Collaborative georreference of ISS night images for light pollution and energy consumption studies

A Citizen Science project

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Right now there are around 1.800.000 images at the Johnson Space Center database (The Gateway of the Astronauts) and around of 1.200.000 images came from the International Space Station (date 20/02/2014). Although, the classified images are a number much smaller and there no archive of georeferenced images. There is a project to classify the day time images (Image detective). But, the techniques that are used in this project are not use full for the classification of night time images. The reason is that the patterns on earth are not the same during the day and night. That's why it's need it other technique to classify night time images.

In this project three applications, and a web site translated into 13 languages, have been developed to classify image quality, city location and city georreference. Though to the large number of images, a collaborative environment has been selected using Crowdcrafting platform. This is a open source platform that allows volunteers provide their help to different scientific projects.

PALAVRAS-CHAVE

Light Pollution, IDE, Portugal, España, Citizen Science.

INTRODUCTION

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The system download all the images from ISS database as raw with some simple metadata. A first selection using an automatic identification is made to get the night ones using our own algorithm based on image histogram. The selected pictures are introduced into the first application, DarkSkies, and the citizen provide a primary quality for them. The best are introduced into LostAtNight, where the users provide a first location for everyone. At last, the located images are used in NightCitiesISS where they are georeferenced.

The result is a set of points on the image and the relationship with the longitude and latitude. At

last, a Python script using GDAL creates a georeferenced image. This is used on general cartographic software as new layer to identify the brightest zones.

At the moment, more than 455000 answers have been collected, and more than 1000 images have been georeferenced. The source code, original images and the georeferenced ones are available for free through the different applications. The project is supported by NASA and ESA

The aim of this work is take advantage from photographs taken from the International Space Station, where appear lot of cities. These photos are only used for advertising purposes, and only works as Zamorano, J. Et al 2011 [1]

From the outset has been raised throughout the system as an open, collaborative project. Starting with the initial data, platform development, publishing the source code and results. All this in open formats and Creative Commons and GPL licenses. The source code of all applications can be downloaded, and contribute to its improvement through GitHub, as indicated below for each application.

Fig.1 Pictures taken by ISS missions and area covered planet [Natronics 2013]

The orbit data, when needed were extracted from the following orbital elements of two lines TLE published daily by NASA:

1 25544U 98067A 14299.52559916 .00018781 00000-0 32583-3 0 3068
2 25544 051.6452 168.5399 0002517 306.8314 123.9571 15.50895423911704

Epoch (UTC):	domingo, 26 de octubre de 2014 12:36:51
Eccentricity	0,0002517
Inclination:	51,6452°
Height of perigee	412 km
Height of apogee:	416 km
Longitude of ascending node	168,5399°
Argument of perigee	306,8314°
Revolutions per day	15,50895423
Mean anomaly	123,9571°
Number of orbits	91170

LIGHT POLLUTION

In scientific terms, means light pollution is altering the natural darkness of the night environment

produced by the emission of artificial light. This is one of the environmental problems that have increased in recent years, mainly due to night time outdoor lighting and a location associated with the urban environment, but with far-reaching implications. Negative impacts are more evident and affect not only the landscape and ecosystems, disrupting biodiversity, but also human health.

Global light pollution maps shows that, since the late 90s, there is no area of the country devoid of stray artificial light in the atmosphere (CD The first world atlas of the artificial night sky brightness.[2]). This is a factor of degradation of the natural environment of artificial origin that affects the landscape and ecosystems of all existing protected natural areas, and particularly in those in the vicinity of urban environments. Light pollution has hardly been considered in the framework of protection of these areas, and only in isolated cases, such as the Natural Park of Albufera of Valencia and the Doñana National Park has initiated measures for diagnosis, study and / or prevention.

Light pollution affects specifically all species that develop fully or partially active life in a night environment, with known examples of very different taxonomic groups such as mammals, birds, reptiles, amphibians, fish, invertebrates and plants [3]

Besides these problems, artificial lighting is a major consumer of energy resources. The total energy consumption for street lighting in Spain amounted to 3,400 GWh / year, which translates to 475 million euros and 1.5 million tonnes of CO2.

