Discuss whether SIFT-like approaches are suitable for the analysis of medical scans

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Introduction

There are a broad range of different medical scans with many different uses in our modern world. In this essay I will discuss some practical uses that have been developed implementing scale invariant feature transform (SIFT). After explaining some of the important technical details, I will describe how it has been used to create low-cost, compact optometric scanning equipment for third world and developing countries, the scale and potential benefits that can come from the particular issue SIFT solves, and then some of the draw backs of using SIFT alone to solve the problem, due to limitations inherent to the technique itself. After, I will look at how it's being used in the detection of Alzheimer's disease through analysis of MRI scan and why these types of scans are perfect for use with SIFT.

Scale Invariant Feature Transform (SIFT) – Technical Outline

SIFT is a method which can automatically detect and describe distinctive features of an object/scene from an image, then detect those same features in images from other viewpoints. Originally described by Lowe, D.G (2004), the general method consists of two key parts. The first of which is the detection of potential points-of-interest, using a difference-of-Gaussian (DOG) function on a generated Gaussian scale space. This scale space is simply a 3-dimensional representation of an image, with the 3$^{rd}$ dimension being versions of that image, increasing blurred by consistent amounts. The DOG gives a representation for the level of local distortion in areas of the image, with relatively high DOG for section of an image giving evidence of detail being lost. This is because blurring intensity contours changes those intensities of surrounding pixels a lot more than plain sections of relatively similar pixel-intensity. The size of features can also be labelled here, as smaller details will distort quicker in the blurring process than larger details.

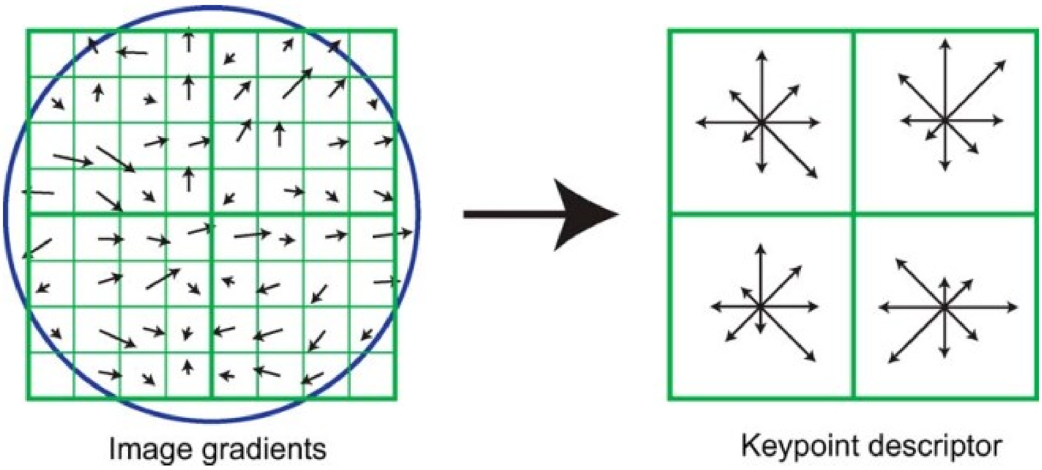


*Figure 1: An example of converting local area-of-interest image gradients to keypoint descriptor histograms.*

These detected areas can then undergo a process of labelling each of the pixels in each area of the original image with the direction where the intensity increases by the greatest amount, creating a local gradient image for that area-of-interest. The gradients can then be collated into "bins" of direction ranges to create summaries of each feature in the image which are called keypoint descriptors, which are stored as basic histograms (Figure 1). These histograms describe features of an image in a way which can be compared with other image feature histograms of the same object/scene from different viewpoints to detect those same points to get an idea of how the view has changed, or detect an object in a different setting. (Lowe, D.G, 2004) (Vedaldi, A., 2007) (Lindeberg, T., 2012).

This detection method provides some benefits and drawbacks, which I will discuss in future sections of this essay as they affect the particular issues when implementing in different medical use-cases. Next, I will discuss this technique’s use in Ophthalmological scanning, for high resolution imaging, without the need for expensive and bulky imaging equipment.

## High Resolution Ophthalmological Scans

One area of medicine where the implementation of SIFT has been tried and evaluated in is in high-resolution microscopic imaging of retinas in Ophthalmology. A major issue with this technique, called adaptive optics (AO), is due to the rapid motion of the eye and the relatively tiny scale of which is being imaged. Therefore, stabilisation of the video images is essential in tackling distortions. SIFT can be applied to automatically detect and match corner points of the retina to remove frames in which these motions occur as you can detect how these points have changed to determine the amount of distortion in the image (Figure 2). This proved extremely useful in processing large amounts of data from video imaging (Li, H. et al, 2011) and practically useful in reducing the quality of equipment for in the field medical scans in third-world and developing countries.

