ASTRONOMICAL OBJECTS DETECTION IN CELESTIAL BODIES USING COMPUTER VISION ALGORITHM

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ABSTRACT

Computer vision, astronomy, and astrophysics function quite productively together to the point where they are completely logical for each other. Out of computer vision algorithms the progress of astronomy and astrophysics would have slowed down to reasonably a deadlock. The new researches and calculations can lead to more information as well as higher quality of data. Consequently, an organized view on planetary surfaces can change all in the long run. A new discovery would be a puzzling complexity or a possible branching of paths, yet the quest to know more about the celestial bodies by dint of computer vision algorithms will continue. The detection of astronomical objects in celestial bodies is a challenging task. This paper presents an implementation of how to detect astronomical objects in celestial bodies using computer vision algorithm with satisfactory performance. It also puts forward some observations linked among computer vision, astronomy, and astrophysics.

KEYWORDS

Algorithm, Astrophysics, Astronomy, Computer Vision, Crater, Detection

1. INTRODUCTION

The detection of astronomical objects in celestial bodies using the techniques of computer vision is not new. Many researches, related to astronomy and astrophysics focused around computer vision, have been performed [1-7]. Takahashi et al. [1] mainly focused on spectro-polarimetry of reflected light from exoplanets which was anticipated to be a powerful method for analyzing atmospheric composition and atmospheric structure. Their concept is one of the more fascinating aspects of using computer vision algorithms for defining features of an exoplanet to analyze of its atmosphere. After establishing analytically derived error formulas the outcome is the estimation for a number of planets, where detection of water vapor is possible. This leads to the resulting calculations of a relatively high number of searches for planets that are possibilities. Explicitly, the characterization of planetary atmospheres using spectro-polarimetry is genuinely possible with an ELT (Extremely Large Telescope) and a direct observing spectro-polarimeter. A healthy amount of an important discovery on survivability of exoplanets came from the TRAPPIST-1 system which made it possible to characterize potentially habitable planets orbiting a nearby ultra-cool dwarf star. Bourrier et al. [2] described the method of performing a four-orbit reconnaissance with the space telescope imaging spectrograph located on the Hubble space telescope which in turn allows the study of the stellar emission at Lyman-α. The Lyman-α line is a spectral line of one-electron ions in the Lyman series which is emitted when the electron

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declines from the principal quantum number being two orbital to the principal quantum number being one orbital. However, their study assesses the presence of hydrogen exospheres around the two inner planets and it determines their ultraviolet irradiation. The lack of proper database management in the gathering of astronomical data as the images and other aspects of databases in astronomy can be large and inefficient. But Erkeling et al. [3] suggested and resolved on the issue at hand. The work of Romano et al. [4] is among the interesting aspects of computer vision in astronomy, as it focused on stellar information which in turn can affect every other astronomical object. They introduced an application of support vector machines (SVMs) that can identify potential supernovae using photometric and geometric features computed from astronomical imagery. Nagel et al. [5] and Upadhyay et al. [6] focused strictly on analysis of surfaces. Nagel et al. [5] discussed general aspect that can be applied to astronomical imagery. Upadhyay et al. [6] used established algorithms and applied them to the surface of the moon to detect craters. To create an encompassing aspect, Nakajima et al. [7] tied to do the spectro-polarimetric characterization of exoplanetary atmospheres. They introduced a method of molecular line spectroscopy of M dwarfs. Carbon and oxygen abundances are derived, respectively, from CO and H_2O lines in the K band which is then applied to Gliese 229A, the primary star of the brown dwarf companion, and Gliese 229B. All of the aforementioned works have separate algorithms which lead to a specific result using astronomical data of more than one simple nature. The goal is to ideally incorporate these parts as a solution to exoplanetary research in general. This incorporation would mean that further work would use a limited amount of data to characterize an astronomical object. For example, an exoplanet using aspects like spectro-polarimetry and spectroscopy, while objectively it could analyze the surface [8] of the object if the data were more meticulous. There are many algorithms which would be implemented as part of the resulting entity.

