Generating Virtually Stained Images of Skin Tissue

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In 2023, only 38% of all Swedes diagnosed with cancer began their treatment in time. One reason for this is the time consuming and poorly standardized chemical staining processes. Staining is needed to visualise structures of tissue under a microscope, in order to arrive at a diagnosis. By replacing the chemical staining process with neural networks, a more efficient and sustainable workflow which produces synthetically stained images, referred to as virtual staining, can be achieved. Our thesis presents a novel virtual staining approach using images taken with a PLS microscope as input to the neural networks to try to answer the questions: Can virtual staining performance be improved using PLS images? Do the virtually stained images retain pathologically relevant information?

A PLS microscope takes a set of images from distinct angles and directions of a tissue sample. The set of images referred to as a PLS image stack has been shown to contain more structural information than a traditional microscopy image in previous work. Therefore it was hypothesized that a neural network given PLS images as input would perform better than a network of the same design trained on only traditional microscopy images.

Generative neural networks take some form of input and generate new data instances. In our thesis we used either a PLS image stack or a traditional microscopy image as input. The networks were then trained to output a virtually stained image by comparing the output of the network to a paired chemically stained image. The images used were of skin tissue from both healthy patients and patients diagnosed with skin cancer. Several different neural networks were trained and evaluated using quantitative metrics to yield the final model, coined **VS-RGAN**.

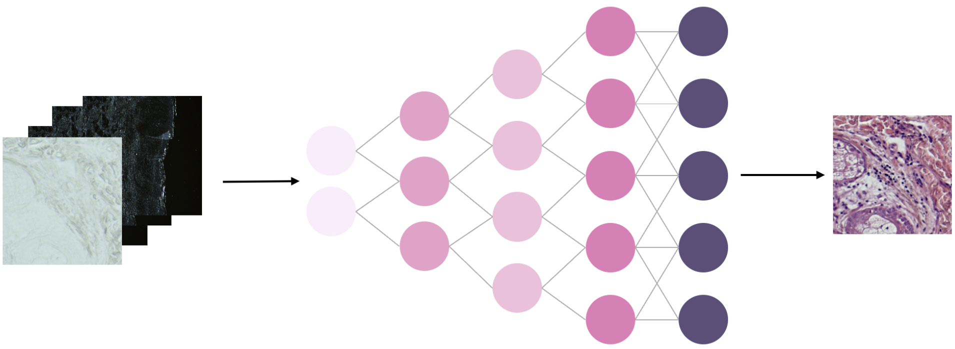

Figure 1: Illustration of a generative neural network which takes PLS microscopy images as input and generates a virtually stained image.

According to quantitative metrics there was a significant improvement in virtual staining performance when training the neural network with PLS image stacks as compared to only traditional microscopy images. As can be seen in the image below, there was also a rather clear visual improvement.

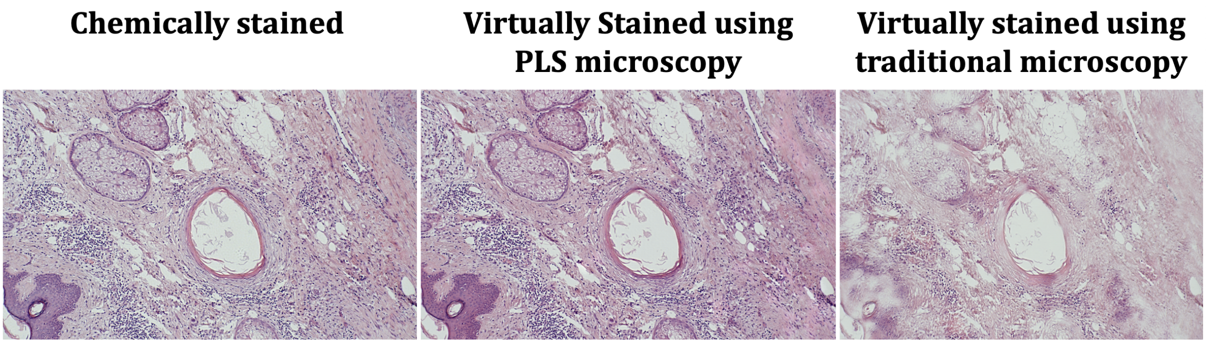

Figure 2: The virtually stained images were generated by the **VS-RGAN** provided with either PLS microscopy images or traditional microscopy images as input.

The virtually stained images generated by the VS-RGAN were also evaluated through qualitative assessment by medical professionals. The professionals were provided with an equal number of virtually and chemically stained images, some of which depicted cancerous tissue. These professionals were unable to distinguish the virtually stained images in regards to the quality of the staining and usefulness of the images for diagnosis. The professionals were also able to correctly diagnose 96% of all images as either healthy or containing cancerous tissue.

The results of this thesis highlights the added benefits of using PLS microscopy in virtual staining. It has the potential of speeding up diagnosis, increasing standardisation and sustainability.