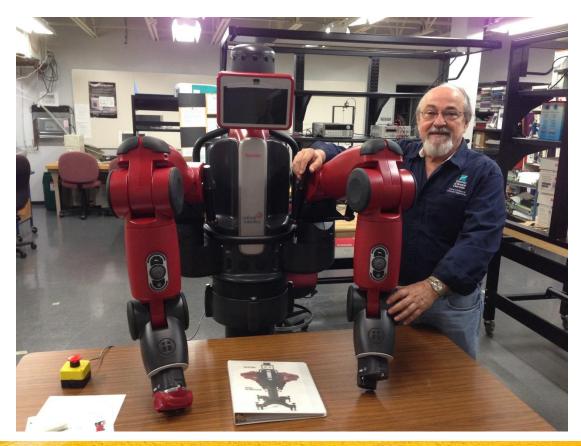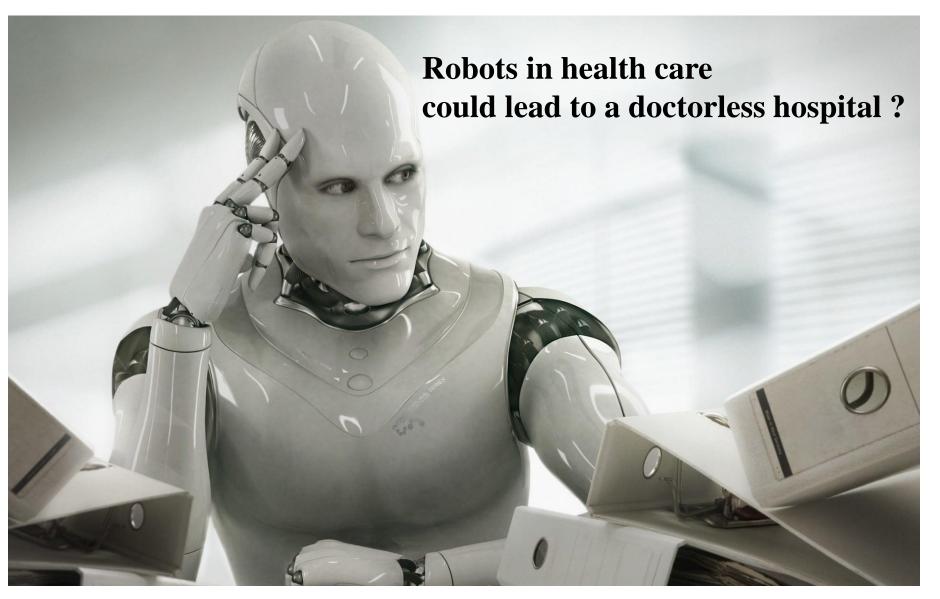# Robots in the Doctor's Office and Beyond

Thomas L. Harman, Ph.D.
Director of Center for Robotics Software,
Department Chair of Engineering
Professor of Computer Engineering,

**Robots in health care
could lead to a doctorless hospital ?**

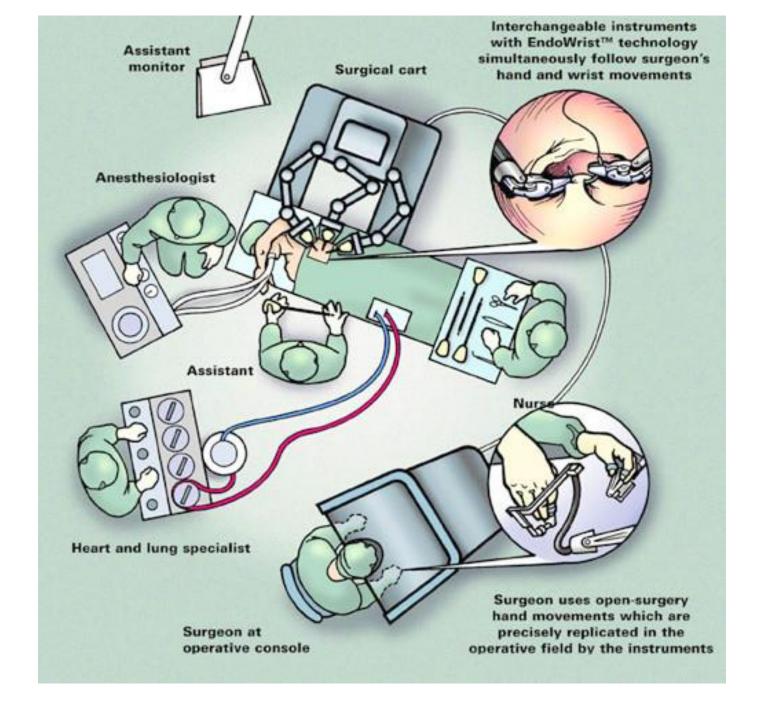10 Aug 2017
•Business

Where should I cut?

OUTLINE

- GENERAL
- APPLICATIONS
- ROBOT SPECIFICATIONS
- RESEARCH WORK
- THE ENGINEERING CONTRIBUTION
- THE FUTURE

Brief History

- 1921 - The term "robot" was first used in a play called "R.U.R." or "Rossum's Universal Robots" by the Czech writer Karel Capek. The plot was simple: man makes robot then robot kills man!

- 1941 - Science fiction writer Isaac Asimov first used the word "robotics" to describe the technology of robots.

  - A robot may not injure a human being or, through inaction, allow a human being to come to harm.

  - A robot must obey orders given it by human beings except where such orders would conflict with the First Law.

  - A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

- 1958 - The transition from science fiction to reality occurred in when General Motors introduced the Unimate to assist in automobile production.

