FEATURE EXTRACTION THROUGH TIME

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ABSTRACT

Robots that perform repetitive tasks without human intervention have been used for decades in automated manufacturing. These systems are programmed to perform simple repetitive tasks with little or no ability to sense or react to changes in their environment. Collisions and other undesirable events are prevented by careful control of their work area. If a collision does occur it is problematic, but work can usually continue after an investigation, the loss of a few parts and some repairs.

Robotic collisions in space do not follow this model. The consequences of a collision for a robotic system during a space flight can be catastrophic. Even a minor collision between the robot and an object in space could cause a system failure, the loss of the mission or even the death of an Astronaut.

There have been many suggested means for avoiding collision in space [1][2]. One approach for solving this problem is to use real-time vision data for authenticating synthetic models used in collision detection. There are many techniques for analyzing digital images, however, space based imagery is constrained by a number of technical challenges including challenges related to imaging, lighting variation, object appearance and system constraints.

INTRODUCTION

This paper addresses challenges related to lighting variation in order to extract key features within a scene. It is proposed that the drastic change in sunlight and shadow within an scene over time can be used to filter out extreme lighting conditions.

Spacecrafts travel at a high rate of speed causing sunlight and shadow to pass over a scene in a matter of minutes. Using this motion to our advantage, the extreme sunlight can be tracked and filtered out to generate a new low intensity image without the loss of image quality in pixel contrast. With this new image, key objects should be able to be extracted for further analysis.

BACKGROUND

Space Based Imaging

Robotic systems will play an important role in reducing hazards and increasing productivity for both human and non-human space exploration. Examples of this include the Mobile Servicing System

(MSS) [3][4] and the Mars Exploration Rovers [5].

Figure 1: MSS & Mars Rover

As tasks performed by these robotic systems become more complicated, the need for more human-like characteristics are required. One of our most important senses is vision. Robotic vision is often the ability to process images in such a way as to enable more efficient, accurate and autonomous control. However, robotic vision on-orbit is constrained by lighting variation. The appearance of objects can vary drastically in space depending on the change in the amount of ambient light that is illuminating a scene as it hurtles through space.

Figure 2 is an example of a set of images taken from the cargo bay of the Space Shuttle. These images of the Canadarm2, taken over several minutes, clearly shows how drastic lighting changes can affect the quality of an image.

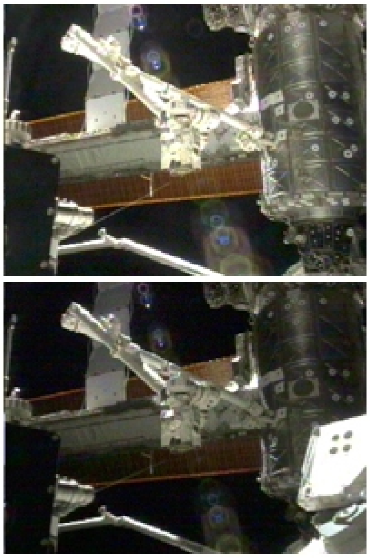


Figure 2: Example Lighting Differences

There have been several vision-based applications that have been developed to assist with on-orbit robotics. The use of vision for target detection is one example used to support on-orbit robotic operations.

Vision-Based Target Detection

The MSS is used to position large modules during construction operations of the Space Station. However, there are measurements and control problems associated with precise positioning. To help solve this problem a vision-based sensing system [6] called the "Space Vision System" (SVS) [7] was designed.

The SVS system digitizes video inputs and processes the digital data. The processed video data is then used to calculate position and orientation measurements of the payloads with respect to known coordinate systems.

A major limitation of the SVS video processing system is in the way it deals with lighting changes. If the lighting is poor SVS will simply discard an image and attempt to reacquire the target on another video camera or at another time through the same camera. As a result, it is impossible to recreate a camera position and setting exactly—making scene calibration impossible.

NASA has investigated the use of machine-vision and target geometry for truss structure assembly [8][9][10]. The NASA Langley Research Center developed a tele-robotic automated structural assembly system for large space truss structures. Targets with retro-reflective dots are used to help align junction points during construction.

Target identification is performed by looking for "target blobs" in order to find the dots. However, lighting causes a large number of extraneous "blobs" to appear making target differentiation impossible.

PROPOSED SOLUTION

Using a sequence of images from one camera taken over time, dynamic lighting conditions can be filtered out and a new optimized image generated for additional processing.

By using Photometry and Mean Value Mapping a tone/contrast map can be generated for each input image. High tone and contrast areas can then be detected and filtered out. The resulting low-contrast pixels are then combined to generate one image with "controlled" lighting. We call this approach "Feature Extraction Through Time (FETT).

The use of FETT for resolving lighting problems can be divided into the following four steps:

1) Acquire Images

A series of images are taken over time from one camera. During the time period the shift in light will change dramatically giving several different contrast images of the same view.