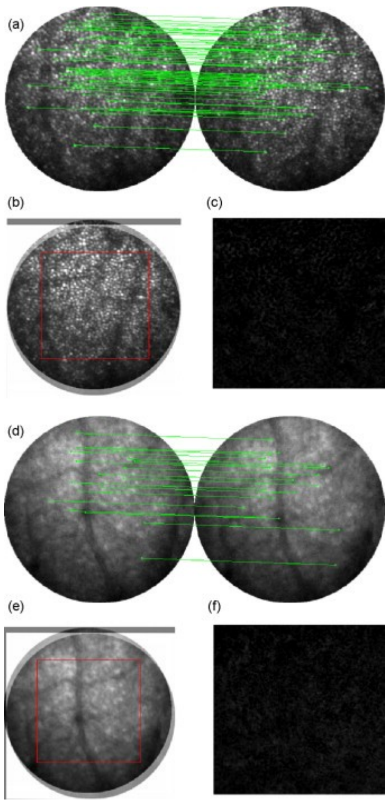


*Figure 2 Keypoint Descriptor Comparison of retina scans. Showing how bad frames can be detected (He, Y. et al 2016)*

The world health organisation (WHO) reported that 51% of world blindness (20 million people) is caused by cataract. Whilst it can be successfully treated through surgery, third-world and developing countries struggle with detection and treatment (WHO, 2020). This implementation of SIFT has been implemented to aid with the detection of cataracts and other retinal diseases. The issue with traditional ophthalmology scans is they require relatively expensive and cumbersome equipment to produce high quality scans which a professional can then use, and so getting them to these places they are needed is impractical. He, Y. et al (2016) developed compact AO Ophthalmosopes, which they were able to do, in part, because of this image stabilisation method using SIFT, along with some image processing techniques. SIFT allowed the scanning equipment to be used portably as the relative movement of the eye and scanner in the images produced could be automatically removed to produce clearer video images. As this is purely a software solution, the cheaper hardware means that manufacturing these devices is much easier and distribution isn't as large a barrier either. This also means that doctors themselves didn't need to visit the patients, and patients didn't need to visit a doctor, as the skill required to use such a device for accurate scans is greatly reduced. For large third-world and developing countries, it is a big benefit as access to hospitals can be challenging for many people (He, Y. et al, 2016).

Limitations of SIFT in Ophthalmological Scans

Despite the benefit SIFT can provide for aiding the detection of cataract and other optical diseases, there are issues present with SIFT which cause practical problems. One problem with SIFT is it relies upon the presence of the features detected in both images to be obvious, and for textured images, that texture can be incorrectly identified as a feature, which are not distinct and so damage the accuracy and reliability of the function. Therefore, for more extreme content or scale changes of low-quality images, as with the portable ophthalmological scanners, the use of SIFT alone is not reliable enough for practical implementation and so researchers have attempted to merge other techniques to boost it's effectiveness.

Automated Alzheimer's Diagnosis

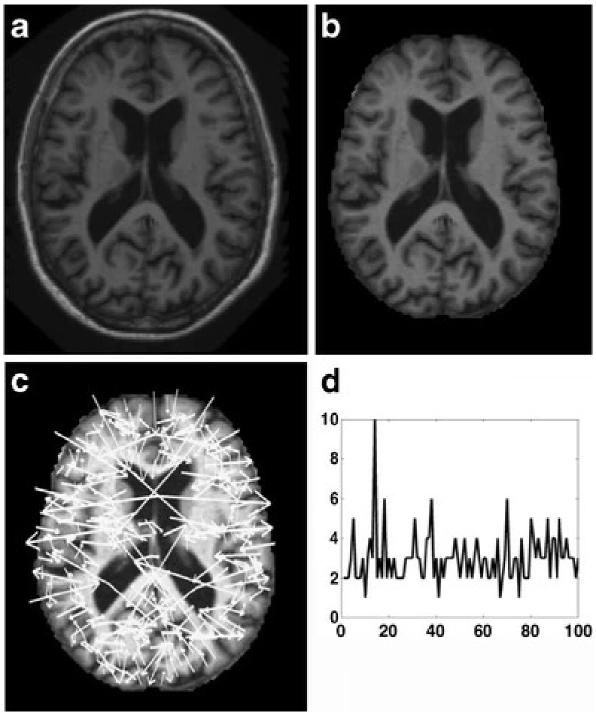


Figure 3 - Example MRI scan of a brain, with **c** showing the orientation of extracted key-points and **d** showing one of the key-point histograms from one of those points (Daliri, M., 2012)

Alzheimer's disease is the most common type of dementia, and most common form of late-life human mental failure (Selkoe, D., 2001). SIFT provides a tool to aid with detection through the analysis of magnetic resonance imaging (MRI) scans of the brain. By detecting and summarising distinct features in brain scans of diagnosed Alzheimer's patients, they can be compared with scans from non-diagnosed patients scans to gauge their structural similarity. Alzheimer’s physically affects the brain in a predictable manner, and so this comparison can give an interesting indication of which patients are more likely to be suffering with Alzheimer’s disease. The implementation of SIFT was adapted to create feature histograms of 3D MRI scans. These are just where multiple scans are done in different perspectives to achieve a 3D image of the brain. Researchers were able to use SIFT with these 3D scans, which means there’s far more information that can be gained from them and more important features of Alzheimer brains can be used (Daliri, M., 2012).

