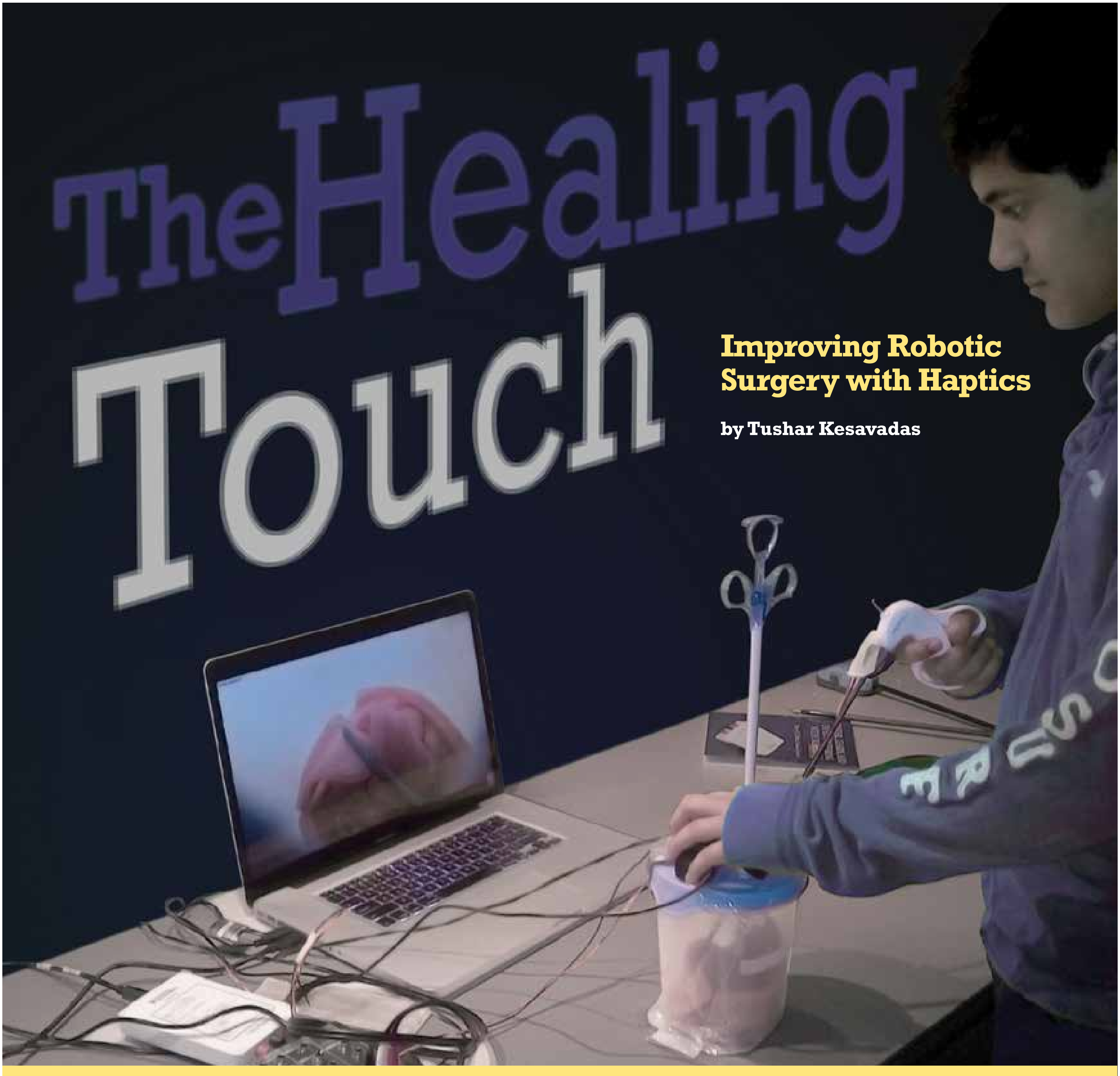
The Healing Touch



Improving Robotic Surgery with Haptics

by Tushar Kesavadas

When I was in eighth grade, my father, a professor of mechanical engineering at SUNY Buffalo, took me to the Roswell Park Cancer Institute (RPCI) to see the da Vinci surgical robot in action. My father had been collaborating on a project with Dr. Khurshid Guru, a surgeon who uses the da Vinci robot, and when he heard that Dr. Guru was holding a training session for other surgeons, he asked if he could come to see the robot and if I could join him.

