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Research Impact of Astronomical Image Processing

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Abstract— *There are numerous applications of digital image processing in different emerging areas of research activities such as satellite imaging, medical imaging, biometrics, underwater imaging etc. Astronomical image processing is another challenging area of research where digital image processing concepts are hugely used in the analysis and processing tasks. There are research contributions in the field of astronomy, particularly those dealing with noise signals in the images captured by charge coupled devices (CCD) cameras. Image Enhancement and restoration techniques play very important role in modern astronomical science and study thereof. This paper presents an assessment of research work and its impact of the related research activities in astronomical image processing.*

Keywords— *Astronomical image, CCD (charged coupled device), image processing.*

1. INTRODUCTION

With basic contributions in the field of Medical Image Processing [1] and Applications (Sinha et al., 2014); Biometrics [2] and its applications (Sinha et al., 2013), it has been extensively studied that digital image processing has wide range of applications starting from biometrics to remote sensing applications. The research works that were applications of image enhancement methods [3] in reduction of speckle noise from ultrasound images (Sinha et al., 2008); Contrast enhancement [4] of underwater images (Sinha et al., 2008); and Assessment of image restoration methods [5] for remotely sensed images (Sinha et al., 2010) substantiate the usage of image processing tools and techniques in applications related to remote sensing, satellite imaging and astronomy.

Actually, all image processing tasks generally involve few important stages namely pre-processing; enhancement & restoration; segmentation and classification; and features for machine learning. The features which are extracted from the images are very useful in determining distinguished characteristics and classification of images [1, 2].

Now, astronomy related research includes huge data for processing; and one of the important data is image signal that requires proper interpretation using a set of tools [6]. The descriptions of image information does not only confine to beautiful appearance of the images but the intricate details of the images. The contrast, intensity, colour, resolution, presence of noise in the signals etc are very important in the process of analysis of astronomical images [7]. An image processing tool, *AstroFracTool*, was developed that provides a set of enhancement methods applied over the digital images, generally the recording time of astronomical images is very large requiring very long exposure to capture the images. The exposure for long time creates difficulties in terms of noise signals that could be addressed using an appropriate image de-noising method [8]. There is paradigm shift in the approaches used by astronomical researchers and scientists and they have been switching to non-traditional approaches, using computer-aided analysis of the images. Virtual observatory projects are implemented and International Virtual Observatory Alliance (IVOA) is constituted that takes care of developing the required standardization at international level [9].

Extragalactic field is used to get deep optical image that collects information of population of galaxies in the universe. CCD (charged coupled device) mosaic camera was used and *Spitzer space telescope* has been implemented in previous research work. The noise due to instrument disturbance or interference is also a concern that requires attention [10]. The images are formed by principle of reflection and incidence; whatever amount of light is incident its some part is reflected and accordingly the image formed. Therefore, in this process of image acquisition, noise or artefacts are added in the images that should be removed so as to get correct information about astronomical images [10]. Optical images are captured mostly by CCD cameras [11]. There are thousands of methods available for noise removal which can remove Gaussian noise, speckle noise, salt and pepper noise, dark noise and the improvement of noise removal, that is enhancement factor can easily be computed using a set of statistical parameters, such as mean, variance, entropy, CNR (contrast to noise ratio), PSNR(picture signal to noise ratio) etc [12]. Wavelet transform based methods, Fourier transform based methods and many others are there in the literature. One common challenge remains

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unaddressed is the robustness which means that a method should be developed so that it could be used to solve all types of noise signals from the images [1, 2]. Image enhancement still remains a subjective matter [12]. Celestial objects are transient in nature and the brightness is found to be changing, such as supernova, and hence dealing with brightness change is very important research task in such types of digital objects. Image subtraction or contrast enhancement or similar of such method can be used in this type of situation where the analysis and interpretation of images becomes bleak due to noise present in it [13, 14].

Tutorials on image processing methods, filtering techniques and few research contributions are reported in literature utilizing the information theory concept [15, 16]. Sometimes, if Nyquist rate is improper then problem arises in resolution and signal to noise ratio (SNR) is also disturbed. This is another challenging task that could be solved with the help of suitable image processing techniques. Colour images and other high quality images are produced using CCD detectors that increase the physical size of image and this dimensionality problem can be addressed by appropriate image processing step [17-19].