Advances in the study of light pollution and its consequences have motivated recently made a legislative effort to address this phenomenon. However, this legislative effort has not benefited the contemporary scientific understanding of the phenomenon in its real dimension. Among other things, we blame the spread of knowledge due to its multidisciplinary nature and excessive compartmentalization between disciplines.

Scientific studies on light pollution are becoming a boom in Spain in recent years. We already mentioned that it is a multi-disciplinary research topic because, apart from energy and environmental problem, the brightening of the night sky degrades the quality of astronomical observations (Astronomy), affects the behaviour and reproduction of nocturnal animals (Biology) of control and circadian rhythms of humans (Medicine) to name three of the most important research areas.

The relationship between the small group of Spanish researchers is very low even within the same areas of research. For example, although several teams measuring the sky background brightness have not yet established standards for data collection and have created a database with this information stateside.

IMAGE PROCESSING

Astronauts on board the International Space Station (ISS) are publishing in internet (Twitter for instance) pictures of Earth taken from the ISS. These beautiful pictures can be obtained from a repository maintained by NASA. A portion of the images is being taken at night and some of them show a network of light of the big cities. This illumination comes mainly from public lighting of the streets and buildings. The intensity in the picture is related to the light being sent to the space and bright light reveals an excess or bad use of lighting.

Detecting light pollution is straightforward by visual inspection of the JPEG pictures. These images speak by themselves and are very useful to draw public attention of the problem. Unfortunately the JPEG compression method is loss, meaning that some original image information is lost and cannot be restored. To obtain useful scientific values from these pictures, the original RAW files are needed. Being the CMOS detector of the digital camera employed (Nikon D3s) a linear device, the intensities of each pixel are proportional to the emitted light and one can directly compare between different zones of the image. Besides, the colour of the light sources can be obtained by comparing

the value of the image in different channels or bands. From these colors the nature of the light bulb employed can be inferred.

This is why we have requested and obtained from NASA iss026e026493.nef, which is a RAW image (with a Bayer matrix) with the format of the digital images of Nikon. Information of this picture can be obtained at the Gateway to Astronaut Photography of Earth:
http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS026&roll=E&frame=26493

Exif data: Nikon D3S f=200mm f/4 1/15s 12800 ISO 4256x2832 pixels 2011:02:11 23:11:50

This is a preliminary report on the work made up to now. The aims of this study are:
1) To obtain useful and scientific information of the light pollution at Madrid city area
2) To emphasize the importance of these ISS nocturnal images for science and public outreach.
3) To design a calibration sequence to be used by astronauts on board ISS for these kind of night pictures when they are taken for scientific studies.

Fig.2. Published JPEG image of Madrid in true color and detail in Madrid downtown. A deep zoom of the RAW image to show the Bayer matrix is also displayed.

Due to the light directly emitted to the space or reflected in the ground, the image shows clearly recognizable features of Madrid at night. These include streets, parks, airport, a soccer stadium, roads, etc.

The target of the application is the georeferencing of images taken from the ISS. The images have catalogued mission, roll and sequential number. In the catalogue these have metadata with information about the technical characteristics of the equipment used in its making, time and location of the ISS. For most images do not have the position of the center thereof, and in the best photographed area information is displayed.

The first step is to download the images and their associated metadata. The images are available through an FTP server and metadata are obtained by a script as developed by this team. This script performs a process on the web scrapping of JSC and stored together with the identification image.

In a first phase, the images were analysed using an algorithm that discriminates against night time images of the day, based on the histogram of the same. This was later replaced by the CitiesAtNight application. He, though more laborious, visual recognition of images to distinguish between images corresponding to other cities without interest. They can also be classified according to their quality.

DEVELOPED APPLICATIONS

In order to provide an environment as simple as possible collaborators, have developed 3 separate applications. It has also launched a website in 13 languages which reports on the project objectives and provides access to each of the applications for participation.

Fig 3. Cities At Night web

3 maps are included with the positions where the ISS was at the time of the picture. Thus the volunteer can select the area he knows best and go about working on these images. It also serves as an index to know which parts of the planet have images

The applications are developed on the Crowdcrafting platform, which is detailed below. The same logic is implemented in Javascript language, using the framework provided by OpenLayers OpenLayers 2.4 and 3.0.

