**Anna:**

Diagram of Needed steps for algorithm:

1. Dataset
   1. Use artificial stool samples for now
   2. Slides from Ghent on the way
   3. Can transform images to allow for more variation
2. Image Enhancement
   1. Allow model to be robust to image quality
3. Machine Learning Algorithm
   1. Count number of worm eggs
   2. Classify number of worm eggs

Possible ML algorithm:

Tchinda, Beaudelaire Saha, Michel Noubom, Daniel Tchiotsop, Valerie Louis-Dorr, Didier Wolf (2019). *Towards an automated medical diagnosis system for intestinal parasitosis.* Informatics in Medicine Unlocked, Volume 16, 2019, 100238, ISSN 2352-9148, https://doi.org/10.1016/j.imu.2019.100238.

* PCA to process images & extract key features
* Contour detection for image segmentation & finding worm eggs
* Multi-scale wavelet technique used for edge detection
* Achieved 100% accuracy -- overfitting???

Artificial Stool sample:

Penn, Roni, Barbara J. Ward, Linda Strande, Max Maurer, Review of synthetic human faeces and faecal sludge for sanitation and wastewater research,Water Research,Volume 132, 2018,Pages 222-240

Materials:

* Beaker (500mL or 1L)
* Baker's yeast or Brewer's yeast (we used Brewer's yeast)
* Micrococrystalline cellulose
* Psillium husk
* NaCl
* KCl
* CaCl2
* Oleic Acid
* Yeast extract
* Miso Paste
* Deionized water
* Glitter

Procedure:

1. Add 3g baker's yeast, 10g microcrystalline cellulose, 17.5g psyllium husk, 2g NaCl, 2gKCl, 1gCaCl to beaker. Mix.

2. Add 20g oleic acid and 27g yeast extract to mixture. Mix.

\*Note: I found I needed to add the oleic acid in order for the yeast extract to mix in.

3. Add 17.5g miso paste. Mix.

4. Add 100mL of water.

5. Stir until mud-like consistency.

6. Take out ~100ug of stool mixture and place in container. Add glitter to desired concentration (we used ~15ug). Take another aliquot of stool mixture without glitter to act as control.

7.Spread thin amount of stool sample onto slide and image using microscope. Adjust lighting on microscope. Aim to have images independent of each other.

\*\* Note, we decreased water content and did not wait the whole length of time

\*\*We can add in specifics about the experiment we did: i.e., 50 slides of each, took images of different portions of the slide and then rotated out the slide after 25 images, used glitter, include images

Research into computing platforms for mobile devices:

Wang, Yingchun, Jingyi Wang, Weizhan Zhang, Yufeng Zhan, Song Guo, Qinghua Zheng, Xuanyu Wang, A survey on deploying mobile deep learning applications: A systemic and technical perspective, Digital Communications and Networks, Volume 8, Issue 1,2022, Pages 1-17, ISSN 2352-8648. <https://doi.org/10.1016/j.dcan.2021.06.001>.

* CNN requires a lot of computing space
* Can compress ML algorithms, use smaller ML algorithms, more efficient matrix operations, re-use intermediate results
* There are some packages for use on mobile devices
* Our best bet will probably be to run the algorithm on the cloud

Nathaly:

The majority of my work done so far has consisted mostly of gathering information both about our team objective and researching potential implementations of photo-editing and egg counting algorithms.

To start, I began by reading the resources provided at the beginning of the semester on the Worm VIP team. Still confused with the current progress accomplished so far and the exact route of approach for this semester, I got into contact with the current capstone team working the project to develop a better understanding of what the VIP team needed to be doing and how we could best pair their ongoing research. In a meeting coordinated with the worm egg counting capstone teams’ members Jennifer Do and Elizabeth Smude, they demonstrated to us artifacts left behind by the previous Paradigm capstone team. To summarize the most important artifacts, this included several 3-D printed prototypes of a manual machine for fecal slide imaging, several lighting and microscopy options for slide imaging, sample slides of fake stool, and materials for making fake stool. Additionally, they assisted us in updating us on what work has already been done with these artifacts, and what still has the potential to be accomplished, including how to improve the image quality of slides imaged through the current prototypes and computational methods for counting worm eggs in fecal matter in a much safer and effective manner. As a supplementary aid for guidance, we were directed to a recently published video on current research conducted by Johnson & Johnson regarding egg-counting that we could gain some ideas and inspiration from as we started our work (Greco et. al, 2021). From here, my individual research branches into two specific topics: photo-editing through software and egg-counting algorithms.

In my research with photo-editing, I explored software potentials for producing the best quality images possible through the current 3-D printed artifacts. Having some experience with photography and image-improvement through code, my first thought was to combine the two to research how to fix image qualities by targeting specific picture parameters, such as brightness and contrast, from a technical, codical standpoint. These thoughts led me to studying an article on techniques for removing blurriness in photos. The language used in the article, such as how the sharpening parameters affect every pixel of the image, inspired me to think of images as simply pixels and how to codically manipulate an image’s pixels in order to restore its quality (Photoworks). I devised a simple idea of using a conditional to determine a blurriness value for each pixel based on its specific metadata and adjusting its metadata by adding some x bits of contrast, some y bits of sharpness, etc to undo the blurriness. This would address the issue of image quality. However, nothing more than notes exist for this idea, meaning there is no supporting pseudocode or written code to better explain the idea. Instead of building an entirely new algorithm from scratch, I sought to find existing code or atleast a theorem that followed my similar train of thoughts such that I could edit the existing code from there. This led me to finding out about the Lucy-Richardson algorithm for image improvement.