2. RELATED RESEARCH

Although, researchers and scientists have attempted applying image processing tools and techniques for better understanding and interpretation of astronomical images but the impact of research and development activities specially utilizing image processing is bleak due to limited research on these areas. This section highlights few important contributions on astronomical image processing and applications [6-19].

Wiley et al. [6] studied image processing for moving sources and computational computations hugely required. Massive data are reported that could be dealt using cloud computing. This presents scalable image processing pipeline architecture for the image database using Hadoop. The multiple overlapping images are registered, integrated and stitched into a single overarching image. Pre-filtering is used to remove irrelevant images from the database. Massive, parallel paradigm based computing was suggested in image co-addition system. This work is not more on image processing techniques but on parallelism used to deal with computational complexity. Christensen et al. (2014) attempted in determining parameters that could influence how well the image can be viewed and the images become quality images from observatory perspective. Theses parameters include good definition, colour, high SNR, removal of artefacts, and good photogenic resolution. Photogenic resolution depends on exposure and hence the exposure related noise can be removed and the resolution is enhanced. Good definition means more time is spent in dynamic range compression in the images. Proper colour combinations result in good appearance, which is important factor; along with this, artefacts were also addressed [7].

Marazzato et al. [8] suggested the implementation of fractional differential calculations for image processing tools which can be used in analysis of astronomical images. *AstroFracTool*, was proposed as enhancement tool for enhancing edges, applying basic operations such as image addition and image subtraction. This tool can be very useful in detection of faint objects and galaxy structures. Although, the tool was trial version and it needs improvement in implemented algorithms but it shows a roadmap to develop a framework of image processing analytics and methods to better analysis of astronomical and celestial images. Katz et al. [9] presents a survey on astronomical imaging data and describes the need for image processing task that could take large scale images and it was discussed using Montage tool. Clements (2016) studied that the experiments are to be performed over the extragalactic sky and capture the optical images using CCD cameras. The pixel counts and brightness play important role and a control is required in both of these factors [10].

Cadmus [11] proposed morphological operations and analysis for galaxies, comets and Jupiter. Remapping and brightness improvement were attempted using Polar and Frequency domain approaches. Image restoration of wide field comet was also achieved by removing sky background gradient values. The focus of work was on spiral galaxy NGC 7741. However, several additions and changes are there in the contribution that needs future work attention [12]. Long exposure, dark current is sources of noise in photographs of astronomy and the method suggested addressing the challenges due to this type of noise. CCD cameras produced black and white or gray scale images over which the image de-noising was tested. While removing the noise, sometimes graininess is also removed this is required in faint stars and nebula preservance. So, an offset or threshold is used to determine the level of graininess that has to be suppressed over which the details to be preserved [12].

Kirov [13] studied a new area of astroinformatics using ICT (information and communication technology) in institutes of the Bulgarian Academy of Sciences and a joint project, “Astroinformatics” was launched. It aims at preserving cultural and historical heritage of astronomical observations. The system employs various instruments for sampling and digitization; processing and representation; and finally for storage of astronomical images in the databases so that the information could be retrieved for future use. Zhao (2013) opined about image subtraction as an effective method used in astronomy for finding and exploring transient objects, which are actually time varying brightness based objects or images. Parallelization of HOTPANTS, astronomical image subtraction package was used on CPUs and GPUs by Andrew Becker and group. There was four times speed up in P-HOTPANTS architecture as compared to existing HOTPANTS that was tested running on a desktop with an Intel i7 CPU and an NVIDIA GTX580 GPU [14].

