

INTRAOPERATIVE INSTRUMENT MOTION SENSING FOR MICROSURGERY

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Abstract

There is a need for instrument motion sensing with sufficient accuracy for microsurgery. An instrument featuring six-degree-of-freedom (6-dof) inertial sensing of intraoperative motion has been developed. With rms noise of 7.8 mm/s^2 and 1.1 mdeg/s and bandwidth over 20 Hz , it is capable of capturing both gross motion and microscopic movements, e.g., hand tremor. Preliminary results are presented.

1. Introduction

Manual positioning accuracy is limited by inherent erroneous movement, physiological tremor being the most familiar type [1]. Many branches of microsurgery are pushing the human performance envelope. For example, vitreoretinal microsurgeons sometimes need to remove membranes $20 \mu\text{m}$ thick from the retina [2]. In this demanding environment, high-quality measurement of microsurgical instrument motion is increasingly important for design and evaluation of new instruments, assessment of manual techniques [3], determination of performance limits, and analysis of voluntary and erroneous components. Presently, microsurgical instrument motion studies rely on laboratory simulators [3]—a step removed from the “real world.” Tracking instrument motion during actual microsurgery would provide true realism in motion studies. This paper describes a microsurgical instrument with intraoperative motion tracking, constructed by adding 6-dof sensing to a Storz DP9603 Madlab Pic-Manipulator. Signal processing work is ongoing.

2. Methods

A triaxial accelerometer (Crossbow CXL02LF3) and three rate gyros (Tokin CG-16D) are mounted at the back of the instrument handle. The sensor suite is $2.8 \times 3.3 \times 4.1 \text{ cm}$ and 38 g . The instrument tip velocity vector, \mathbf{V} , is

$$\mathbf{V} = \mathbf{R}\mathbf{V}' + \mathbf{\Omega} \times \mathbf{R}\mathbf{Q}$$

where \mathbf{R} is the rotation matrix for the current orientation, \mathbf{V}' is the velocity (via integration) in a frame parallel to the accelerometers, $\mathbf{\Omega}$ is the angular rate vector, and \mathbf{Q} is the (constant) tip position in the moving sensor frame. The velocity can be integrated to obtain displacement. Sampling is 1 kHz .

Preliminary tests are presented: (a) a human subject traced an orthogonal frame freehand; (b) the instrument was affixed to a levitation manipulator [4] that generated a 1-dof $40 \mu\text{m}$ peak-to-peak oscillation.

3. Results

The sensor rms noise is 7.8 mm/s^2 and 1.13 mdeg/s . Mean drift (10 min. test) is $1.3 \text{ mm/s}^2/\text{min}$ and 0.12 deg/s/min . Figure 1 presents the results of the freehand test. Figure 2 shows the results from 1-d.o.f. translation. The rms error is $2.7 \mu\text{m}$. The ratio of measured to actual rms motion is 1.037.

4. Discussion

Figure 1 demonstrates the ability to track gross motion, and Fig. 2 the capacity to accurately sense motion on the scale of

physiological hand tremor. Gravity compensation must be implemented before tests involving large rotations can be conducted. Future work also includes further noise reduction and drift cancellation. The instrument will be tested during vitreoretinal microsurgery in the near future.

In addition to scientific data acquisition, the instrument can also be used for real-time feedback of, e.g., tremor amplitude. It also represents a fundamental step in the development of active tremor canceling in a hand-held instrument.

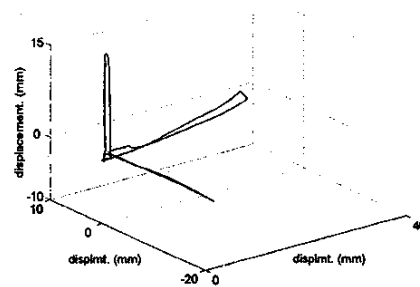


Figure 1. Freehand frame tracing (each segment was traced back and forth).

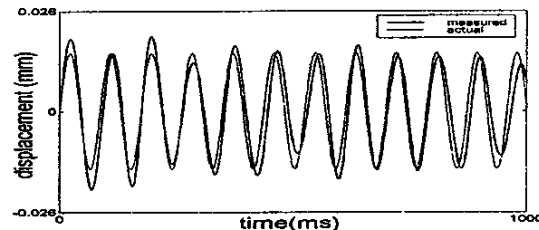


Figure 2. 1-dof translation, with actual (gray) and measured (black) motion.

5. Conclusion

A microsurgical instrument with 6-dof inertial sensing has been developed. Preliminary results were presented.

Acknowledgments

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References

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