Alvin’s Personal Notes

Context:

Goal: given a single image with shadows, produce a high-quality shadow-free image (same scene without shadows)

Classical CV Approach:

1. Estimate shadow scale factors
   1. Either in the image domain (pixel by pixel analyzing intensity value) or gradient domain (rate of change of gradient values)
2. Determine the shadow boundaries (detect where the shadows are)
3. Canceling the effect of shadow scale factors in the image aka reconstruction stage

Approach of 1.

1. Separate image into image channels (red, green, blue versions of same image)
2. Treat the image as a bunch of intensity surfaces added up (changes of intensity)
   1. Regions with shadows become intensity surfaces as well
3. A shadow removal technique
4. Computes the intensity surface of the entire images concurrently as opposed to a localized approach
5. Single model for the approximation of shadow regions (uniform and consistent methodology for handling shadows)

Benefits of 1.

1. Works for both shadows that are uniform and nonuniform (consistency of intensity)
2. Preserves original texture (how realistic the picture looks)
   1. The specific case of shadows w/ wide penumbras is challenging bc there is a gradual transition from shadow-free areas to umbra regions (darkest regions), could lead to unrealistic images
   2. This algorithm solves that shortcoming
3. Final shadow-free region enhancement: takes a look at the image with removed shadows, looks for noise/artifacts (unwanted severe variation of illumination) and reduces that
4. Global approach has efficiency advantages and can capture global features much more accurately, leading to much more realistic images

Disadvantages of 1.

1. Could have poor generalization performance
2. Run takes several minutes on a 500x500 pixel picture, current images are 8064 x 6048 from iPhone, ofc image reduction methods could be undertaken
3. Requires anchor points to be manually plotted, manually process images
4. computationally expensive, requiring complex mathematical operations to identify and reduce the effects of shadows created by objects within a scene

Approach of 2. (Specifically shadow detection + shadow removal)

1. Deep learning approach
2. Datasets: Road Disease, (Shadow dataset + Shadow-Free + Shadow-Mask Dataset)
   1. Pic of road disease without manual added tree branch in image
   2. Pic of road disease with manually added tree branch
   3. Shadow-Mask (black-white picture, white is where shadow is) created through third-party annotation program
3. Shadow removal model and road disease model were trained on the dataset
4. Simultaneously trains both shadow detection and shadow removal models based on GAN (Generative Adversarial Network) bc they are related tasks
   1. Type of neural network architecture used in generative tasks
   2. Consists of generator and discriminator
      1. Generator creates images
      2. Discriminator determines if image is generated or real (from dataset)
   3. Generator and discriminator are trained together and competitively
      1. Generator aims to produce images indistinguishable from real images
      2. Discriminator aims to distinguish generated from real better and better
5. Separated into G-D, D-D, G-R, D-R
   1. Input of G-D is original shadow image, output is image of predicted shadow location

Benefits of 2.

1. Unrelated to field

Drawback of 2.

1. Not discussed
2. (not discussed but assumed) Simple outdoor scenarios, model is not trained on scenes with cluttered backgrounds and shadow patterns, suffers from data scarcity

Approach of 3.

1. First train model on synthetic images and develop shadow detection model that is able to obtain a pixel-perfect detection map (able to accurately pinpoint for every pixel if it belongs to a shadow)
   1. adversarial-learning-based supervised model
   2. light-weight architecture
   3. skip-connections
2. Style transfer - adapting the synthetic model onto real world dataset
   1. Does this by converting real stuff into the synthetic style to mitigate domain bias and then feeds that into the model
3. For shadow removal, adversarial learning on synthetic data that has been converted to the real world style, also train the model on a real dataset
4. Shadow detection model is trained on synthetic and synthetic and passed onto the shadow removal model, which is converted into real style

Benefits of 3.

1. Uses a corpus of synthetic data to solve the issue of not enough data (usually tripled w/ shadowed, shadow-free, and shadow mask)
   1. Can be used to generate complex images, which a dataset has very little of usually
   2. Image rendering machine from gaming to capture photorealistic images (used for generating shadowed/shadow-free images)
2. Addresses the issue of domain variation (model on generated dataset vs model on real world dataset), usually would have to take expensive/long amount of time to create large dataset, unfeasible
3. Just as accurate as state of the art even with not spending that much money creating a really large dataset

Drawbacks of 3.

1. All experiments were performed on Intel(r) Core(TM) i7-5930K CPU @ 3.50Ghz and a 64GB of RAM running a 64-bit Ubuntu 16.04 edition. The software implementation has been in Pytorch on four Titan X 12GB GPUs. ADAM [24] optimizer was used in all the experiment with momentum
2. None, more data is always better

Approach of 4.

1. GPUs (Graphical Processing Unit) accelerates capabilities of said shadow removal/shadow detection algorithm through data parallelization
2. Simplifies computational steps/algorithm, removes steps that don’t compromise overall accuracy
3. ll GPU results were obtained using the NVIDIA Tesla P100 GPU that has 56 streaming multiprocessors each with 64 cores operating at 1190 MHz. All CPU results were obtained using Intel i7-8700 CPU operating at 3.2 GHz.
4. For Shadow removal specifically
5. Algorithm is split into 6 kernels, or components/algorithmic stages, and the GPU processes all 6 in parallel, shortening computation time
6. ensuring coalesced reads and writes will see a speed increase. Coalescing memory transactions reduces memory bank conflicts, which will decrease run-time

Benefits of 4.

Drawbacks of 4.

1. Shadow Removal Using Intensity Surfaces and Texture Anchor Points
2. SRODNet: Pavement Crack Detection Based on Deep Convolutional Neural Network and Shadow Removal
3. Efficient Shadow Detection and Removal using Synthetic Data with Domain Adaptation

# Accelerated Shadow Detection and Removal Method

Context:

To take in the input

1. Talk about how shadow removal and shadow detection are two parts
2. Talk about classical cv vs deep learning

the understanding that shadows typically reduce the illumination intensity of affected regions

Many fundamental computer vision tasks including object detection and depth perception are susceptible to inaccuracy