APPLICATIONS

- SURGERY
- ASSISTANCE
- PROSTHETIC DEVICES
- REMOTE SURGERY & TELECOMMUNICATION
- MILITARY

Assistant monitor

Surgical cart

Interchangeable instruments with EndoWrist™ technology simultaneously follow surgeon's hand and wrist movements

Anesthesiologist

Assistant

Nurse

Heart and lung specialist

Surgeon at operative console

Surgeon uses open-surgery hand movements which are precisely replicated in the operative field by the instruments

7

Michael Yip and Nikhil Das

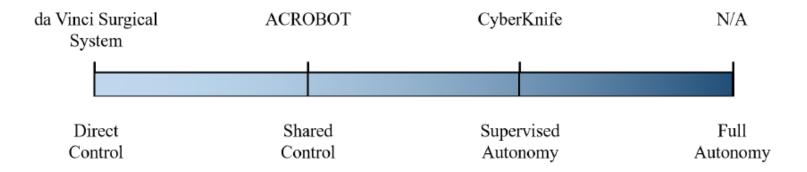| da Vinci Surgical System	ACROBOT	CyberKnife	N/A
Direct Control	Shared Control	Supervised Autonomy	Full Autonomy

Fig. 1.   Spectrum of autonomy in robotic surgery and examples of systems. There are currently no examples of surgical systems that can operate without any level of human involvement.

Michael Yip and Nikhil Das

Table 1.   Advantages and disadvantages of humans and autonomous robotic systems

	Human	Robot
Advantages	Good judgement	Good mechanical precision
	Adaptable and able to improvise	Untiring and stable
	Able to use qualitative information	Can work in hazardous environments
	Easy to train	Multimodal sensory integration
	Easy communication with humans	
Disadvantages	Limited mechanical precision	No judgement
	Prone to fatigue, tremor, inattention	No qualitative abilities
	Cannot work in hazardous environments	Limited in haptic sensation
	Limited quantitative abilities	Expensive

Michael Yip and Nikhil Das

Table 2. Robotic systems with various levels of autonomy

Name	Branch of surgery	Level of Autonomy
da Vinci Surgical System	General minimally-invasive	Direct control
EndoBot	General minimally-invasive	Direct, shared control, supervised
Trauma Pod	General	Direct control
Sensei Robotic System	Cardiac	Direct control
NeuroMate	Neurosurgery	Supervised
Probot	Urologic	Supervised
ACROBOT	Orthopedic	Shared control
RIO	Orthopedic	Shared control
Precision Freehand Sculptor	Orthopedic	Shared control
ROBODOC	Orthopedic	Supervised
CyberKnife	Radiosurgery	Supervised

Teleoperated robot-assisted surgical system for minimally invasive procedures. (Credit: Intuitive Surgical, Inc.)
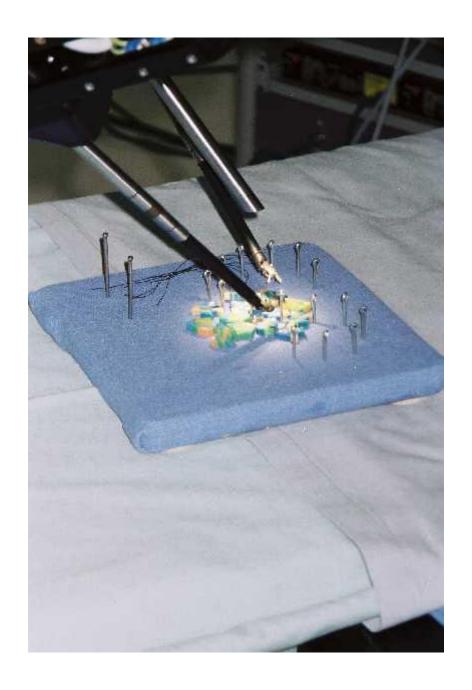
UTMB daVinci System

FEATURES

- TELEOPERATED BY SURGEON
- MINIMALLY INVASIVE SURGERY
   USING ENDOSCOPES
- PRECISE MOVEMENT OF INSTRUMENTS
- EXAMPLES: Heart valve repair; stomach surgery;
   cutting and suturing; prostate removal, etc.

LEVEL: Direct control

CyberKnife Radiation Treatment
ACCURAY.COM

CyberKnife® is a non-invasive option for patients who have inoperable or surgically complex tumors, or who may be looking for an alternative to surgery. The CyberKnife system enables our radiation oncologists to deliver targeted, high doses of radiation to a broad range of tumors throughout the body.

Potential benefits of the CyberKnife system include:
- No incision
- No pain
- No anesthesia or hospitalization
- Greater comfort (patient can breathe normally during treatment)
- Little or no recovery time
- Immediate return to normal activities
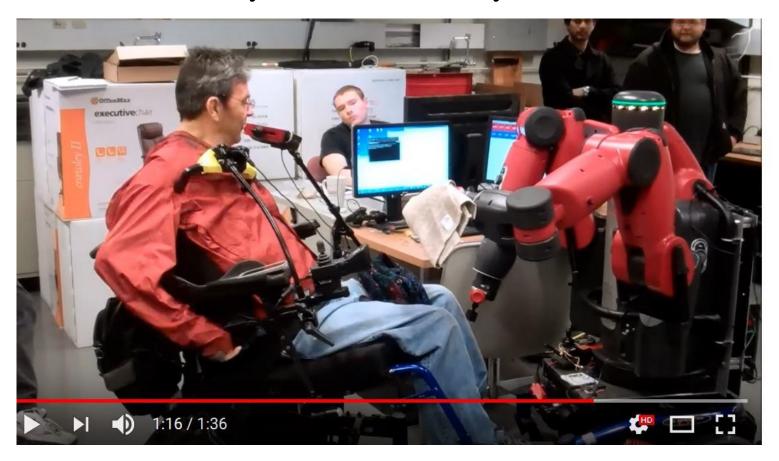
"Nurse, get on the internet, go to SURGERY.COM, scroll down and click on the 'Are you totally lost?' icon."