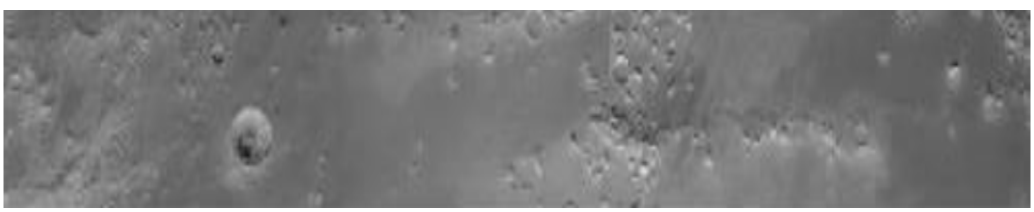


Figure 1. How to detect the number of craters from this sample image of the planet of Mars?

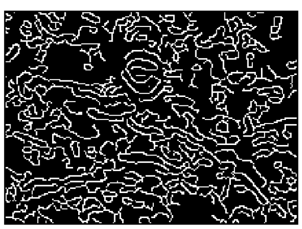
Crater is one of the key astronomical objects in celestial bodies. Crater detection is one of the key interests of many computer vision researchers [9-11]. Craters provide key information on planet formation. Statistical information of the size and number of craters help in determining the geological age of a planetary surface. Detection of craters is challenging because they come in all shapes and sizes. Size is one of main problems, as some craters could be a few pixels wide while others could be hundreds of pixels wide. Craters can be inside of other craters. Color of the craters can play a dramatic role. Different celestial bodies usually have different surface colors. For instance, the Mars is more orange and red in color while its moon the Phobos is greyer in color. Shades of craters play an important role, i.e., craters can contain shades due to neighboring hills or mountains. Such craters have been proven to be the hardest to detect. Various methods for detecting craters autonomously using computer vision have been applied but the methods have a high error percentage and the images from various satellites differ a lot from one another along with their thresholding conditions. For instances, Honda et al. [9] added a variant of the genetic algorithm to form a candidate of craters before using a self-organizing mapping to categorize the craters from non-craters. Meng et al. [10] constructed candidate areas that might contain craters. Their method represented a boost in performance. However, Hough transforms are essential in the algorithm used for this variant of autonomous crater detection. Viability becomes a problem when the craters do not contain a clear edge, resulting in false positives. Mu et al. [11] used ideas from biology to detect craters on celestial bodies. Craters do have some features like cells and they attempted to try cell algorithms on crater detection. The cells, on which the algorithm was applied prior, were complex cells of the human cortex. As with cells, the craters were subjected to a variant of an approach that strives to improve the Haar like features, which contain gradient texture information. Hence it is making easier to detect them in the long run.

In this paper, we are more interested to focus on crater detection in celestial bodies. Figure 1 demonstrates a sample image of the planet of Mars. We wish to detect the number of craters exist on this image. How can we detect the existing creators in this image? We have implemented an algorithm based on circular Hough transformation to detect craters. The algorithm constructs candidate objects that resemble the looked-for objects, whether they are perfectly or imperfectly shaped. The candidates are chosen on the basis as a local maximum in the parameter space. The algorithm was applied to detect craters from the online available Planetary Science Archive Images of the Mars [12]. We obtained some convincing results in terms of crater detection.

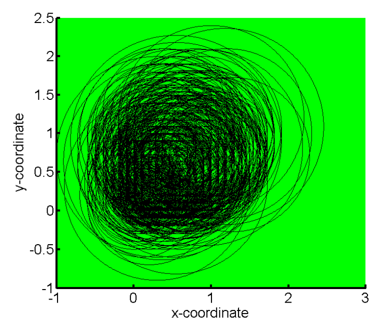
The rest of the paper has been organized as follows. Section 2 discusses algorithmic steps. Section 3 presents sundry experimental results followed by some of our observations and a few clues for further investigation. Section 4 makes a conclusion.

(a) An original camera view image of size 156x214x3.

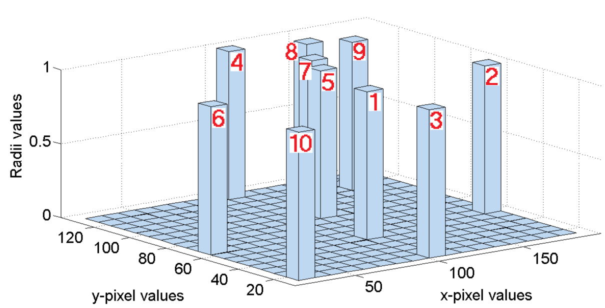
(b) The converted grayscale intensity image of size 156x214.