Applications are organized into tasks. Each task consists of evaluating an image and can fully realize it, or if you can not, through ignorance of the area or any other reason, you may proceed to the next. Users are presenting to them the tasks sequentially, and each image is presented to different users, a minimum of 10. These are described below

DarkSkies. It is aimed at the general public, and its purpose is to determine whether each image corresponds to a night shot, whether it is a city or not, and give a classification of basic quality. It is thus distinguished whether they are clear or covered by clouds.

Access: http://crowdcrafting.org/app/darkskies/

Source code: https://github.com/pmisson/darkskiesISS

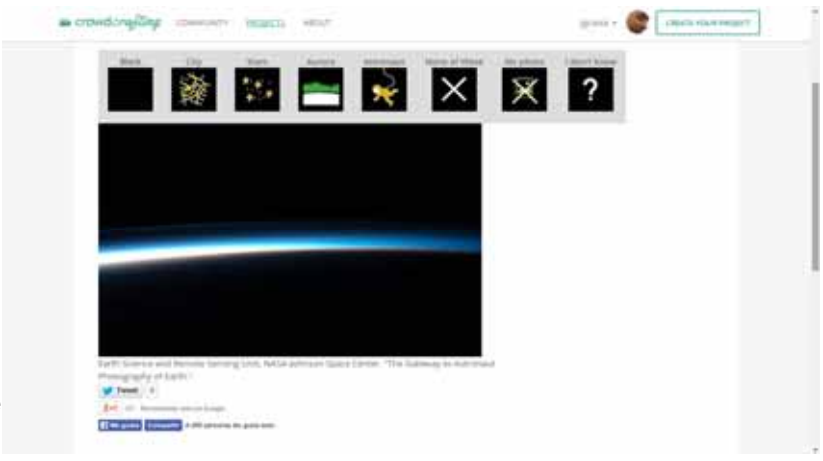

Fig 4. Dark Cities user interface

LostAtNight. The result of each classification made in DarkSkies, pass to LostAtNight. Also easy to use, images and categorized as corresponding to nighttime and cities are not located, and the information we have of them subterrestrial point corresponds to the position of the ISS at the time of shooting.

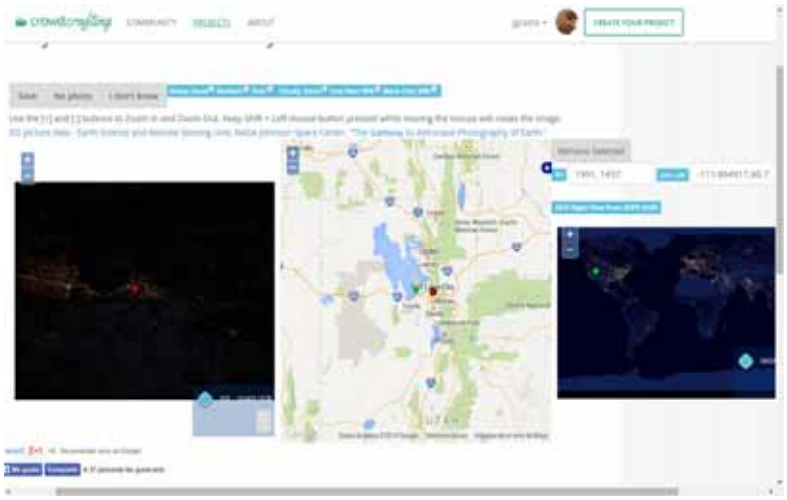

Fig 5. Lost At Night user interface

In this application the user has the image study, a central map layers OSM and Google Maps, and one with the image of VIIRS. The image can be enlarged, moved and rotated to allow the user to identify it. In the central map, for help, a green dot shows the position of the ISS subterrestrial point, with a value corresponding to the altitude of the ISS zoom. Changes layers and functionality of any map are also available. The VIIRS for the entire planet and the point of the ISS subterrestrial shown, allowing to interact with it.