ASSISTANCE

- Baxter Robot Aids Handicapped
- Baxter controlled by Brain Waves
- Rodent thinks and eats!
- Robots help in the Hospital
- IBM Watson Checks your health

David Whalen using Jammster for the first time! Work done at the CATS laboratory at Rensselaer Polytechnic Institute.
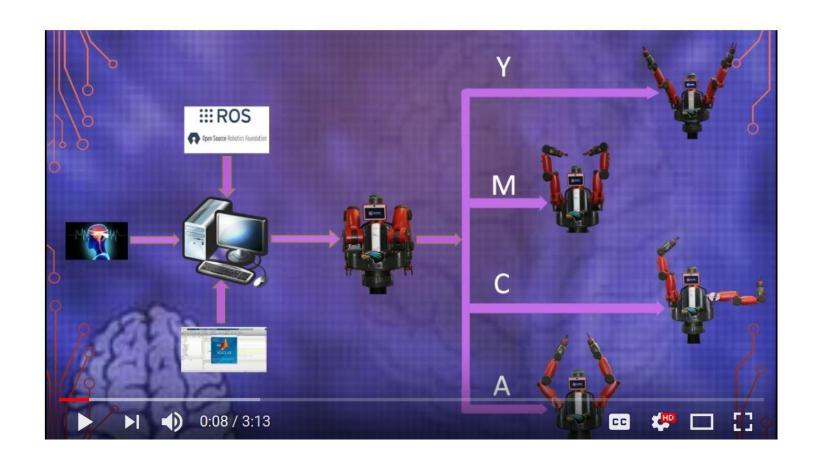
RODENT BRAINS CONTROL ARM

Rat's Brain Activity Controlled a Robot Arm

Baxter's Lab UHCL

Pepper Guides you

Watson for Oncology combines leading oncologists' deep expertise in cancer care with the speed of IBM Watson to help clinicians as they consider individualized cancer treatments for their patients.

PROSTHETIC DEVICES

- ARTIFICIAL LIMBS
- ARTIFICIAL ORGANS

HISTORY

1268 Earliest recorded mention of eyeglasses
Roger Bacon made the first recorded comment on the use of lenses for optical purposes. However, by that time reading glasses made out of transparent quartz or beryl were already in use in both China and Europe.
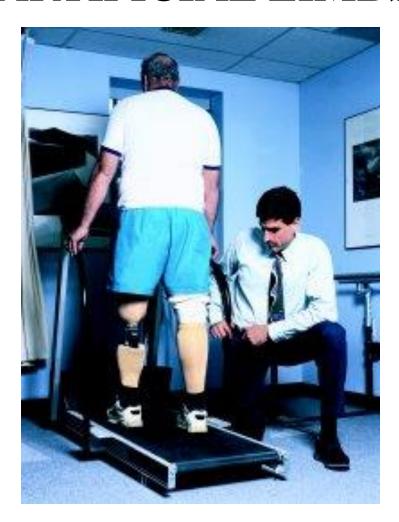
1665 Robert Hooke calls for augmented senses
Micrographia preface 1665: "The next care to be taken, in respect of the Senses, is a supplying of their infirmities with Instruments, and as it were, the adding of artificial Organs to the natural... and as Glasses have highly promoted our seeing, so 'tis not improbable, **but that there may be found many mechanical inventions to improve our other senses of hearing, smelling, tasting, and touching."**

From "A History of Wearable Computers"

The History of Prosthetics

Orthotics & Prosthetics | September 21, 2015 | John Marshall
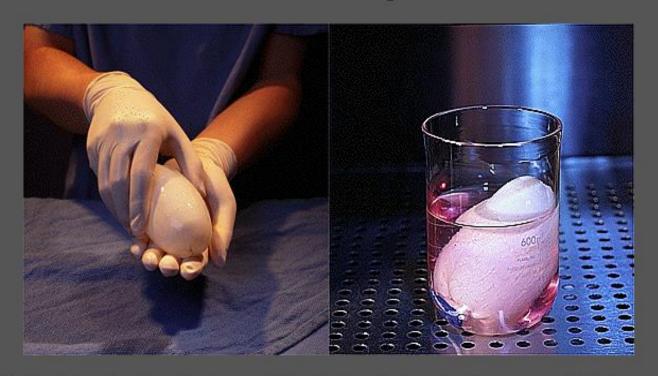
ARTIFICIAL LIMBS

DIGITALLY CONTROLLED LEG

SANDIA LABS

In order to simulate a real leg's action when walking uphill, downhill or across uneven terrain, scientists plan to install a microprocessor-controlled module in the leg that will respond to signals from sensors placed along the foot and leg.

Artificial Organs

Artificial bladder being developed by James J. Yoo M.D., Ph.D. at the Department of Urology at Harvard Medical School.

ARTIFICIAL ORGANS

Dean Kamen Segway inventor develops neurally controlled arm.

The DEKA Arm was created by famed inventor Dean Kamen and his team at DEKA Research and Development Corp., in Manchester, N.H., as part of DARPA's Revolutionizing Prosthetics program.

The DEKA Arm, which has similar size and weight to a natural limb, relies on a combination of control inputs. The main signals come from electromyogram (EMG) electrodes, which sense electrical activity on muscles close to where the prosthesis is attached. A computer on the prosthesis receives the EMG signals and interprets them to make the fingers open or close, or change the grip configuration to let the user pick up a coin, for example.
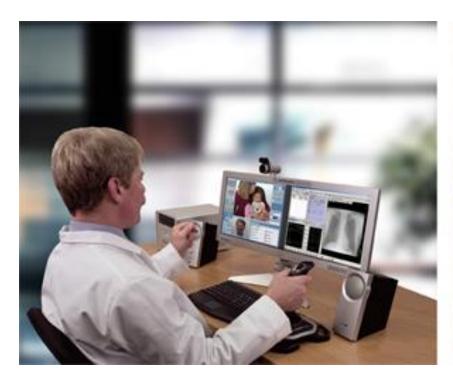
REMOTE SURGERY
AND
TELECOMMUNICATION

- Gall Bladder Surgery Across the Ocean

- "Dr. Robot will see you now"

- Wearable Sensors for Monitoring Health

- Technical Considerations

- Doc at a Distance – Trama Pod

Lindberg Operation Patient in Strasbourg (Doctors in New York)

Dr. Robot will see you now!