The Lucy-Richardson algorithm “is one of the most commonly used procedures for image deblurring/enhancement” that looks to “reduce the homogeneity of the subregions in images” (Hojjatoleslami et. al, 2013). The algorithm does this with the idea of deconvolution where the convolution between light and an original object, or the point-spread function, are estimated with the application of an inverse filter on an image in order to create the next point-spread function necessary for degranulating the original image (Fish et. al, 1995). After finding the seemingly perfect solution to our issue of image enhancement, I tried finding open source code to manipulate with my own testing images; however, I came to learn that Lucy-Richardson is actually incorporated into many coding languages already like Python and Matlab (Scikit-image, Mathworks). This was excellent news as it allowed me to move onto researching egg-counting algorithms.

My peers found an article on counting nematode eggs infesting soybean yields detailing a technical procedure nearly matching exactly our goal of distinguishing these eggs from other particles in its surrounding (Akintayo, 2018). Their approach was described as creating a network with layers of many images overlapping in order to create metadata from aggregated regions in the images indicating whether or not an egg was present in the subsection pictured (Akintayo, 2018). Fascinated by this potential solution, I found a way to access their code to research and edit for our needs and plan to continue future work this semester by further exploring this implementation.

Likewise, one last approach I plan on exploring for egg-counting is researching circular object detection algorithms. A specific source currently being explored mentions methods of cleaning an image with contrasts to create an outline of the circular object and an area of dense pixel concentrations for counting (Smereka & Duleba, 2008)..

Moving forward with this knowledge, I plan on continuing to research specifically the code found with the nematode egg study and the noted circular detection algorithm in hopes of combining the two to create the codical solution we are looking for.

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Chenyu Li:

Generally, the goal of our project is to improve the diagnosis of STH (soil-transmitted helminths), so at the beginning of the semester, I started by researching the existing diagnostic methods for STH. Basically, the diagnostic methods of STH include microscopy-based ones like Kato-Katz, FLOTAC, and DNA-based ones like PCR. Though some new methods like PCR have shown a slightly better diagnostic accuracy according to some studies, their higher requirement of equipment and expertise made me choose the “WHO golden standard”, Kato-Katz smear as the focus of study. (Mbong et. al, 2020) Then, I researched more about the Kayo-Katz technique and got familiar with its procedures. Still confused about the direction of our project, I went to the office hour of Dr.K, where she gave me a recap of the background information and the work done by the previous BME capstone team with a specific focus on their device design. The device is basically a 3D-printed box with an installed microscope through which the users can take pictures of stool slides in the box with their phone and analyze the pictures afterward. After that, we brainstormed on the possible research directions for the semester. We wanted to make the device more efficient and reduce the manual work involved. One way is to develop a model or algorithm to automatically detect and count the worm eggs in the pictures taken by the device. To that end, the image quality must be good enough for the algorithm to process, so our first research focus should be improving the image quality.

Then for the following several weeks, the main part of my research was on how to improve the image quality. In the case of pictures of worm eggs, the image resolution and contrast are of great importance in order that the eggs can be distinct from the background. I learned about how to improve image resolution by photo editing software like GIMP and Photoshop. Theoretically, resolution correlates to the number of pixels in a digital photograph or image. The more pixels there are, the higher the image's resolution. To improve a picture's resolution, we can increase the size of the picture and fill more pixels in the image at the loss of sharpness. We can use the “resize” tool to increase the resolution by changing the width and height of the picture. We can also change the pixel density by increasing the PPI (pixel per inch) in the coordinates. After the editing, we can use the built-in sharpen tools in GIMP or Photoshop to reduce the negative effect of the loss of sharpness. These methods generally work for most pictures, but since we didn’t have the pictures of sample stool slides, I didn’t have a chance to test them on the target images.

In order to get a dataset of slide images to test the image improvement methods and train the detection algorithm later, we divided into two groups to make artificial stool samples in a BME lab and used glitter as the fake worm eggs. Each group took 50 pictures of the sample without glitter and 50 pictures of the non-glitter sample. The procedure of making fake stool sample is in line with the paper.(Penn, 2018)

In the meantime, I also researched the worm egg detection algorithm. Particularly, I found R-CNN (region-based convolutional neural network) suitable for egg detection. R-CNN is a family of computational models that work specifically on object detection. Traditional R-CNN uses a selective search algorithm to generate about 2000 regional proposals that are wrapped and fed into a convolutional neural network to process and classify the objects in it. It is, however, slow to be used for real-time problems. This led me to search for its more recent variant. Faster R-CNN replaces the time-consuming selective search algorithm with RPN network to self-learn the regional proposals based on different features. Then, the regions of interest will be fed into the RoI Pooling to be classified as target objects. I found an article in which the researchers used Faster R-CNN in worm egg detection. This method has proved good accuracy and efficiency in processing the data.(Viet, 2019) It could be our focus of research in the future.

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