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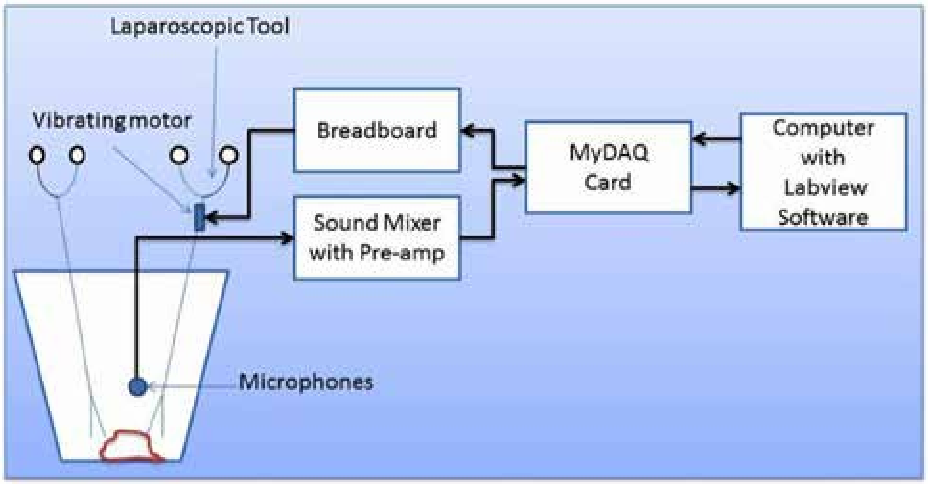

Doctors who perform robotic surgeries currently rely only on visual feedback during procedures. Tushar's prototype provides surgeons with tactile feedback by translating the sounds created by surgical tools into vibration.

Meet the Robot

At RPCI, Dr. Guru took us to the operating room, which was equipped with high-tech displays, flat screen TVs, and, in the corner, the da Vinci surgical robot. It had two major parts: a console where the surgeon sits and controls the robot, and the robot itself, with tools that operate on the patient. The surgeon uses two "joysticks" to control the robot's tools while watching high-definition video of the robot end effector inside the patient's body.

Dr. Guru introduced me to several surgeons-in-training who that day were practicing multiple timed tests, such as placing small balls on pillars of various heights. When the trainees finished their lessons and I was given a chance to operate the robot, I quickly discovered that it was more difficult than it looked. When I first moved my right hand to control the right tool, I brought the tool way too close to the camera. To fix this, I had to push my left foot down on a pedal to switch the controls to the camera, move the camera to a new position, and retry. I also could not tell how much pressure I was applying, so I sent one ball flying across the room when the tool grasped it too tightly. The Lego robots I had built at home were nothing like this.

Like Music to My Hands

Last summer, still interested in medicine and bioengineering, I asked Dr. Guru if I could volunteer in the center for robotic surgery. Fortunately, he found a way to include me in his research. Dr. Guru is a pioneer in removing bladder cancer through robot-assisted radical cystectomy (RARC), and he was collecting data pertaining to patients' quality of life after undergoing RARC. My job was to assimilate the data from questionnaires and populate the database so that it could be analyzed by a biostatistician. The project ultimately showed that recovery time for RARC was much better than for open surgery. The paper about this work, of which I am a co-author, will appear in the journal *Urology* later this year.

One major reason for the improved recovery time is that robotic surgery is less invasive than traditional surgery. In traditional surgery, when the surgeon moves his hand one inch, the scalpel in his hand also moves one inch. However, in robotic surgery, if the surgeon moves the controller one inch, the tool on the robot moves only one-third of an inch. The robot scales down the surgeon's motion, resulting in greater precision.

However, robotic surgery does not provide surgeons with the same sensory feedback they receive during traditional surgery. Most significantly, when the robot's tools make contact with tissue, the surgeon does not feel it. Every surgeon learns to control the contact pressure by using only visual cues. Talking with Dr. Guru and others in the lab, I realized that this was a well-known weakness in the robot.