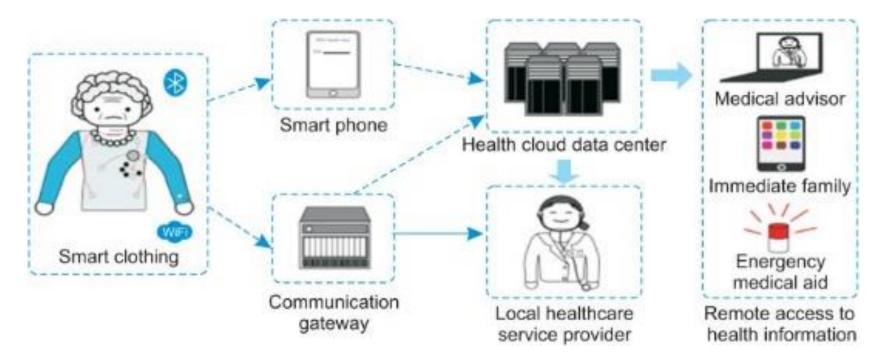Remote communication, examination and record keeping

For the Patient

For the Doctors

Smart clothing

Smart phone

Communication gateway

Health cloud data center

Local healthcare service provider

Medical advisor

Immediate family

Energency medical aid

Remote access to health information

Listing of some commercial products for monitoring physiological signs and activities.

Product Name	Monitored Parameters	Wireless Platform	Battery	
			Type	Life
Hexoskin® Biometric® Shirt	Heart rate (HR), HR variability, respiratory rate, number of steps, distance traveled, pace, maximal oxygen consumption, and calories burned.	Bluetooth	6–7 days (standalone) 14+ h (multi-training)	
Jawbone UP3™ Fitness Tracker	Sleep stages (REM, light and deep), HR, food and liquid intake, number of steps, distance traveled, running.	Bluetooth LE	Li-ion poly	7 days
Striiv® Fusion Bio Fitness Tracker	HR, number of steps, distance traveled, calories burned, and sleep quality.	Bluetooth LE	Li-ion	5 days
Microsoft® Band 2	HR, calories burned, sleep quality, food, and liquid intake, number of steps, elevation, climbing, running, biking.	Bluetooth	Li-poly	2 days
Fitbit Charge HR™ Fitness Tracker	HR, calories burned, sleep quality, food, and liquid intake, number of steps, elevation, climbing, running.	Bluetooth LE	Li-poly	5–7 days
Garmin vivosmart® HR Fitness Tracker	HR, calories burned, sleep quality, number of steps, climbing, running, swimming.	Bluetooth LE, ANT+	Li-ion	5 days

Wearable Sensors for Remote Health Monitoring

Sumit Majumder, Tapas Mondal, and M. Jamal Deen

TECHNICAL CONSIDERATIONS for COMMUNICATION

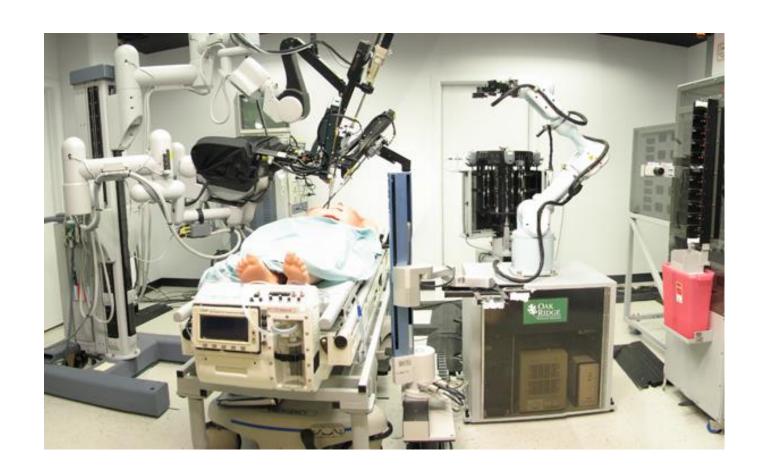- Reducing Timing Delays
- Reliability

Doc at a Distance

- DARPA has funded a number of projects to create remotely operated surgery units
- The surgical robot would be controlled by a doctor at some remote location
- Trauma Pod is a prototype example

TRAMA POD

ROBOT SPECIFICATIONS

- DEXTERITY
- ACCURACY (PRECISION)
- SMALL SIZE
- FEEDBACK (Visual, Tactile)
- USER INTERFACES
- VISUAL PRESENTATION (2D, 3D, etc.)
- SAFETY

RESEARCH

- TREATMENT - UHCL Example
- MINIATURE MOTOR for Precise Control
- RICE UNIVERSITY
- NASA
- UH

Early Work in Bioengineering

- J. W. Clark, E. C. Greco and T. L. Harman, "Experience with a Fourier Method for Determining the Extracellular Potential Fields of Excitable Cells with Cylindrical Geometry," Critical Reviews in Bioengineering, CRC Press, Inc., 1978

