Ali Batouli
Stanford University
Summer 2006: PI: Dr. Peter Kazanzides
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Neurosurgery Robot

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Abstract

We (Dr. Peter Kazanzides, Babak Matinfar and I) continued the development of a CT image guided robotic surgical assistance system for skull base drilling. The system allows the surgeon to describe a forbidden region before surgery which the drill tip will not impinge upon during the procedure. Velocity constraints also hinder the surgeon from approaching the forbidden region with high speeds, thus decreasing the risk of accidental penetration. The accuracy of the system is limited by the CT image accuracy, the localizing camera precision, robot compliance and calibration errors. No actual drilling has taken place yet.

Adam Bosen
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Central Pattern Generator Implementation Using a Floating Gate Neuron Model

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Abstract

A silicon chip implementing 24 floating gate neurons was previously developed, although no work had been performed to make this chip emulate a central pattern generator. General floating gate programming techniques were refined for use on this chip. Using these programming techniques it was shown that the chip could generate the output patterns necessary to implement a central pattern generator. Due to time constraints current work has not actually created a central pattern generator, but there appears to be sufficient evidence that with more programming a central pattern generator can be implemented on this chip architecture.

David Burkhardt
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C-arm Reconstruction using Elliptic Curves

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Abstract

A C-arm pose reconstruction algorithm was designed that relies on ellipses in several C-arm images. It was found that the projection of elliptic curves constrain 5 of the 6 degrees of freedom of the C-arm pose. To completely recover the true C-arm pose, an additional constraint in the form of available point correspondences in the images is employed. An algorithm to obtain a virtual correspondence across several images is provided and it is shown that two correspondences can always recover the true pose uniquely. Phantom experiments across three images indicate a pose estimation accuracy of 1.9_ and 3D reconstruction accuracy of 1.5 mm using only an ellipse and two point correspondences. The method appears to be sufficiently accurate for many clinical applications and particularly appealing since it works without any significant modification of the clinical protocol.

Eva Dyer
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Validation of Needle Insertion Procedures for a Comparative Study of MR/CT Image Overlay Guidance and Other Needle Insertion Techniques

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Abstract

Augmented reality (AR) systems are generally defined by the assimilation of physical and virtual objects into a real environment. AR systems have numerous medical applications in the fields of: laproscopic surgery, neurosurgery, otolaryngology, and orthopedics. In order to aid in needle insertion procedures, an image guided AR system has been created by Fichtinger, et al. (2004). This system provides “tomographic” vision for the interventionalist by aligning a pre-operatively obtained image on top of the patient’s body in the proper scale and position.

In typical freehand interventions, the interventionalist will often probe the patient until the desired target is reached. These procedures will often take up to a half hour, and in order to confirm proper placement of the needle, the interventionalist will take multiple CT or MR scans of the patient’s anatomy after each attempt. By using CT, the patient is exposed to unnecessary amounts of

radiation. On the other hand, MRI does not expose the patient to radiation, but measuring needle placement accuracy in MR images is greatly limited by paramagnetic artifacts. Both modalities are very costly, with a typical charge of $ 200-500/hr for scanner time.

In order to combat these issues, an offline electromagnetic tracking validation system has been created. This system will be used in both validation of accuracy and in gesture tracking of needle insertion procedures under guidance of the image overlay, a bi-plane laser guide, and also in freehand interventions.

Tricia Gibo
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Summer 2006: PI: Dr. Russell Taylor
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"Smart" Tools: Measuring Retraction Force Exerted on Patients During Surgery

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Abstract

During surgery, tools are used to retract tissues and organs to give the surgeon better visualization of the operating field. However, excessive force on tissues can result in ischemia (decreased blood supply due to constricted blood vessels) and cell death. "Smart" tools will enable surgical instruments to monitor and measure such factors as retraction forces and oxygenation levels. This project focuses on two force sensing Kelly retractors – one with piezoresistive load cells and one with strain gages – used to retract a patient's abdominal wall during open surgery. The two retractors were first calibrated using a set up that simulated the abdominal wall. In subsequent experiments, the load cell and strain gage retractors were found to have a maximum error of approximately 7 N and 2 N, respectively. The strain gage retractor, the more accurate of the two instruments, was then used in a porcine trial which served as a practice run for its use in impending clinical trials.

