcw/mars-in-motion

www.zooniverse.org/projects/ezzjcw/mars-in-motion-v2

For access please contact the authors of this document

Panoptes 'Project Builder' interface, available at: https://www.zooniverse.org/lab

Requires registration with the Zooniverse platform

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