UHCL
Robot Control from
Sequential Image Planes
of a 3D Object

S. B. Premkumar, T. L. Harman, A. G. Houston
University of Houston-Clear Lake, Houston, TX

L. A. Nguyen
Lockheed Engineering and Sciences Co., Houston, TX

Image Coordinates

- TRUS image data of sequencial cross-sections are obtained at 2_{mm} intervals from base to apex of the gland. Prostate
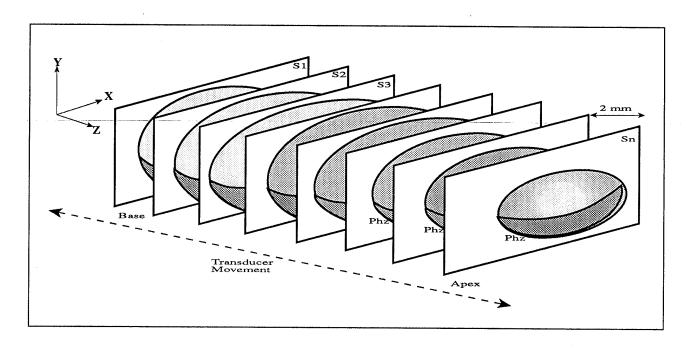
Fig 1. *Sequential TRUS image planes comprise the 3D volume of the gland.*
Transrectal Ultrasound images of the prostate

Robot Coordinates

- Scorbot - ER VII robot system has five degrees of freedom and is mounted on a slide base. Slide base provides additional degree of freedom.
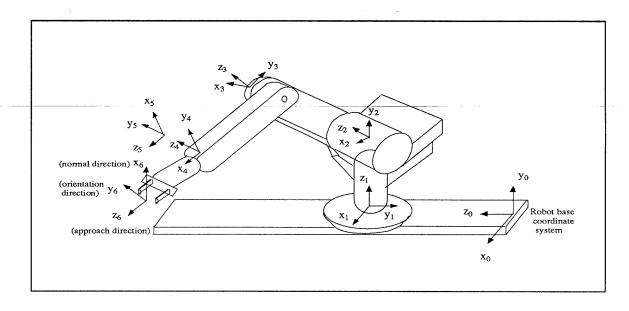

Fig 2. *Scorbot - ER VII coordinates systems at various joints are shown.*
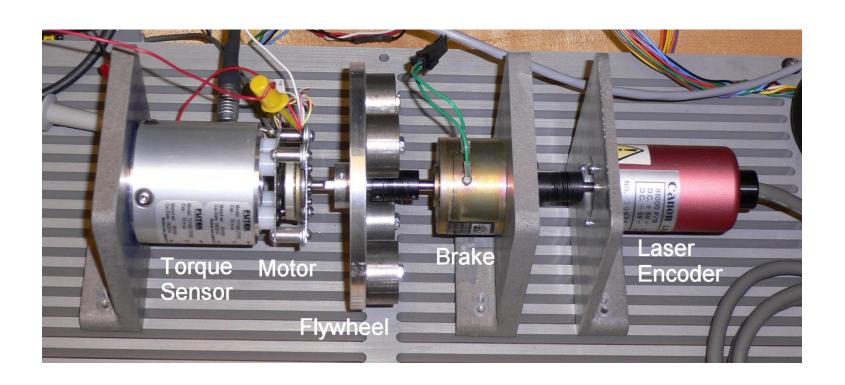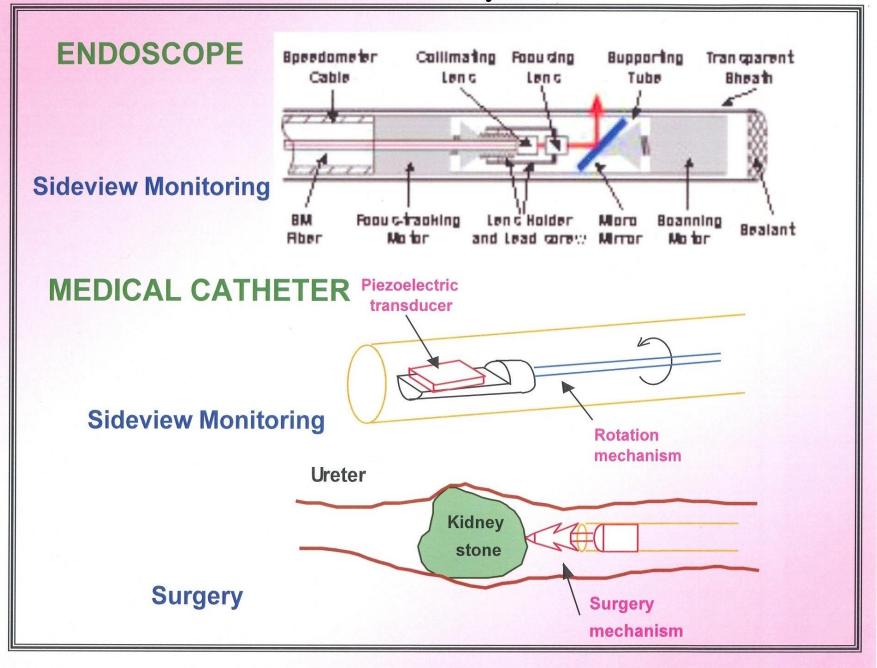
Robot System

Piezoelectric Ultrasonic Motor

The powerful magnetic field generated by an MRI machine makes hazards of even small ferromagnetic objects like screws, let alone, motion devices like permanent magnet motors, gearboxes, and actuators. It was obvious from the outset that the MRI robot had to be based on non-traditional actuation. The answer proved to be a **piezoelectric device.**

Experimental Setup to Characterize motor

Systems Laboratory in Delta Building, Dabney and Harman

ENDOSCOPE

Sideview Monitoring

Labels: Speedometer Cable, Collimating Lens, Focusing Lens, Supporting Tube, Transparent Sheath, SM Fiber, Focus-tracking Motor, Lens Holder and Lead screw, Micro Mirror, Scanning Motor, Sealant