Kimberly Harrison
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Yield Detection and Prevention for EMG-Controlled Prosthesis

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Abstract

Users of prosthetic hands may have difficulty maintaining a steady grip force, thereby causing accidental damage to delicate objects. The ability of a prosthetic arm to detect yielding in an object using stress-strain data was assessed. Four yield detection methods (YDMs) were used: offset yield point, apparent elastic limit at 50%, apparent elastic limit at 80% and human yield detection. Four trials were performed for each YDM; for each trial, the yield strain predicted by the YDM and the strain at which actual yielding occurred were measured. The apparent elastic limits at 50% and 80% successfully prevented breakage, but the offset yield and human yield detection methods allowed test objects to break. The large measurement error made meaningful analysis very difficult. The difference between predicted and actual yielding in the apparent limit tests may be reduced by using a smaller percentage threshold. The offset yield method may be improved by translating the linear region by a smaller amount. Examination of the mechanical properties of the prosthetic hand may be necessary in order to more accurately assess the abilities of the YDMs.

Elia Junco
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Surgical Modeling: the Foundation for Objective Skill Assessment and Training

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Abstract

As the need for improved methods of assessing and evaluating surgical technical skill grows, it is imperative to establish a foundation for objectively analyzing surgical training and performance to ensure the ability to communicate among educators, education researchers, responsible training bodies, and credentialing boards. The objective of our current study was to use the Intuitive Surgical's da Vinci, a minimally invasive surgical system, to obtain a large amount of stereo-vision video recordings and da Vinci kinematics data of subjects with varying da Vinci or surgical skill levels doing predefined surgical tasks. A da Vinci stereo-vision recording environment was developed in the Haptics Laboratory at the Johns Hopkins University. The stereo-vision cameras were calibrated, and a Matlab da Vinci stereo video/API data file analyzer and a API data file/surgical motion analyzer were created.

David Mayhew
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Imaging Coronary Arteries and Valves with MRI

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Abstract

Coronary arteries and valves are difficult to image using MRI given their complex movement. Tracking the movement of both of these structures provides a way correcting for this motion while imaging. By tracking the position of coronary arteries in real-time with low resolution images, their window of minimal motion can be predicted and imaged in high resolution. This technique provides a robust, patient-specific method capable of correcting for respiratory motion. Similar tracking can be performed in cine imaging of heart valves. By tracking the movement in a view orthogonal to the movement of the valve, the plane of the valve can be determined for a second cine MRI scan by changing imaging planes to match the plane of the valve.

Hye Sun Na
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Summer 2006: PI: Dr. Allison Okamura
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Virtual Fixture Control for Compliant Human-Machine Interfaces

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Abstract

Joint compliance and human-input dynamics degrade the performance of virtual fixtures in human-machine cooperative systems. To account for these effects, dynamic virtual wall methods were proposed to create a movable virtual fixture that prevents the end-effector from entering a forbidden region. Additionally, the Force-Only Method is added as another virtual wall method. When applied in an openloop fashion, these methods stop the user at an undesired or conservative distance from the true forbidden region. In this study, we propose a closed-loop control to implement with the virtual wall methods which will allow the user to reach the forbidden region following an overdamped trajectory. Two user experiments were conducted on a 1-DOF testbed to evaluate the virtual wall methods. A vision system was used for real-time position tracking. In the first experiment the users relied solely on haptic feedback. Since in real applications, visual feedback and cognitive load are typically present, these two factors were introduced and tested in the second experiment.

Robinson Seda-Padilla
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Experimental Modeling of Needle Steering

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Abstract

Needle insertion is an essential aspect of many minimally invasive procedures; however, it does not guarantee targeting accuracy. Needle steering provides ways to not only improve accuracy, but also to steer around obstacles and reach targets that were not accessible via straight trajectories. This steering can be enhanced by combining the effects of two physical characteristics of the needle: cross sectional area and tip configuration. The results obtained by fitting needle trajectories to circles using the least squares method present that pre-bent hollow needles will achieve higher curvatures than existing bevel-tipped needles. In the future, this work will aid in advanced studies in 2-dimensional and 3-dimensional path planning and modeling within a patient.

Rocio Vargas-Pinto
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Development of a Position Tracking System for the C-arm

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Abstract

The C-arm is a device that uses x-rays to produce real time images. In order to perform any quantitative analyses based on the c-arm images, accurate information about the pose of the device is required. Many c-arms used nowadays do not provide pose information. Instead, optical tracking devices are used to recover pose information but these devices require a clear line-of-sight. A system based on 3 uni-axial accelerometers mounted orthogonally on a cube was developed to track the C-arm position and orientation relative to the Earth's gravity field. The system is attached directly to the c-arm, eliminating the line-of-sight restrictions. The assembly is portable and fit a range of different c-arm sizes. The sensors were calibrated using the rotational calibration procedure. The sensitivity and offset values for each sensor were obtained. The system measures the direction of the static acceleration

(gravity) vector and compares it with the vertical direction. The angle between those indicates the position of the c-arm when the c-arm is rotated on a plane.