The user goal is to identify a point on the image and on the corresponding mapping. Once marked, the information captured on the box on the right and then can be stored. If not identifiable, we can discard the image and move to the next.

Access: www.crowdcrafting.org/apps/LostAtNight

Source code: https://github.com/jgcasta/lostatnight

NightCitiesISS. After finding the city that bears the image, they pass the stage of georeferencing. You attempted to make the interface as simple as possible. The objective is to select pairs of points on the image capturing system coordinates X, Y of the same, and the corresponding latitude and longitude coordinates in the map center. On the left is a box appears that allows image magnification, reduction, displacement and rotation, using the framework of OL3. For the central map is chosen Google Maps, but you can select the layer of OpenStreetMap, anyway. As a guide on the right includes a map with information from VIIRS, with the red dot marking the position of the ISS subterrestrial point.

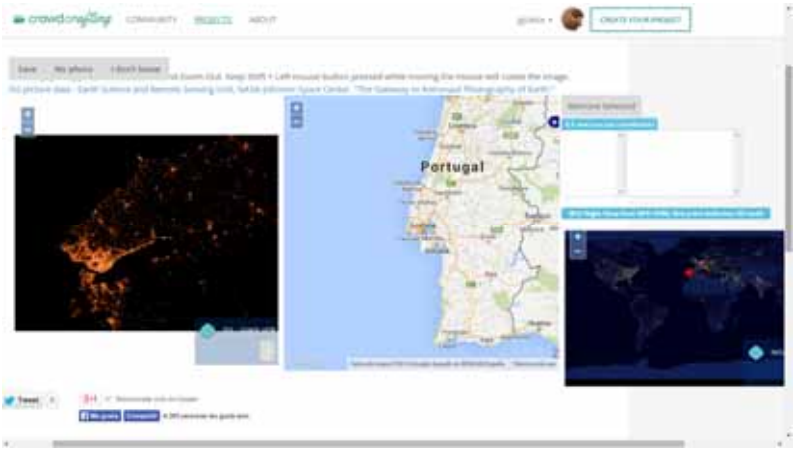

Fig. 6 NightCitiesISS user interface

The user can select as many pairs as you want and points will appear on the map image and not to re-select. The selection will appear in the box to the right, and in case of error, you can delete the items you want.

Access: www.crowdcrafting.org/apps/NightCitiesISS

Source code: https://github.com/jgcasta/nightcitiesiss

In all applications, each image is presented for evaluation to several visitors, with a minimum of 10. This error is minimized where possible.

DATA SOURCES

The data that has been worked can be divided into satellite imagery and mapping. The first comes from the ISS and other satellites. The main georeferenced images are from the ISS, but we have added a map showing a mosaic of images from the VIIRS sensor on NPP Satellite 2012. This presents a resolution of 750 meters per pixel, and helps the user to identify an area night, which may differ materially from where is visible during the day.

As a source of mapping data were chosen according to two criteria. On the one hand should be open, as far as possible, and be allowed to use for georeferencing. Furthermore, should cover most of the planet, or at least the areas covered by the ISS missions.

At first he is thought of as the sole source OpenStreetMap, but found that for some parts of the world, those least populated, lacked sufficient coverage. Therefore it has added a layer corresponding to Google Maps. In both cases we have used the reference system EPSG 4326