MEDICAL CATHETER

Piezoelectric transducer

Sideview Monitoring

Rotation mechanism

Ureter

Kidney stone

Surgery

Surgery mechanism

RICE UNIVERSITY

- Dr. Marcia O'Malley - REHABILITATION
- NASA - Robonaut
- Dr. Frank Tittel – Optical Nose
- Dr. Aaron Becker UH – Magnetic Control of nano-robots

ARM EXOSKELETON

HAPTIC FEEDBACK

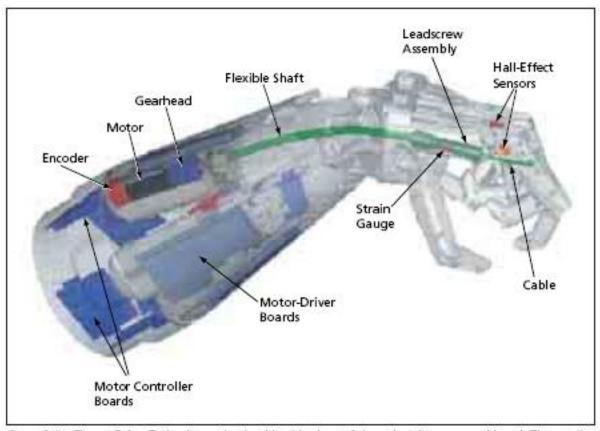# STROKE REHABILITATION
Mirror Image Movement Enabler
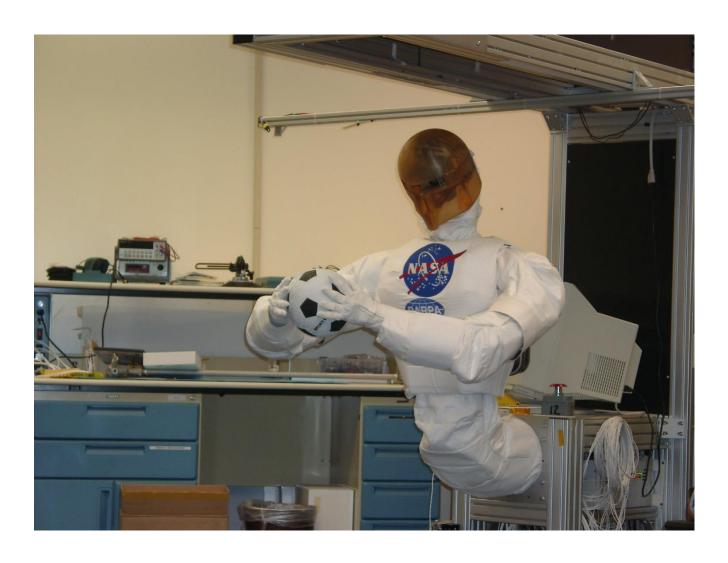
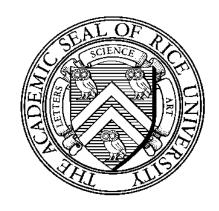# ROBONAUT JSC

ROBONAUT WITH BALL

ROBOT FOREARM JSC

One of the Finger Drive Trains is emphasized in this view of the robot forearm and hand. The motive forces for the fingers are generated in the forearm and are transmitted to the fingers by flexible shafts, leadscrews, and cables.

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OPTICAL NOSE?

Development of Quantum-Cascade Laser Based Biosensor Technology

Thomas L. Harman [UHCL] / Frank K. Tittel [Rice U] / John C. Graf [NASA-JSC] / Yury Bakhirkin [UHCL]
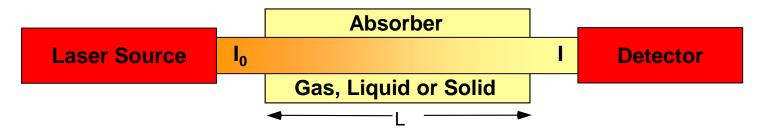
Master's Thesis UHCL

RICE UNIVERSITY

**NOVEL LASER-BASED GAS SENSORS FOR TRACE GAS
DETECTION IN A SPACECRAFT HABITAT
BY**

DARRIN PAUL LELEUX

**DOCTOR OF PHILOSOPHY
HOUSTON, TX
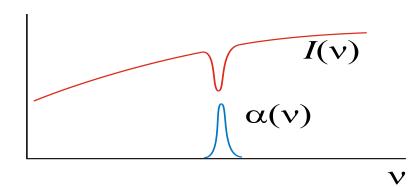APRIL, 2002**

Direct Laser Absorption Spectroscopy

| Laser Source | I_0 | Absorber | I | Detector |

Absorber

Gas, Liquid or Solid

L

Beer-Lambert's Law of Linear Absorption

$$I(\nu) = I_0 \cdot e^{-\alpha(\nu) \cdot P_a L}$$

$\alpha(\nu)$ − absorption coefficient [cm^{-1} atm^{-1}]; L − path length [cm]

ν − frequency [cm^{-1}]; P_a − partial pressure [atm]

$$\alpha(\nu) = C \cdot S(T) \cdot g(\nu - \nu_0)$$

$I(\nu)$

$\alpha(\nu)$

ν
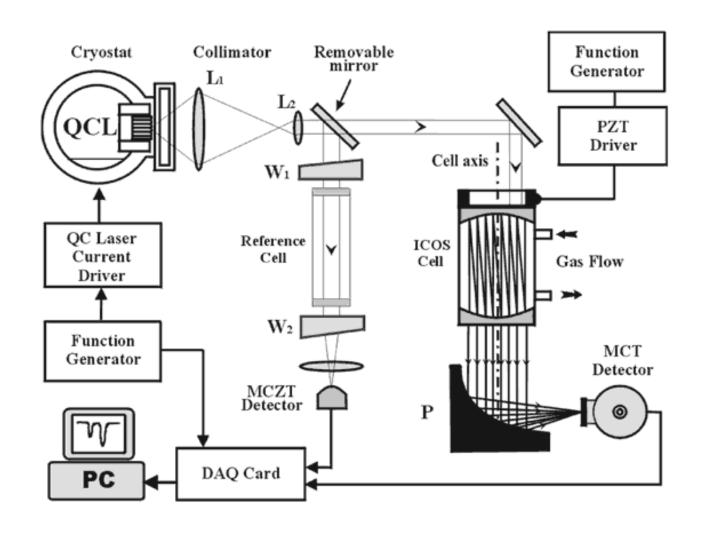
C − total number of molecules of absorbing gas/atm/cm^3 [molecule·cm^{-3} ·atm^1]