(c) The found edges in the grayscale intensity image using Canny approximation.



(d) The circles on hough transform image.



(e) The most 10 prominent peaks order on the hough transform image.

(f) The most prominent peak has been located on the original image.

Figure 2. An example of the algorithmic steps of our implementation.

2. ALGORITHM

We have implemented a crater detection algorithm to detect craters from images of celestial bodies. Our algorithm is based on circular Hough transformation. The Hough transform is a technique which can be used to identify the parameters of a curve which best fits a set of given edge points. This edge description is commonly got from either a Roberts cross operator or a Sobel filter or a Canny edge detector. But these edge detectors may be noisy because there would be multiple edge fragments corresponding to a single whole feature. The output of an edge detector only determines the location of features an image, and then Hough transform determines both type of features and how many of them exist in the image. However, these properties of Hough transform provide us a reasonable selection for crater detection without limiting the possibilities to one astronomical object. It constructs candidate objects that resemble the looked-for objects, whether they are perfectly or imperfectly shaped. The candidates are chosen on the basis as a local maximum in the parameter space. Standard Hough transform and circular Hough transform are used in many computer vision applications. The standard Hough transform uses the parametric representation of a line to detect straight line. The input of this transform is usually a binary image containing the edge pixels. During the transform, it iterates through the edge points and calculate all {angle, distance} pairs for them. Each sinusoid curve belongs to a point. The crossing of two sinusoids indicates that the two corresponding points belong to the same line. The more sinusoids cross a given point, the more edge points are on the same line. However, we have implemented the circular Hough transform to detect astronomical objects such as craters. The circular Hough transform relies on equations for circles. Thus it has 3 parameters namely the radius of the circle as well as the x and y coordinates of the center. A larger computation time and memory for storage are required to compute these parameters. Thus it increases the complexity of extracting information from an image. For this reason, the radius of the circle may be fixed at a constant value. For each edge point, a circle can be drawn with that point as origin and radius. The circular Hough transform also uses a 3D array with the first two dimensions indicate the coordinates of the circle and the last third specifying the radius. The values in the array are increased every time a circle is drawn with the desired radius over every edge point. The array, which kept counts of how many circles pass through coordinates of each edge point, proceeds to a vote to find the highest count. The coordinates of the center of the circles in the images are the coordinates with the highest count. Suppose that Figure 2 (a) demonstrates an image of the Moon surface. We are interested to look for specific patterns which exist on its surface. Especially, there exists a visual crater in it. How can we detect that? The images of Figure 2 (b)-(f) depict the algorithmic steps of our implementation to detect the crater.

3. EXPERIMENTAL RESULTS

3.1. Experimental setup

Basically, we have performed our experiment on a computer of 8-Core CPUs at 3.50 GHz with 16 GB RAM. The algorithm was tested against the online available Planetary Science Archive Images of the Mars [12].

3.2. Detection results

The camera view images in Figure 3 (a), (c), and (e) depict three of the Planetary Science Archive Images of the Mars [12]. The algorithm had almost consistent results with satisfying accuracy as shown in the images of Figure 3 (b), (d), and (f), respectively. Although an excellent outcome of the algorithm is desirable for any application related to astronomy and astrophysics, the existing outcome of the algorithm is not so bad. But it is very important to try making improvements in the field of computer vision which by extension makes advance in astronomy dynamically. Any observation made on the aspects, ideas, theories, and facts achieved through the analysis of data and astronomical imagery is worth partaking by considering as different outlooks and minds reach their aim in various ways. The observation can lead into more interesting connections made between computer vision and the entire field of astronomy. Without the help of computer vision algorithms, the factual data reached through the inputs of multiple sources the progress would have slowed down to somewhat of a standstill.

