Design of an Motorised Endoscope Manipulator Interface for Sinus Surgery

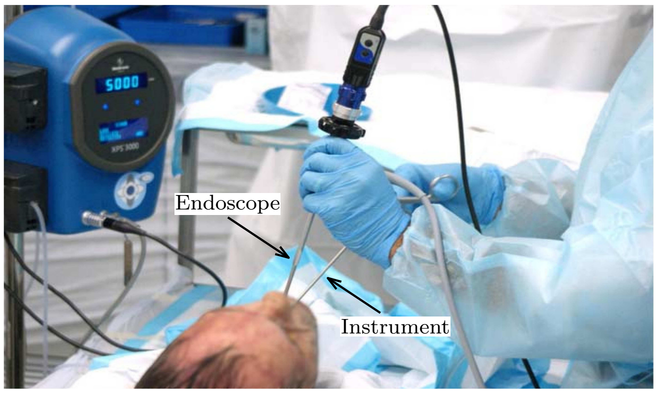

Fig. 1. In traditional FESS, the surgeon directly manipulates the endoscope.

***Abstract*—This paper presents the development of an endoscope manipulator interface for the control of active structures for functional endoscopic sinus surgery (FESS). The motion control system is based on a real-time Linux kernel that processes the commands from the surgeon and controls the manipulators active joints. A user control interface based on an IMU fastened on thesurgeons head and a RGB-D sensor(kinect) settled before the user's head is developed is developed; This interface measures the head's posture and position, it provides the desired pan/tilt/zoom motions of the endoscope. The developed endoscope manipulator allows the surgeon to conduct two-hand operations while retaining direct control of the camera. We present an experimental study to validate the performance of the robotic prototype.**

***Index Terms*——Robot manipulators, endoscopic sinus surgery, remote centre of motion, motion control, human-machine interface.**

I. Introduction

Endoscopes are important imaging devices that are commonly used during minimally invasive surgical operations. These systems carry a camera and light source that capture in-body images, which are used by the surgeon to conduct the operation. During traditional functional endoscopic sinus surgery (FESS), the surgeon uses one hand to manipulate the endoscope and the other hand to manipulate the surgical instruments, see Fig. 1. This situation limits the surgeons dexterity during the procedure, where in order to conduct two-hand operations, an assistant surgeon needs to manipulate the camera (this requires an excellent communication between both sides).

A. Related Work

Many robotic systems have been proposed in the literature to perform the endoscope manipulation task, see e.g. [1]. A cable driven surgical endoscope manipulator, with low cost and easy setup, is presented in [2]; in this work the surgeon controls the endoscope with voice commands, pedals, a joystick and head movements. In [3], a robotic prototype for trans-nasal neurosurgery is proposed. This endoscope manipulator provides the surgeon with real-time images, has a 2 rotational joints for pan and tilt motions, and a 2 translational joints for positioning the system. In [4], a computer-integrated surgical system using CAD/CAM models and data from surgical devices is proposed. The work [5] develops an remote center of motion (RCM) mechanism and two prototypes of endocavity ultra- sound probe manipulators. In [6], an endoscope manipulator with eight motorized joints is proposed for sinus surgery; this robot is controlled using multiple foot pedals.

B. Contribution

Our aim in this paper, is to present a new hand free controlling interface system (head and voice controlled robotic system) that releases the hand- busy surgeon from the camera manipulation task in a more intuitive way, and enables him/her to retain direct control of endoscope's position.

C. Organisation

The article is organized as follow. First, in section II we briefly explain the role of every sensors which enables the hand-free control in a more intuitive way. Then we describe our multisensor framework and algorithm to complete the manipulation of the controlling signals. In section III we draw a brief conclusion of perfermence about the system and introduce the future work of the development.

II. Interface and sensor algorithm

In this section, we present and analyse the structure of the proposed endoscope manipulator.

A. Control system architecture

The control system is composed of two Linux-based industrial PC, an embedded Galil DMC-1440 control board with analog outputs, Maxon current amplifiers, electromagnets, wireless communication modules and an IMU. The Galil control board decodes the motors position and outputs the analog control signal (calculated by an inner PID algorithm) to the current amplifiers. One linear joint and two rotary joints of the active manipulator are controlled in velocity mode. For safety reasons, the motor of the insertion joint is controlled in current mode; this joint moves with a small and constant feed-forward force, which can help to prevent applying excessive

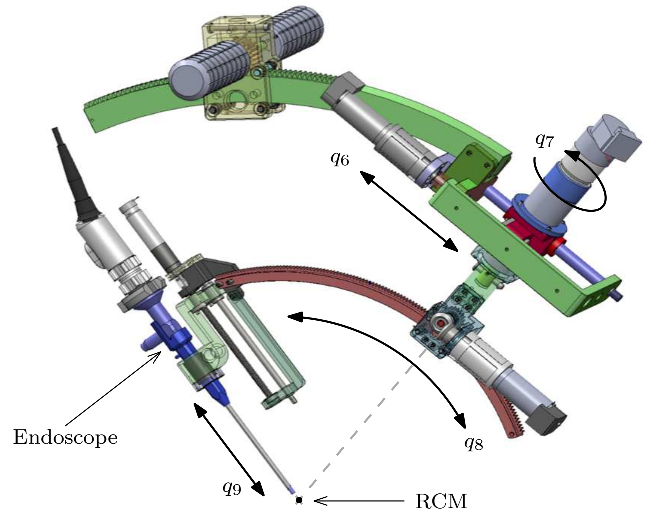

Fig. 2. The active endoscope manipulator.

