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Project Title:

Produce a rectangular shaped 360° panorama from a series of omnidirectional camera images taken by Clearpath Husky rover, while reducing lens effects such as vignetting.

Project Description:

- ***Problem definition***
  Given a dataset collected by the rover during a run, how to produce a rectangular shaped 360° panorama around the rover given a camera frame, and how to reduce the vignetting effect?

- ***Relevance of the project to a Mars rover and why it is interested to me***
  Since the communication delay between Earth and Mars is at least 3 minutes [1], the Mars rover must operate fully autonomously, and it needs to operate safely for a continuous exploration on Mars. In my opinion, it is vital for the rover to be fully aware of its surroundings in real time. Being able to produce a 360° panorama with less flaws (e.g. by reducing the vignetting effect) during the rover's operation can be an important enhancement to the rover. Since the omnidirectional camera images alone are discrete, 'stitching' these discrete images and producing the panorama allow the rover to have a better vision of its surroundings. Therefore, it can operate more safely on Mars and bring more interesting news back to us.

  Personally, I think that having the rover producing 360° panoramas could be potentially contributing to VR applications such as VR gaming. One could produce a VR application directly from the images collected by the Mars rover. This can be exciting for some people including me. It can allow us to 'walk' on the real Mars! Moreover, since I am more of a visual type of a person, for this computer vision project, I would prefer working towards a result that allows me to 'see' it and to evaluate it qualitatively.

- ***Project details and general approach outline***

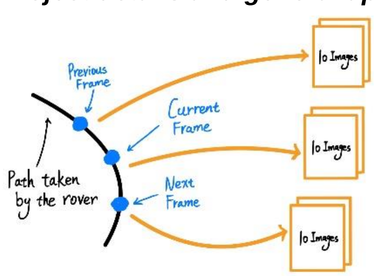

Figure 1: Illustration of the images used for producing the panorama

Here I want to talk a little bit about the rover's omnidirectional camera because the configuration of it is important for this project. The omnidirectional camera has two rows of cameras, each is consisted of 5 individual cameras [2]. Theoretically, based on this configuration, only one row is needed (i.e. 5 images) to produce a panorama for a given camera frame. However, this project aims to use more images to potentially produce the panorama with a higher quality.

For the first trial, given a frame, I intend to use 10 images from the 10 individual cameras as the input. If the result is not adequate, images from the previous frame and the next frame will be added (refer to figure 1) for producing the panorama for the current frame.

After the input is defined, the general approach will follow from the Automatic Panorama Stitching algorithm introduced in section 7 in Brown and Lowe paper [3]. Moreover, by looking at the images collected by the rover, one can notice illumination changes from cameras to cameras because the Sun is not always shining at the top of the rover (i.e. in a given camera frame, light intensities in different images are different) [2]. Hence, the advantage of this method I want to utilize is that it makes the stitching insensitive to illumination changes which can be important for improving the quality of the panorama created from the rover dataset.

Here is a brief summary of all intermediate algorithms/methods needed (in order):
SIFT (feature extraction) || *k-d tree (k nearest-neighbours)* || *RANSAC [4] (sample feature matches)* || *Homography (between pairs of images)* || *Multi-band blending (render panorama)*

- ***Software libraries intended to use***
  - *NumPy (for basic computations if needed)*
  - *Scipy (k-d tree [5])*
  - *OpenCV (SIFT [6], Homography [7], Multi-band blending [8])*
  - *imutils (potentially useful for making basic image processing such as translation, rotation, resizing easier with OpenCV) [9]*

- ***Portion of the CPET dataset intended to use for testing/evaluation***
  The dataset that will be used for producing the panoramas is a subset of Run3: Human-readable (base) data download (11.2 GB):
  omni_image{0 to 9} **||** *cameras_intrinsics.txt* **||** *omni_stitched_image*

- ***Resources required***
  No need for a GPU

- ***Potential challenges***
  1. *The major challenge needed to be overcame is improving the quality of the panorama (e.g. by reducing vignetting effect).*
  2. *The final shape of the panorama needs to be in a rectangular shape. Knowing the size of the rectangle that will be cut is important.*
  3. *If there are depth variance in the chosen images, I need to make special accommodations since homography does not work very well with those images.*
  4. *Algorithm introduced in the Brown and Lowe paper might be challenging to implement since there are some intermediate steps that I need to investigate.*

Project Evaluation:

- ***Quantitative & Qualitative metrics for evaluation the outcome***
  For the quantitative metric, omni_stitched_images from the dataset will be used as the benchmark for the evaluation of the outcome of this project. Given a frame, computing the RMSE value between the produced panorama and the corresponding omni_stitched_image. The less the RMSE is, the closer the project outcome is to the benchmark.

  In addition, for the qualitative metric, one should be able to see the difference between the produced panorama and the benchmark image. Based on the observation from the naked eye, one could make a heuristic comment on the overall quality of the panorama.

  By combining the above two metrics, one can determine the successfulness of the outcome of the project.

- ***Justification of the choice of the metrics***
  For the quantitative metric, since the stitched images were produced by a group of graduate students who are more experienced in making such panoramas, it would make sense to make their images as the benchmark and compare the outcome with it. However, if the project outcome was able to make better panorama, RMSE does not necessarily tell the quality of the outcome. In other words, if the outcome were able to deal with light intensity issues that were presented in the benchmark, the RMSE would be large. But, in fact, the outcome should be of a higher quality.

  Moreover, the reason I chose this project is because I want to 'see' the result. I believe that this is a project which the outcome should also be evaluated by our eyes. We can immediately provide the feedback to the outcome based on what we see. Hence, I want to add this qualitative metric to make up for the evaluation that cannot be done by the quantitative metric.

References:

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