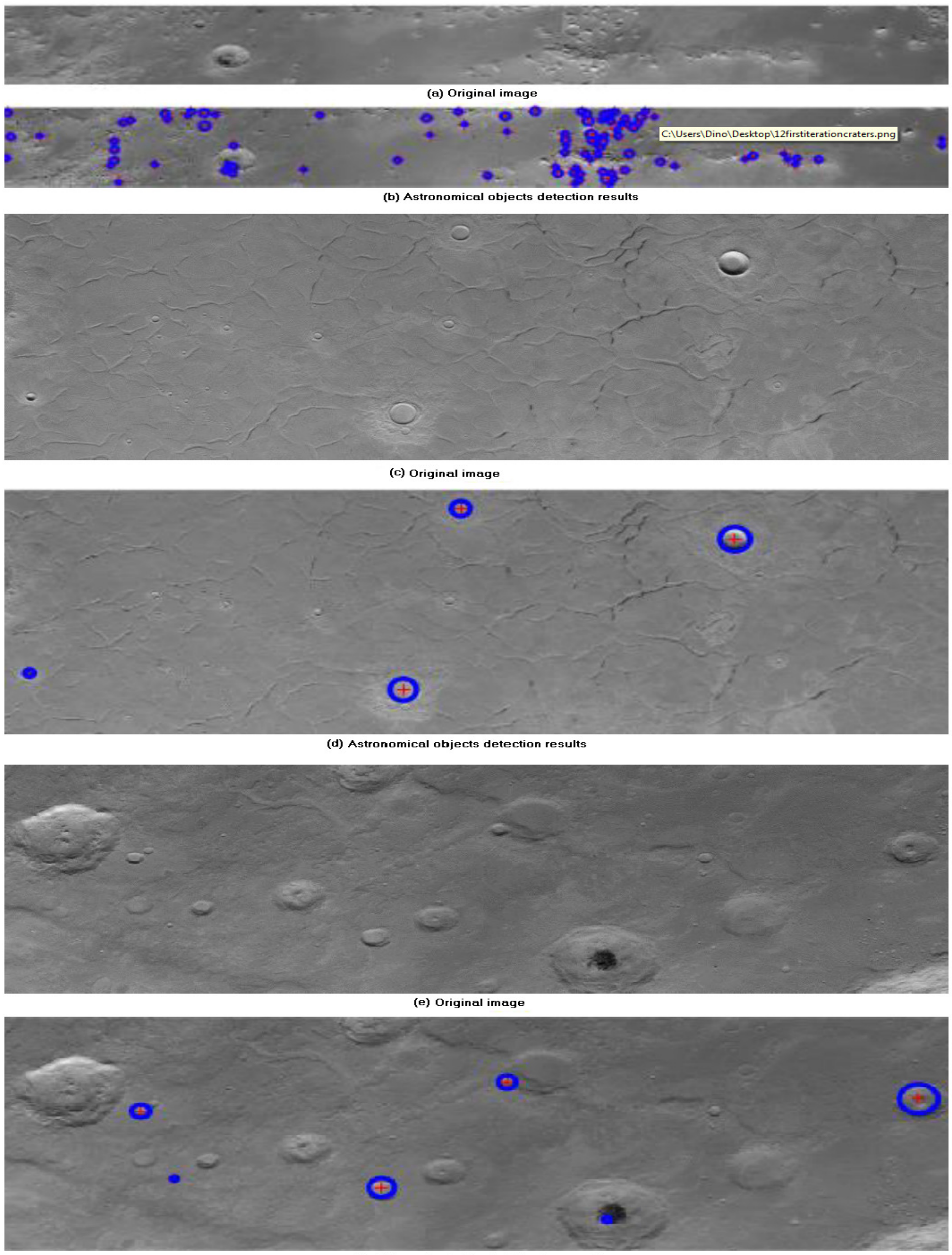


Figure 3. (a), (c), and (e) belong to camera view images; whereas (b), (d), and (f) depict the detected craters as pointed to the blue solid circles with red marked centers.

