Design of a Haptic Forceps for Microsurgery Training

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Abstract. While feedback of the grasping force is necessary to manipulate objects skillfully, most Virtual Reality systems do not provide such feedback. Grasping an object is often reduced to pushing a button on the interface. This paper presents the design and realization of a haptic forceps for microsurgery training, and its integration on a haptic 6DOF DELTA device. Psychophysical experiments were first conducted to determine the critical factors for the design. The haptic forceps has similar dimensions as a microsurgery forceps and integrates two active degrees of freedom for rotation about its axis as well as opening and closing. The transformation of the force/torque from the forceps tip to the haptic device TCP, necessary to compute the desired force/torque at the forceps tip, was derived and implemented. Preliminary experiments demonstrate the potential of this haptic forceps in a VR microsurgery trainer.

1 Introduction

Microsurgery is currently trained on mocks, animals or cadavers, and by observing and assisting experienced colleagues. A surgeon requires significant training to manipulate objects skillfully under a microscope. Tremor becomes critical at the microscopic level. The surgeon further has to master modified hand-eye coordination with angles differently oriented and distances magnified by the microscope, and with less depth of field compared to normal vision. If the training is inefficient it is hard to identify problems; for safety, cost and ethical reasons (less training with animals), one cannot try all possible strategies. It is expected that Virtual Reality (VR) systems will enable more effective and systematic training, and to test the future surgeons. As an analogy, who would accept to fly on a plane driven by a pilot who has not undertaken extensive training on a simulator, and thus not learned to deal with most possible complications? Potentially, virtual environments can provide "transparent" feel of the forceps as in the real task. Furthermore, "artificial" computer-controlled environments with hyperrealistic sensory cues may provide better means of learning than natural environments. For example, it was recently shown that training movements in unstable force fields results in increased accuracy [1].

Surgery involves hand held tools such as forceps and scissors. Probably all current VR learning systems for surgery provide vision [2,3], some also provide feedback of the force exerted on the tool [4,5]. However, while psychophysics [6] and robotics [7,8] have shown that a stable grasp requires feedback of the grip force on the hand, such feedback is not provided in most current VR surgical training systems. The currently available general-purpose interfaces are by far not sufficient to render the feeling of handling a forceps.

Therefore, we have developed a haptic forceps to train microsurgery and more generally micromanipulation using forceps. This forceps is mounted on a DELTA haptic interface with six active degrees of freedom (DOF) [9] and integrated with the VR workstation used to train micromanipulation and microsurgery [10,11]. This system will now be described in detail along with a first simulation task of suturing in microsurgery.

2 Microsurgery Tools and Constraints

Microsurgery involves surgical procedures performed under an optical microscope with magnification ranging from 10 to 40. Typical tools used by the surgeon are:

- retractor
- jeweler micro forceps
- jeweler micro forceps curved at 45°
- micro needle holder
- straight scissors
- curved scissors
- double vessel clamp
- single vessel clamp

Most of them are scissors and forceps (Fig.1). A forceps is a tweezers-like instrument. It is used to grip human tissue and to hold and guide the needle. The forceps is composed of a handle and a gripping part (Fig.1a). While the handle is similar in most forceps, the gripping part depends on the application (Fig.1b).

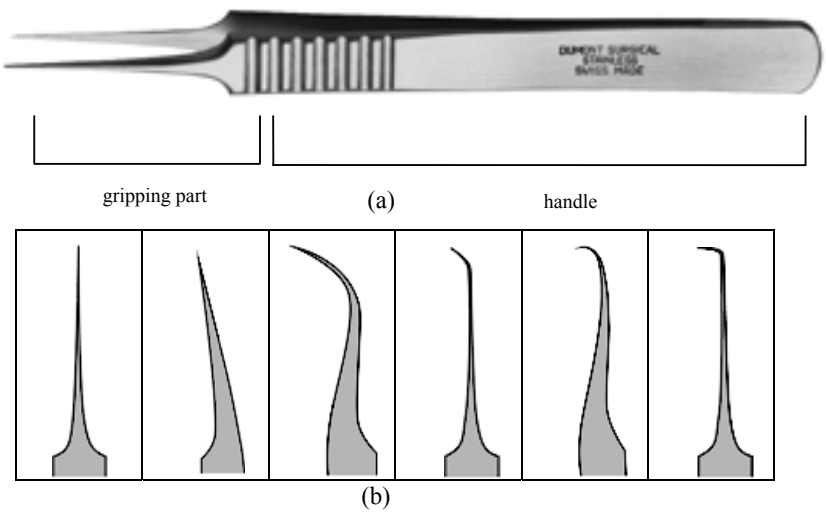

Figure 1. **Structure of a forceps (a) and different gripping parts (b).**

Emulating visual control through the optical microscope requires magnifying the image on the monitor while performing hand movements with the haptic interface at real scale. Typical dimensions in microsurgery are:

- The workspace is about $400mm^2$
- The nylon thread is typically $20cm$ long, with a diameter of ~$70\mu m$, i.e. approximately the width of a human hair.
- The needle fixed at one extremity of the nylon is about 3-4mm long for a width of $140\mu m$.