S − molecular line intensity [cm ·molecule^{-1}]

$g(\nu - \nu_0)$ − normalized lineshape function [cm], (Gaussian, Lorentzian, Voigt)

RICE

EXPERIMENTAL SETUP

Target Gases – 1
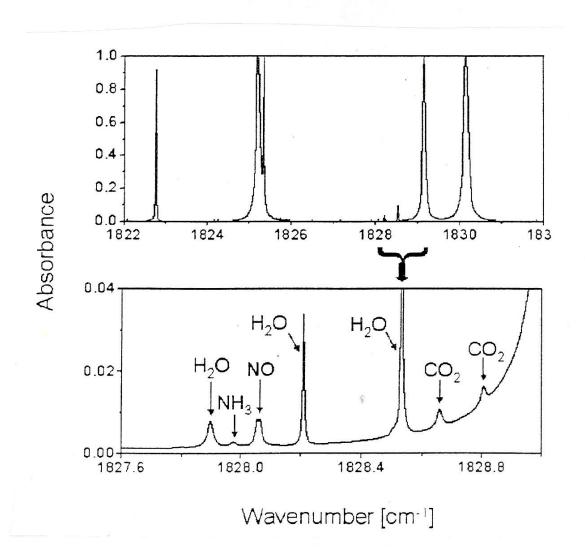
Molecule	Formula	Trace Concentration in Breath (ppb)	Biological/Pathology Indication
Nitric Oxide	**NO**	**6 - 100**	**Inflammatory and immune responses (e.g., asthma) and vascular smooth muscle response**
Carbon Monoxide	**CO**	**400 - 3000**	**Smoking** response, CO poisoning, vascular smooth m**uscle response, platelet aggregation**
Hydrogen Peroxide	H_2O_2	**1 - 5**	**Airway Inflammation, Oxidative stress**
Carbonyl Sulfide	**OCS**	**100 – 1000**	**Liver disease and acute allograft rejection in lung transplant recipients**
Formaldehyde	**HCHO**	**400 - 1500**	Cancerous tumors, breast cancer

RICE

Molecule	Formula	Trace Concentration in Breath (ppb)	Biological/ Pathology Indication
Pentane	$CH_3(CH_2)_3CH_3$	4 - 20	Lipid peroxidation, oxidative stress associated with inflammatory diseases, immune responses, transplant rejection, breast and lung cancer
Ethane	C_2H_6	3 - 100	Lipid peroxidation and oxidative stress
Carbon Dioxide isotope ratio	$^{13}CO_2/^{12}CO_2$	$4 - 5 \times 10^5$	Marker for Helicobacter pylori infection associated with peptic ulcers and gastric cancer, drug clearances rates
Methane	CH_4	1000 - 8000	Digestive function, colonic fermentation
Ammonia	NH_3	100 - 500	Hepatic encephalopathy, liver cirrhosis, fasting response
Acetone	C_3H_6O	1000 - 5000	Fasting response, diabetes mellitus response, ketosis

RICE

Example Scan for Exhaled Breath-
Detection of Asthma and Respiratory Problems

Rice System 2002

New Circuit Board 2008 with Stephen So

Design at Rice for handheld spectrometer

Rice air sensors tested near Beijing's Olympic stadium
Laser-based devices measure ozone-precursor nitric oxide

Aaron Becker, UH

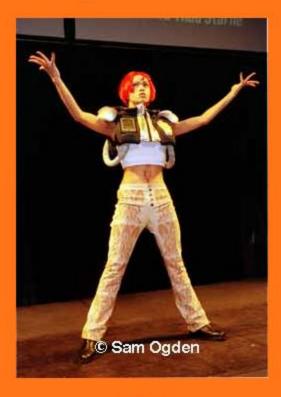**Swarm control of cell-based microrobots using a single global magnetic field**

THE FUTURE

- BIONIC PEOPLE
- ROBOTIC HOSPITALS
- ROBOTS FOR HOME CARE
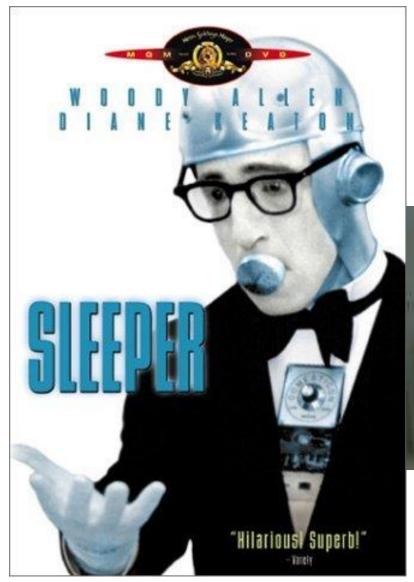- MICROROBOTS, NANOROBOTS