3.3. Our observations

As this paper has structural points, there is a way to gradually define the technical observations that will propel the idea further and inevitable lead to palpable success. It is a fair assumption to make that many of the aspects that surfaced as parts of the research might be unknown to a substantial percentage of potential readers which would place higher education as part of computer vision as an immediate success of this paper. Valuable findings will be resolved with a discourse on befitting areas and observations that always convey progress in development. When explaining spectro-polarimetric characterization of exoplanetary atmospheres [7] it was formulated and defined what the goal of that direction was. One of the findings was the understanding and recognition that the task of probing atmospheric composition and structure would be able to be completed using direct observing instruments. It is fascinating indeed. It was concluded that detecting these features would have requirements which might have to be met and that it could have obstacles in the form of errors which may have to be overcome. Once feasibility is evaluated, the action creates results. Another observation is that after going through a set of defined aspects in the realm of solar behavioral patterns, there are ways to make the detection of certain events much more efficient. Emphatically, it would take up fewer resources. In this case, SVMs created the improved situation during supernovae recognition.

Once the realization was made that anything which predicts or detects patterns in any analytical way can be applied to more than just what it was originally used, i.e., the doors opened to a much wider field of view. So far the focus was on comparing large areas that can be interchanged to work in different environments and situations. But the fact is that any type of pattern recognition algorithms would yield dissimilar results. If there are established pattern models for muscles, any given algorithms might produce stimulating results when applied to a much larger scales, e.g., potential maps of exoplanetary surfaces. The databases which technically could have an endless amount of data are not managed to the smallest points. For this reason, the multi-temporal database is used. It can be considered an inspiration for astronomers to thrive towards creating an easily accessible data warehouse which would make the target learning process more powerful. Another technical observation is the fact that upon understanding the position and advancement made when discussing the Gliese 229 star system it is official proof that when it comes to scales of that size. A small part of information on one object can alter and complete missing data to encompass the more knowledgeable way of thinking. Detecting crater boundaries was one of the more palpable results. In the case of creating the resulting images, the findings were based on the different ways astronomical objects behave that are still susceptible to comparison and in that way comprehension too.

One can try to make improvements in the field of computer vision which by extension makes progress in astronomy and astrophysics in a dynamic way. It is worth mentioning that any observation made on the aspects, ideas, theories, and facts achieved through the analysis of data and astronomical imagery is worth dealing. Because of diverse views and minds reach their goal in diverse ways. Without the aid of computer vision algorithms the progress of the factual data reached through the inputs of multiple sources would have slowed down to somewhat of a standstill. Consequently, when focusing on establishing advancements the factors such as the possibility to identify exoplanets, categorize astronomical objects, and define the details in a high resolution image of a planet’s surface with the help of computer sciences should be insisted. Branches of astronomy and astrophysics can be connected effortlessly without worrying about the apparent intense differences. Many research works connect to the astronomical object surface study in a productive way through the analysis of universal events e.g., supernovae and the structural categorization of exoplanets. This should drive any person with an interest in astronomy as well as computers to try and create the most effective applications using astronomical imagery. It can be observed that through any situation and by all means we can use computer vision algorithms to find out more about any astronomical and astrophysical aspect. Many researches were facing towards a focal point of matter as target analysis. For analyzing a small sector of the observable universe, we can use computer vision algorithms to determine whether a black hole or absence of light exists there. The absence of light towards the center of a distant area can be categorized undoubtedly much more efficient with computer vision algorithms and their implementations. By some luck, if a method is invented to record a miscellaneous type of aspect of the Universe (e.g., dark energy), then the data gathering and analyzing method will clearly be through computer vision means.

3.4. Future works

As the inevitable research in the field of astronomy and astrophysics continues, there will be separate future works and projects. A web application would be developed to focus on assisting astronomers, astrophysicists, and inquisitive stargazers to acquire factual information on astronomical data. Such web application can eliminate all existing redundant steps. Many computer vision algorithms are used in astronomy and astrophysics. A dedicated astronomical library for the beginners with unique and essential features would be implemented. The presented solution of this paper would be implemented on a larger scale with a more functional duality.

4. CONCLUSION

We implemented a computer vision algorithm to detect craters in celestial bodies. The efficacy of the algorithm was satisfactory for many applications of astronomy and astrophysics. We also presented some observations connected among computer vision, astronomy, and astrophysics. Without any shadow of doubt, we can conclude that out of computer vision algorithms the advancement of astronomy and astrophysics would have slowed down to somewhat of a deadlock.

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