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The Sonic Penlight for Guidance of Superficial Subdermal Access

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Abstract. Here we present our design and implementation of the Sonic Penlight, a miniaturized device that utilizes Real-Time Tomographic Reflection to create a virtual *in situ* ultrasound image in superficial body regions. It aims to provide ultrasound guidance to clinicians for procedures like tendon surgeries and ophthalmologic operations, often performed with the aid of magnifying glasses known as "loupes," to which the stability of the virtual image lends itself without further adaptation. We have built and proved the validity of our design.

Many clinical procedures require obtaining meaningful images at very superficial depths. Surgery for carpal tunnel syndrome, for example, involves tendons in the first subdermal centimeter [1]. Ophthalmologists are exploring real-time ultrasonic guidance for corneal surgery and in accessing structures in the anterior chamber of the eye [2]. Gaining vascular access in premature neonates is impeded by their vessels' small size and mobility [3]. Motivated by these applications, we have developed a visualization device called the Sonic Penlight to provide *in-situ* ultrasound guidance for a clinician performing invasive procedures in superficial regions.

The concept underlying the Sonic Penlight is Real-Time Tomographic Reflection (RTTR) proposed by Stetten et al. [4], [5] and Masamune et al. [6]. Stetten's RTTR system was developed for real-time visualization of ultrasound. It functions by fixing the relative geometry of the ultrasound transducer, the display, and a half-silvered mirror to project the ultrasound image on the display into the scanned area, creating a virtual image in the patient. Through the half-silvered mirror, the virtual image is naturally merged into the viewer's direct vision and seen as if it "shines out" from the probe and illuminates the inner tissue. For this reason, the implementation of RTTR is named the Sonic Flashlight (SF). Now we extend this work to build a miniaturized SF, dubbed the Sonic Penlight (SP).

The SP is designed to illuminate low-depth areas with high resolution. Our current prototype adapts a catheter-based phased array ultrasound probe (ACUSON Sequoia Echo 256, Siemens Medical Solutions USA, Inc., Malvern, PA) recently introduced for intra-cardiac imaging, operating at 10 MHz. The small footprint of this probe (a 10 French catheter, 3.3 mm in diameter) would allow easy access for a clinician to the imaged area with a surgical tool or needle. To create an image whose size is less than a centimeter, we are utilizing a new miniature organic LED display (eMagin SVGA+

OLED Microdisplay, eMagin Corp., Hopewell Junction, NY) that supports a resolution of 852x600 with 15-micron pixels, resulting in a brilliant display only 12mm by 9mm in size. The OLED technology offers superior off-angle viewing, a requisite for implementing the method of RTTR. The stable virtual image is fully compatible with the magnifying loupes worn by physicians in current microsurgeries.

The left side of Fig. 1 shows the CAD/CAM design of the SP hardware. A half-silvered mirror is mounted halfway between the tip of the probe and the bottom of the display. As a result, the ultrasound image, shown in real-time with the proper scale, orientation, and location on the OLED display, is reflected in the mirror and exactly occupies the space being scanned.

The right side of Fig. 1 shows the insertion of a needle into a tube in a gel phantom simulating a blood vessel (diameter = 4mm) performed by an author while using the SP. With the *in-situ* visualization of the target, it was very easy to aim the needle and hit the target successfully.

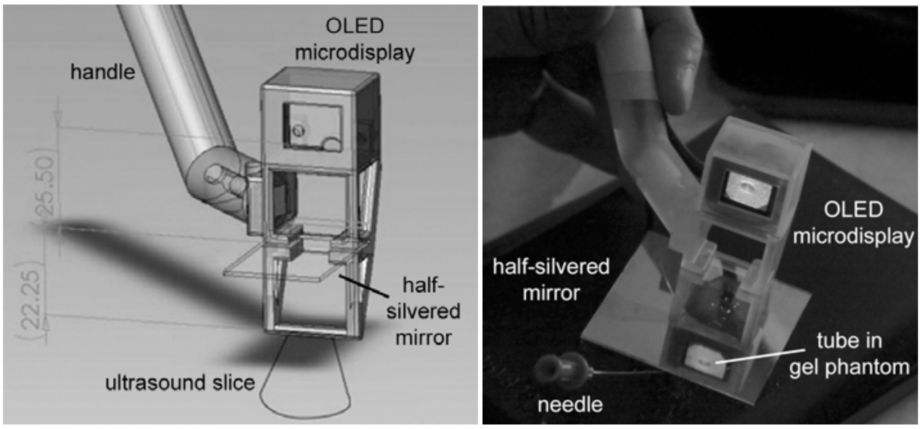

Fig. 1. Left: CAD/CAM design of the Sonic Penlight housing. Right: First prototype of the Sonic Penlight and the insertion of needle into a gel phantom with its guidance.

Future models of the SP will incorporate high-frequency phased array ultrasound transducers (>20 MHz) as they are introduced, increasing the ultrasound resolution to take full advantage of the OLED microdisplay. We have demonstrated the basic design and functionality of the SP, and believe that it may lead to increased accuracy and safety for superficial invasive procedures. The use of loupes by surgeons is already standard practice and should facilitate acceptance of the SP.

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