Wearable Computer Fashion Show at MIT
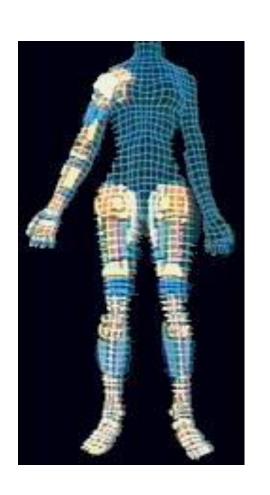
Wear it

next

Back to Sam Ogden Photography

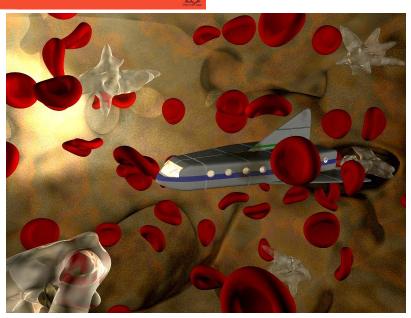The SIX MILLION DOLLAR MAN and THE BIONIC WOMAN were inspired by the novel *Cyborg* (1972) written by Martin Caiden.
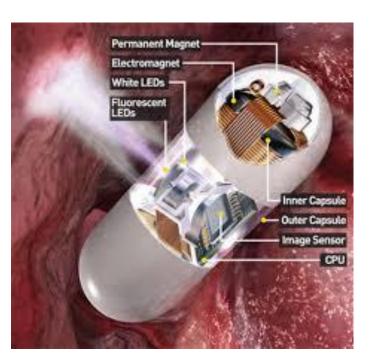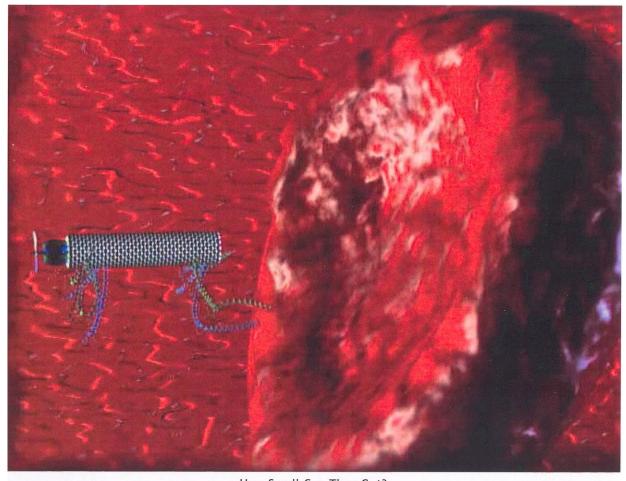
Robot Butler at Your Service!

FANTASTIC VOYAGE

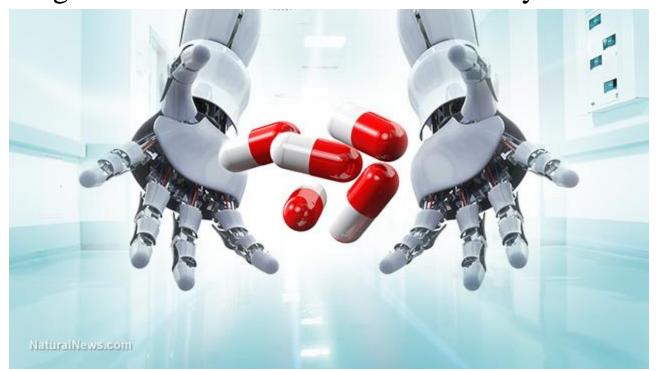Endoscope Camera

How Small Can They Get?

By 2020, scientists at Rutgers University believe that nano-sized robots will be injected into the
bloodstream and administer a drug directly to an infected cell. This robot has a carbon nanotube body

Soon, robotic pills will usher in a new era in healthcare technology by reducing the number of surgeries altogether. Researchers are working on easy-to-swallow remote-controlled robotic pills. These pills will be able to move inside a patient's bodily fluids and deliver drugs to the desired area, conduct biopsies, film the area, and even clear clogged arteries. Exciting new robots such as nanobots can travel in the bloodstream with the help of light and remove tumors from the body.

NaturalNews.com

ISSAC ASIMOV

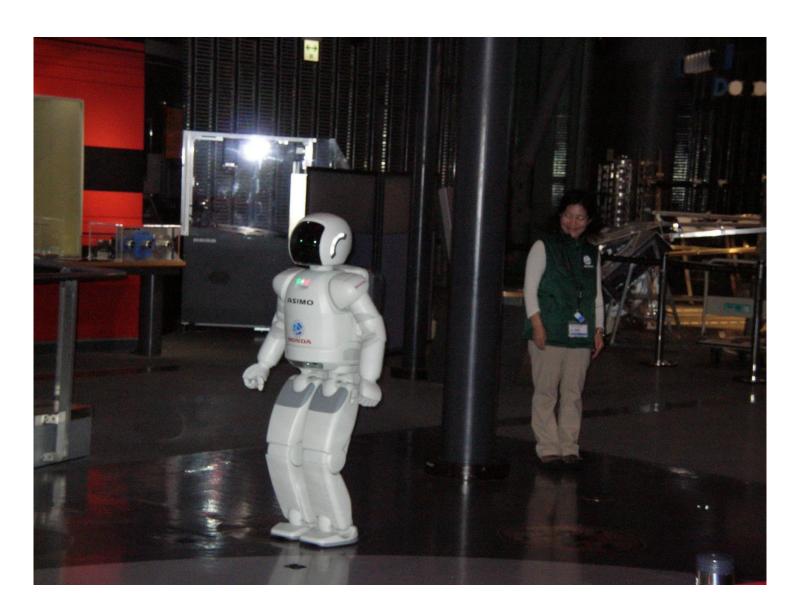300 BOOKS!

Asimov's Take on Life

"If the doctors told me I had six months to live, I'd type a little faster."

Isaac Asimov

ENGINEERING CONTRIBUTION

- COMPUTERS AND COMMUNICATION
- MAN-MACHINE INTERFACES
- MODELING OF BIOLOGICAL SYSTEMS
- ADVANCED CONTROL METHODS
- MEMS (Micro-electromechanical Systems)

A "Better than Amateur Player"

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