Improving Mammography Training Using Subtle Gaze Direction (sap_0224)

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Abstract

The ability to direct viewer gaze about an image has important application in medical image training and analysis. We use a novel gaze manipulation technique called Subtle Gaze Direction to guide novice users as they try to identify abnormalities in digital mammogram images. Subtle Gaze Direction is achieved by performing brief image-space modulations on specific regions of the viewer's peripheral vision in order to attract their attention. The viewer's gaze is monitored in real-time and the modulations are terminated before the viewer is allowed to scrutinize them with their high-acuity foveal vision. This approach is preferred to more overt techniques which require permanent alterations to the original images in order to highlight specific areas of interest. In our experiment we use Subtle Gaze Direction to guide novices along the scanpath of an expert radiologist. We hypothesized that this approach would increase the likelihood of novices correctly identifying irregularities in the mammograms.

CR Categories: I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms;

Keywords: gaze manipulation, radiological training, mammography, image-space modulations

Links: DL PDF

1 Subtle Gaze Direction

The *Subtle Gaze Direction (SGD)* technique [Bailey et al. 2009] provides the ability to guide a viewer's gaze to specific regions of a display. The technique, which combines real-time eye-tracking with subtle image-space modulation, has minimal impact on viewing experience as it does not change the overall appearance of the scene being viewed. Subtlety is achieved by presenting the modulations only to the low-acuity peripheral regions of the field of view so the viewer is never allowed to scrutinize the modulations. The technique has been shown to be fast and accurate: viewers typically attend to target regions within 0.5 seconds of the onset of the modulation and the resulting fixations are typically within a single perceptual span of the target. While this shows that the technique is successful in directing gaze, its usefulness for training applications has not yet been established. We present an experiment which explores the application of Subtle Gaze Direction within the context of digital mammography training.

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Figure 1: *Photograph of experiment setup. The eye-tracking hardware is fixed to the bottom of the screen. Participants were asked to identify irregular regions in a sequence of mammogram images. Gaze manipulation techniques were used to influence their sequence of fixations during the experiment.*

2 Approach

The database of mammogram images used in this study was provided by the Mammographic Image Analysis Society [Suckling et al. 1994]. The database contains pairs of mammogram images from 161 patients along with a separate text file containing information collected from an expert radiologist such as the x,y image coordinates of the center of abnormalities and the approximate radius in pixels of a circle enclosing the abnormality. What is missing however, is the expert's scanpath (sequence of fixations) when trying to locate these abnormalities. We hired our own expert radiologist to view the images from the database and to mark any abnormalities present by drawing a circle enclosing the abnormality. The expert's scanpath was recorded during this process and later used to guide the novice participants.

During a training session, twenty novice participants (4 females, 16 males) viewed a randomized sequence of 20 pairs of mammogram images from the database and were asked to identify what they considered to be irregularities using a mouse (see Figure 1). Participants were randomly assigned to one of four groups:

- **Static group:** 5 participants viewed the images without the use of gaze manipulation. This group served as the control group for the experiment.
- **Gaze-directed group using expert scanpath:** 5 participants viewed the images with gaze manipulation used to guide them to follow a similar scanpath (sequence of fixations) as the expert.
- **Gaze-directed group using expert selections:** 5 participants viewed the images with gaze manipulation used to guide them

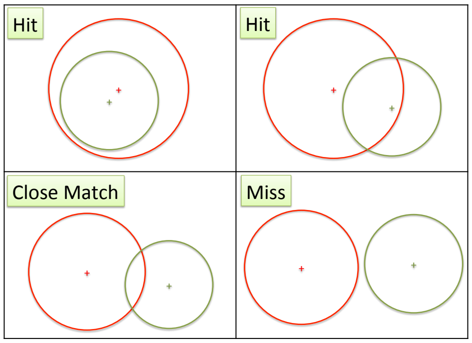

Figure 2: *Illustration of hits, close matches, and misses. The circles represent selections by the expert and novice. The center of the circles are represented by the crosses.*

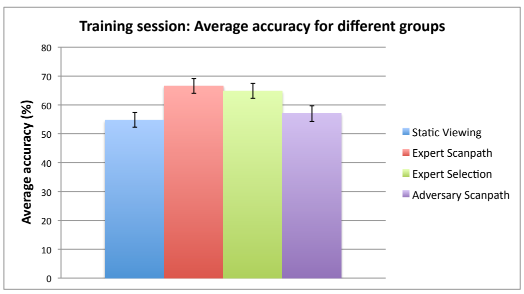

Figure 3: *Average accuracy for different groups of participants during the training session. Error bars represent standard error.*

only to the regions marked by the expert as irregular. The overall scanpath of the expert was not used.

- **Gaze-directed group using adversarial scanpath:** 5 participants viewed the images with gaze manipulation used to guide them along a scanpath that was chosen by the researchers to follow different directions and locations than that of the expert.

3 Results

To facilitate analysis of the novices' performance, we define accuracy as a weighted sum of hits, misses and close matches between the selections made by the expert and the selections made by the novice. Figure 2 illustrates the concepts of hits, close matches, and misses. Figure 3 shows the average accuracy for the various groups of participants during the training session. We observed the following effects:

- Participants who were guided by the expert scanpath performed significantly better than the participants in the static group.
- Participants who were guided by the expert selections performed significantly better than the participants in the static group.
- Participants who were guided by the expert scanpath performed significantly better than the participants who were guided by the adversarial scanpath.
- Participants who were guided by the expert selections performed significantly better than the participants who were guided by the adversarial scanpath.

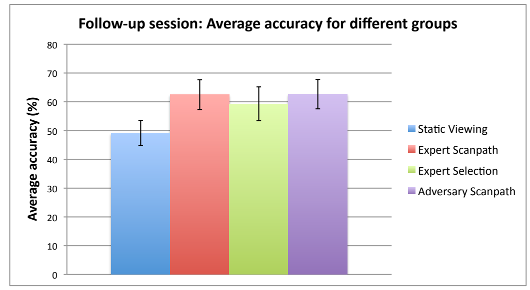

Figure 4: *Average accuracy for different groups of participants during the follow-up session. Error bars represent standard error.*

Following the training session, the participants were given a five minute break. A follow-up session was run using five fresh images. No gaze manipulation was used in this session for any of the participants. The purpose of this follow-up session was to determine if the novice participants had become sensitized to the strategies used during the training session. Figure 4 shows the average accuracy for the various groups of participants during the follow-up session. We observed the following effects:

- Participants who were guided by the expert scanpath during the training session performed significantly better than the participants in the static group.
- Participants who were guided by the expert selections during the training session performed significantly better than the participants in the static group.
- Participants who were guided by the adversarial scanpath during the training session performed significantly better than the participants in the static group.

4 Conclusion

The results of our study hold great promise for digital mammography training as well as training on other medical image modalities such as X-rays, CT scans, PET scans, and MRIs. Our observations also have implications for a wide range of visual search and learning applications including surgical simulator training, education and online learning, and pervasive advertising. In addition to these applications, there are several other avenues for future work. In order to better understand the short-term and long-term post-training effects on subjects guided using Subtle Gaze Direction, a larger and more comprehensive experiment is planned. We also plan to conduct further analysis of the eye-tracking data recorded during this experiment to quantify how much deviation was present between the scanpaths of the novices and the expert. Finally, we plan to explore the feasibility of combining computer vision techniques with the recorded scanpath data of the expert to develop an automatic scanpath predictor algorithm for mammograms.

References

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