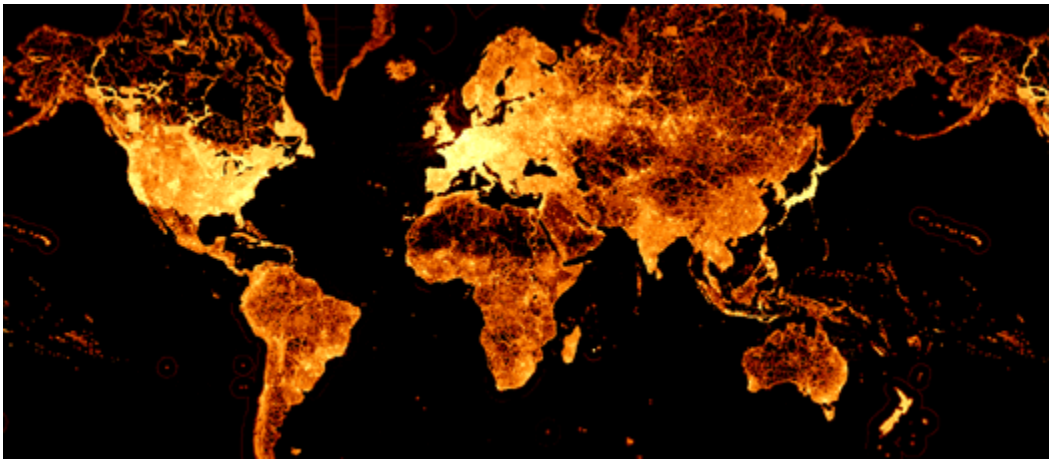

Fig. 7 OSM coverage[4]

Thus, within the same interface different sources using WMS and WMTS services published by NASA, allowing the user to interact with them are provided.

CROWDCRAFTING: A CITIZEN SCIENCE PLATFORM

Crowdcrafting is a hosted service of the open source framework PyBossa. The goal of PyBossa and Crowdcrafting is to provide a generic and 100% open source, science and data platform where citizens can participate in scientific project as well as creating new ones themselves.

Access: http://pybossa.com/

Source code: https://github.com/PyBossa/pybossa

PyBossa has a very simple architecture: it is a web service with a database. The back-end is written in Python while the front-end features HTML5, CSS3 and JavaScript for modern web browsers. The database is PostgreSQL.

Documentation: http://docs.pybossa.com/

One of the main features of PyBossa is its RESTful API (http://en.wikipedia.org/wiki/Representational_state_transfer) that allows any third party service or project to communicate with the server for creating new projects. Thanks to this API the software is integrated via its API to volunteer sensing platforms like epiCollect+ from Imperial College (http://www.epicollect.net/), or data stores like CKAN from the Open Knowledge Foundation (http://ckan.org/).

In PyBossa, and therefore in Crowdcrafting, a project has a set of tasks. Each task is a problem in itself, that volunteers will try to solve. For example, for Dark Skies, each task consisted in the classification of an image according to a set of rules.

PyBossa distributes the tasks among the volunteers being sure that each participant can only save one answer per task. By default, each task is reviewed by 30 different persons, but this threshold can be modified.

In Crowdcrafting, PyBossa has featured an amazing performance storing one day more than 1 answer per second, becoming a “real-time” framework in the sense that every second one answer from a

volunteer was saved for 24 hours in a row.

Thanks to these features and its amazing performance, PyBossa is widely used by international institutions like the British Museum (http://crowdsourced.micropasts.org/) or United Nations department UNITAR (http://geotagx.org/).

USED TOOLS

In addition to the exposed platform various tools have been used to perform the download and processing of images.

- QSIG and gvSIG desktop tools
- Python for scripting
- GDAL for georeferencing

RESULTS OF PARTICIPATION

The participation of citizens around the world has been made possible by the chosen platform and the support of the various institutions that have relied on the project. NASA, ESA, Medialab MIT, Prado ... This has caused lot of media have echoed the fact global initiative. TV stations like FOX, NBC, the German broadcaster, Spanish media recently, especially the large amount of digital media

Social networks have become an important means of dissemination. Through Twitter, Facebook and Google+, has spread the project and has attracted 27044 participants.

Fig. 8 Evolution session

Taken into account the 3 applications and associated website, we have collected 190,000 unique sessions, and half a million actual measurements, allowing finally classify 1948 images

Country	Sessions	
USA	68.522	35,98%
Spain	17.975	9,44%
Germany	14.861	7,80%
New Zealand	8.702	4,57%
United Kingdom	8.468	4,45%
Canada	8.203	4,31%
Italy	6.328	3,32%

Lithuania	4.391	2,31%
Denmark	4.027	2,11%
Australia	3.775	1,98%

Fig. 9 Distribution of visits by countries.