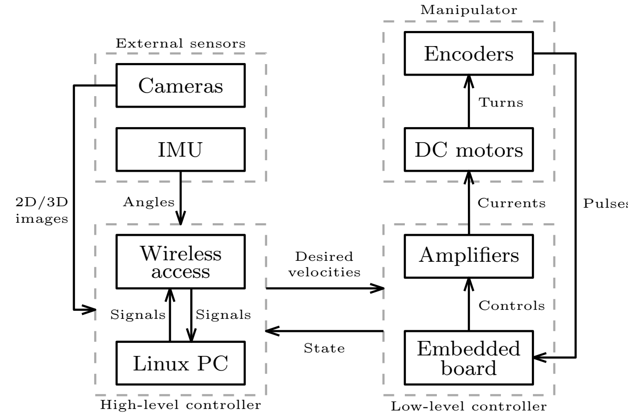

Fig. 3. Schematic representation of the motion control system.

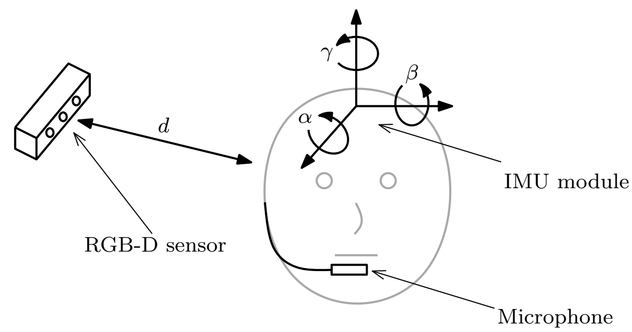

Fig. 4. The head-controlled interface with orientation angles, and microphone.

forces to the tissues. A schematic representation of the control system is shown in Fig. 2.

The control software is divided into two parts: robot control core and human machine interface (HMI). The robot control core manages the hardware resources and is in charge of implementing the low-level control tasks, such as computing the motors velocity and current commands, enabling and disabling the algorithms, communicating with the HMI and monitoring the error events

B. Algorithm of control interface

In our system we use an IMU and a RGB-D sensor(kinect) to control the active manipulator, see Fig. 4. An IMU with an Arduino micro-controller unit is fastened to the surgeons head to measure the heads orientation,and the RGB-D camera is settled to measure the head position; the measured feedback is sent to PC via bluetooth channel and TCP/IP channel respectively. The HMI receives the feedback data, identifies the head gesture and position from user, and sends the motion command to the core control application. The IMU interface measures the pitch and yaw angles while the kinect measures-the distant between the user and camera, besides, a microphone is mounted on the user's head to receive speech voice as the highest command to enable and disable the whole system; We use these parameters to implement the following actions: (1) enable/disable the whole control process, (2) command the joints forward/backward motion.The interface control logic is described with following set of rules:

loop ▷ Main loop of the head-controlled interface
  if "enable/stop control" command is detected **then**
    Enable/disable interface
  end if
  if Interface enabled **then**
    if $|\gamma| > 30°$ **then**
      Move joint q_7 in the direction of $\mathrm{sgn}(\gamma)$
    else if $|\beta| > 30°$ **then**
      Move joint q_8 in the direction of $\mathrm{sgn}(\beta)$
    else if $|d - d_0| > 10\text{cm}$ **then**
      Move joint q_9 in the direction of $\mathrm{sgn}(d - d_0)$
    else if No command for 10 seconds **then**
      Disable interface
    end if
  end if
end loop

In this algorithm we use the symbol γ to represent the panning directionof user's head. Note that the threshold parameters (e.g. 10) can be calibrated during set-up depending on the user requirements. Different joints are controlled by γ, β and d each standing for panning tilting and zooming of the endoscope respectively. To facilitate the operation of the interface, the commands are automatically verbalised by the system as follows: enabled, disabled, pan, tilt, and zoom.

III. Conclusions

In this paper, we developed a new surgical endoscope manipulator to assist the surgeon during a FESS. The system is composed of a 5-DoF passive positioning arm, and a 4-DoF active robotic manipulator. To control its motion, we proposed an IMU-based human-robot interface which is attached to the surgeon foot; the ex-vivo experiments showed that this interface is intuitive and easy to use. As future work, we would like to incorporate automatic control mode into the system, e.g. the use of image-based method to automatically position the endoscopic camera inside the nasal cavity. To improve the safety of the system, we would like to integrate the feedback of a force/moment sensor into our control methods.