The implications of this technique are really interesting as the accuracy of the study described above, found an accuracy of 86% with subjects aged from 60 to 80 years old. This is a high level of accuracy, given that it relies on the scans of brains alone. One reason for this is because these MRI brain scans are one of the perfect examples of where SIFT can be used effectively. The lack of texture and the clear structural elements of the images mean that the features that are detected are much more accurate and relevant to the brain itself (Figure 3). This increases in the accuracy of the technique means that these sorts of results could be used to identify high-risk patients for further investigation by a specialist. This could mean that specialists are not needed to analyse every MRI scan, and instead just the ones that are flagged by the SIFT algorithm, as the accuracy isn’t perfect, a threshold for those flagged by the system of likelihood of having Alzheimer’s disease could be implemented and, as the algorithm is developed, potentially with implementation of other image processing techniques or neural networks, the threshold could be increased as the likelihoods will become more and more reliable.

Panoramic Medical Ultrasound Scans

When ultrasound, and many other types of, scanning occurs, the resultant images of the specific part of the body have tended to be a set of images of that part of the body which requires a specialist to interpret. SIFT has been applied to these scans of many different parts of the body as it can aid in stitching together each of these images to create 3-dimensional, high resolution panoramic images of that section of the body. Thus allowing a doctor to diagnose issues much more easily as they have a wholistic view of the body part. This uses an improved version of the SIFT algorithm which can detect artefacts in those images which keeps the quality high (Ni, D., et al, 2008).

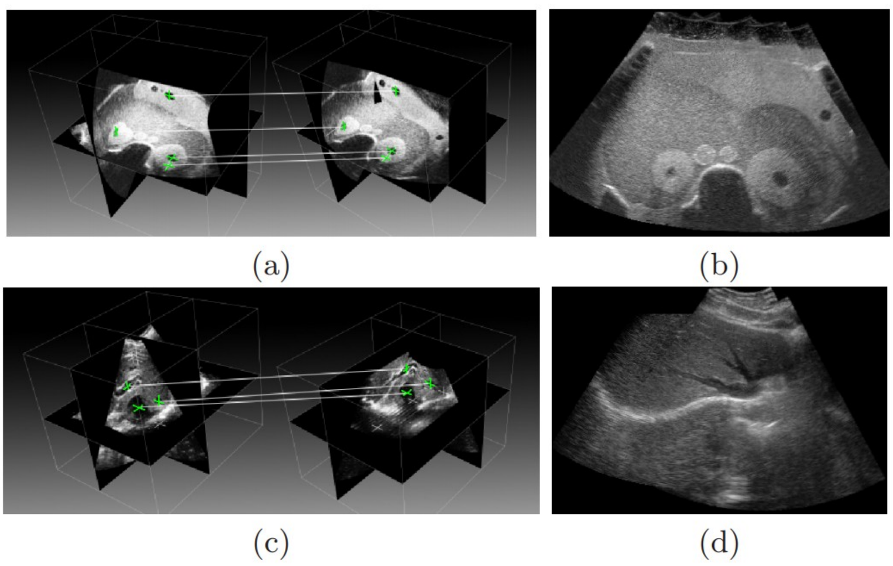
(a) (b) (c) (d)

*Figure 4: Example of a 3-dimensional ultrasound image being created (Ni, D., et al, 2008)*

The success of such a technique is due, in-part, to it's similarity with the problem of creating normal panoramic images with mobile phones. SIFT detects features of the set of images you take when creating a panorama. Then detects those same features in each of the next set of images which are then used to align the images together for stitching. This has meant that there has been an effort to make these panoramas accurate and the alignment as close as possible by the mobile operating system manufacturers and these techniques can be adapted for uses like the one described above.

## Conclusion

Overall, SIFT is clearly an extremely useful tool in supporting the analysis of medical scans. Despite it's pitfalls; with textured items  and large context changes, it's flexibility for use with other techniques is becoming increasingly apparent. Thus helping to negate some of these issues. This fact along with the implications it has with technological innovation for the global medical community have already proven to be immense. Since the first paper in 2004, there have been many different medical medical use-cases examined and many that continue to be looked into, even today. This has shown SIFT to be a long-term resource which will continue to be developed and utilised and help to produce tangible global benefits.

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