Kubickova [15] presented a study for finding meteors in astronomical images using Hough transformation. This was implemented in MATLAB based image processing tool that helps in processing and analysis of static digital meteoric snaps. Meijring (2002) presented an overview of interpolation theory for astronomical image processing applications [16]. Masci (2004) suggested genetic algorithm for image registration and refinement of astronomical images by matching positions and fluxes of available point sources in overlapped image regions. The work was tested with the help of Monte Carlo simulations and compared with image data acquired from the Infrared Array Camera (IRAC). The Spitzer Space Telescope was used in data capturing and the data refinement that was achieved range in ~70 and ~280 mas (2 j radial). The input digital images were calibrated properly over non-uniform pixel values. However, sufficient area overlap was required between adjacent image frames [17]. Lubkin (1995) reported that astronomical image processing has become extremely sophisticated tasks employing image enhancement, restoration, registration and classification. Collaboration was aimed to apply image processing tools over images to detect micro-calcifications [18]. Rector [19] discussed about quality of astronomical data and the need for image processing techniques to improve the quality of images.

The above study of literature based on astronomical image processing study suggests that there is no general theory or framework of image processing tools that could be used commonly to the images for their better understanding and analysis.

3. PROPOSED METHOD AND RECOMMENDATIONS

From the literature survey extensively made and reported few of them; it is obvious that the image processing has been used over astronomical applications very limited way. So, based on other potential applications and relevant usage such as satellite and remote sensing images; a set of tools or framework of image processing techniques, is suggested here; that can be applied over astronomical images so as to achieve better understanding of images that can greatly help the scientists and philosophers working in the area of astronomy.

Fig. 1 shows a flow diagram highlighting the stages of image processing to be applied over astronomical data. The stages are briefly explained as:

- *Image acquisition*— The astronomical data is to be pre-processed and image data has to be separated and finally a database of images to be developed.
- *Pre-processing*— The raw data has several problems related to improper format, poor lighting, long exposure etc and therefore, a set of pre-processing tools requires to be applied over the astronomical images. The pre-processing steps include image de-noising methods that are different types, namely spatial domain and transform domain methods.
- *Feature extraction*— The image features are many as can be seen in various literatures [1, 2], and hence an appropriate set of features may be used for subsequent stages of the astronomical image processing.
- *Segmentation and Classification*— Features may then be represented into templates if required; otherwise we can use suitable segmentation methods to select the regions of our interest and apply certain classification algorithms to classify the astronomical data or images into suitable information.

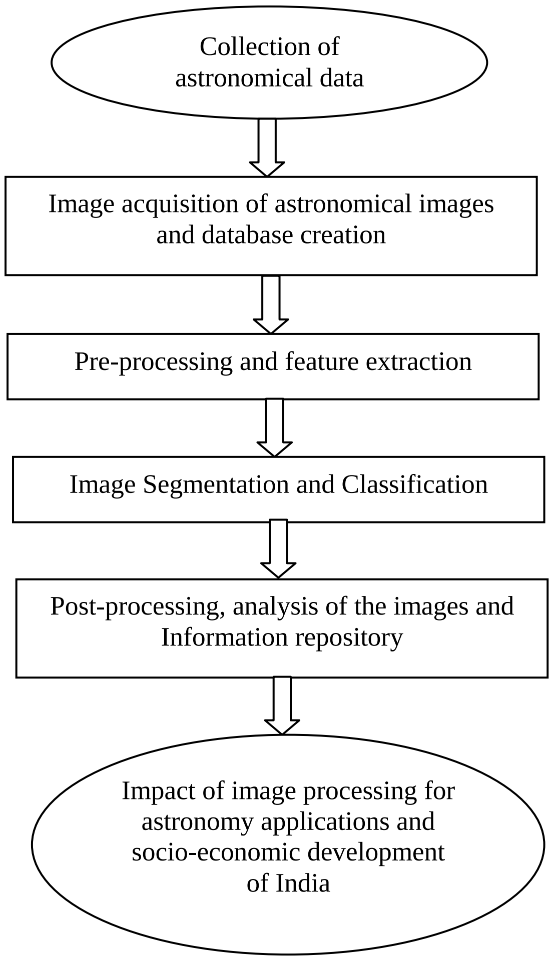

Fig. 1: Framework of Astronomical Image Processing.

- *Post processing and information repository*— Finally, the classified data may be used to conclude various observations deeply explaining about the images. The post processing results can be stored in information repository for future use.

- The impact study of astronomical image processing over socio-economic development of the country.

Astronomy has potential scope of using image processing techniques; rather a framework of image processing tools is suggested and recommended for improved visualization and information extraction from the astronomical data, images in particular.

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