While I was volunteering for Dr. Guru, I was allowed to observe surgeries live on video screens in the adjacent room. I could see exactly what the surgeon saw on the da Vinci console, and I noticed that surgeons sometimes unintentionally hit the surgical tools together. I remembered reading an article about how deaf people could "listen" to music by converting the music to vibration. It occurred to me that every time the tools hit each other, or bone or other tissues, a distinct sound would be made. I wondered if that sound could be sent to the surgeon in the form of tactile feedback.

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Sound Check

After doing some research, I found that many institutions, including Johns Hopkins University and the University of Pennsylvania, are devising solutions to provide touch feedback for robotic surgery. Their approaches include adding sensors on the robot to measure forces or adding vibration sensors and an accelerometer to the base of the tool.

I thought it might be simpler to measure the sounds created in the operating field and transform them into some sort of tactile feedback. Collecting audio and converting it to haptic (force) or tactile (touch) feedback would require no advanced sensors on the robot; instead, tiny microphones could be placed either inside or on the surface of the patient's pelvic region.

To test my idea, I placed a piece of soft plastic material that doctors use to learn suturing, a gel-filled mouse pad, a gummy bear, a guitar string, and other materials inside a clear plastic box. I selected these materials to simulate the sounds that would come from the interaction between surgical tools and soft tissue, bone, and cartilage. I borrowed two laparoscopic tools from the lab—a grasper, used to hold the tissue tight, and a scalpel—that are very similar to the tools used on the da Vinci. I inserted two small but very sensitive microphones and a miniature camera inside the box. Next, I collected audio samples of tool-to-tool and tool-to-tissue collision.

When I began to analyze the sound data, it quickly became obvious that I needed an advanced method to filter the audio data. There was a lot of static and extraneous noise, which I didn't want to convert to tactile feedback. It occurred to me that I could enhance sounds within a certain frequency range and convert only that frequency to vibration.

While I was working for Dr. Guru, I had learned how to use a software package called LabVIEW from National Instruments. The sound collected by the microphones was converted to digital information by LabVIEW's data capturing board, called myDAQ, and then sent to a laptop running a program I had devised in LabVIEW to filter the audio, getting rid of background noises while enhancing certain frequency ranges to capture the sound produced by the tool interactions.

Now that I had the sound, I needed the tactile feedback.

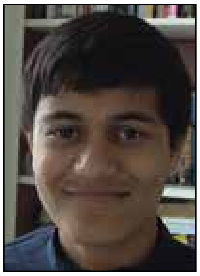
The Feel of Sound

I was searching a hobby store when I landed on the idea of using an eccentric motor, a small motor that spins on an axis that is slightly off-center. Unbalanced, the motor shakes when spinning at high frequencies. I attached an eccentric motor to each laparoscopic tool with small pieces of tape.

Now, the filtered sound data would be sent from the laptop to a breadboard (a small board used to make circuits), which converts the sound into electricity that powers the vibrating motors. This vibration is felt by the surgeon. I tested the various collisions several times and then tested the vibration created for each signal. After months of adjusting and refining, I came up with a prototype that works in real-time.

Dr. Guru suggested that we set up a time to show my prototype to other surgeons, and I am very interested to see how it will be perceived by experts and novices. If my device has the potential to improve the surgeons' ability to control the robot, then maybe it will be patented and incorporated in future generations of surgical robots.

Recently, I asked Dr. Guru what he thinks the future holds for robotic surgery. He believes that sometime in the future, surgeons will be able to plan their actions on a virtual patient and upload the surgical plan to a robot that could execute it anywhere on the planet, without human intervention. But will patients allow such an independent robot to operate on them? That is an interesting question that may be answered in our lifetime. i



CTY alumnus **Tushar Kesavadas** is a junior at Clarence High School in New York, where he is treasurer of the Science Olympiad team and a member of the varsity tennis team and the National Honor Society. He has played the piano since age four and sings in his school's choral group. In his spare time, Tushar duels in the virtual world of Xbox.