RESULTS

In the same way that the whole process of data collection, processing and participation has remained open, the publication of the results follows the same philosophy. In the current phase of the project, there are two paths to the results:

Download data processing applications. From every application it is possible to download the set of tasks performed by the participants. Any user, no need to register, you can download them in JSON format. Dark For Cities, the list of classifications, in Lost At Night, image coordinates, and the Night Cities of ISS, the relationship of image points and their corresponding coordinates.

This allows any researcher to conduct a verification process georeferencing results, in addition to the verification process easier.

Image visualization. As a result of georeferencing has been said above that an geoTiff file is obtained. This is displayed through Google Maps Engine [Google] platform. Each image is correctly oriented and superimposed mapping. This tool allows to change transparency, zoom in on each image and scroll through all the images that are being georeferenced. Using this platform, thanks to the offer of Google Spain, allows everyone to have quick access to the results and to compare them with the environment.

Fig 10 Distribution of georeferenced images on Google Maps Engine

FUTURE WORK

Much remains to be done, especially in the third application. It is a living project that continues to evolve, especially in the part concerning the publication of final images and analyzing them.

With the set of georeferencing images being passed to a new phase of scientific analysis of them. The ultimate goal is to identify the sources of more light output and make studies are distribution of these emissions. This is achieved by applying the detailed process [5]. The images used are not directly from this project. Original taken by astronauts in RAW format are used, and the parameters are used to georeference each image.

This way you can use each image as if it were a map layer for comparison with other more to help identify the light sources responsible for each point. For each image, distribution is obtained isophotas

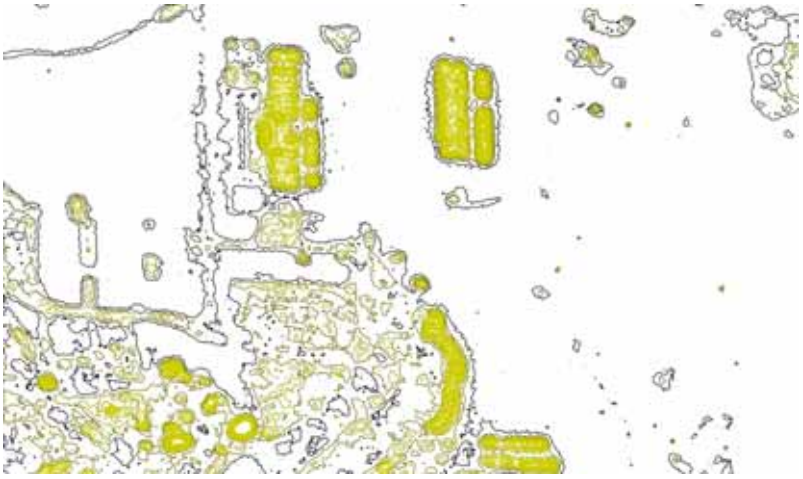

Fig. 11 contour lighting in the area of Barajas airport

Across the geographic information in digital elevation model generated from contour lighting, copper 3D model that can identify the elements responsible for each emission is obtained. In Fig. 12 is also used, the layer of PNOA Aerial orthophotography.

Fig. 12 Digital Elevation Model using altitude as the amount of light emission

CONCLUSIONS

At present we have identified all the images in the catalogue of all ISS missions Cities At Night. Location within LostAtNight is running, taking more than 135000 images treated. Cities At Night Inside were treated properly georeferenced images and 1948, you being posted on Google Maps Engine 114 total.

In addition to the imaging results, the main conclusion to be drawn from this project is that the support of volunteers has been key to its success. Such projects may be contacted scientists with the general public by involving them in scientific work.

It has also been able to utilize all the work carried out in the different missions.

ACKNOWLEDGMENTS

This section could occupy the whole space of this paper, as were thousands of volunteers who participated, and continue, in various applications. The authors wish to express their gratitude to all of them, many anonymous, but who have contributed their selfless work of this scientific work, and who believed in this project.

We also want to thank the support provided by NASA and ESA, as well as other national organizations as CSA-ASC Canada and the astronauts who have made the shots, and the Cultural Centre Media Lab Prado. Do not want to forget all the world's media, which has been echoed by the project, both in its print, electronic and through their participation in social networking issues.

A special section requires the personnel responsible for Crowdcrafting platform.

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