2) Create an Intensity Scale

Using photometry calculations generate an intensity scale base on the pixel intensity for all input images.

3) Perform Mean Value Tone Mapping

A grid is placed over each input image where area [1,1] on Image-1 lines up with area [1,1] on Image-2 and so on. Mean Mapping Values are calculated for each image and compared.

4) Generate New Image

The selected images and regions are then extracted from the original images and pieced together to generate a new optimized image for further processing.

A block diagram of the process is shown in the figure below. .

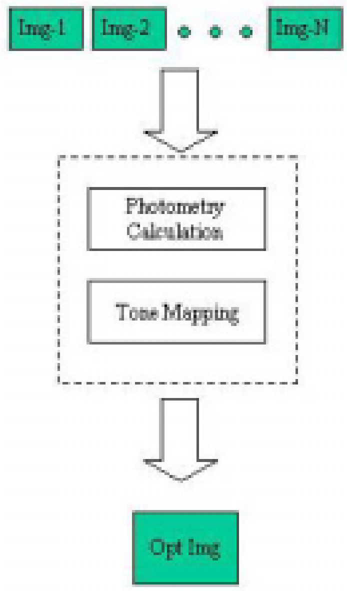


Figure 3: Process Block Diagram

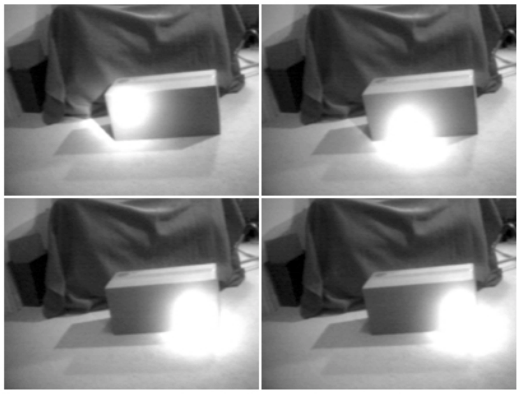
RESULTS

A series of tests have been performed using the FETT method. Testing was conducted in two steps.

First a test environment with controlled lighting was employed. Next we used on-orbit images where lighting was not controlled.

Controlled lighting tests were completed using two basic shapes--a box and a cylinder. A light was slowly moved across the shape and images were taken over time.   The image sequence was then used to extract the variance in lighting, producing an image of the object with “adjusted” lighting.

Below is an example of a test depicting a cardboard box as a simple object. Figure 4(a) shows the image sequence (taken over time) of light transitioning across the surface of the box. Figure 4(b) is the optimized image generated after the light is adjusted using FETT.



(a)

(b)

Figure 4: Controlled Light Extraction

On-orbit imagery from downlinked video and past mission tapes was next used for testing.

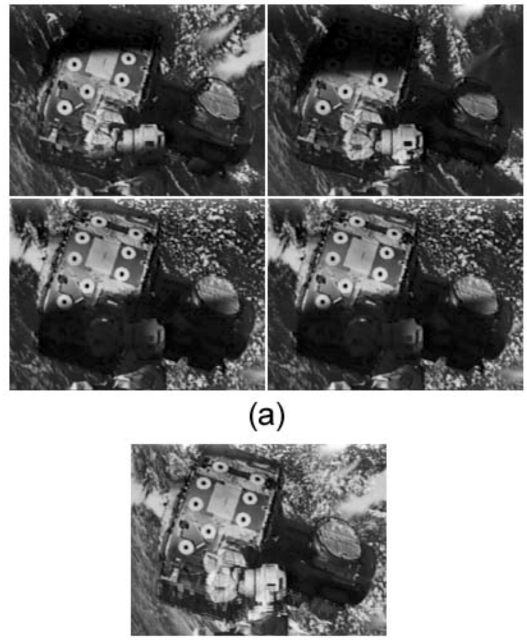
The first test case was to extract bright light from within an image. The following is a view of the Latching End Effector (LEE) of Canadarm2 in the cargo bay of the Space Shuttle. Figure 5(a) shows four images taken over the span of approximately two minutes. As can be seen, the transition of light/shadow produces four very different images from the same camera. Figure 5(b) shows the optimized image generated with the bright light filtered out.

(a)

(b)

Figure 5: Uncontrolled Sunlight Extraction

In some cases the “better” pixels are contained within the light and thus the shadows must be filtered out. A shadow extraction test was also performed as a test case using on-orbit images. Figure 6(a) is a view of the Quest Airlock as shadows transition over it through time. Figure 6(b) is the optimized image with the shadows filtered out.



(a)

(b)

Figure 6: Uncontrolled Shadow Extraction

CONCLUSION

This paper proposes a method for using a sequence of images taken from a single camera over time to extract extreme light and shadow from a scene. With the use of Photometry calculations and Mean Value Mapping techniques, sunlight and shadow regions within a scene can be detected and removed. Using the remaining pixel information, an optimized image can be generated with better lighting for further processing by other vision systems to use.

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