From Puma of Unimation 6000 Robot to Tonatiuh Robot and Hand Free Navigation System.

Laparoscopic assistant 1996-2003

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Abstract

Objective: We describe the technological development and the surgical applications on surgical robotics builted in Mexico. The robots have been designed to assit the endocopic surgeons with robots to hold and to position laparoscopes since 1996 to 2003.

Material and tools: Two Mexican Institutions have been participated in the technological development. The Escuela Superior de Ingeniería Mecánica, Eléctrica y Robótica, ESIME, Unidad Azcapotzalco of the Instituto Politécnico Nacional. The Centro de Investigación y de Estudios Avanzados CINVESTAV of the Instituto Politécnico Nacional, was the second. In the ESIME the Industrial Robot Puma Software of Unimation 6000 of six degrees of

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freedom was mdified for four undergraduate Students. With the new Robot software had the next surgical tasks: The robot holds and position the laparoscope to be manipulated by a remote assistant surgeon. At the CINVESTAV was builted a surgical robot of four degrees of freedom and a harness (Electromechanical system). The last device is mounted on the surgeon's thorax. Both robots hold and position laparoscopes.
Results: Three cholecystectomies were carried out with the industrial PUMA 6000 robot on pigs on June 12 1996. The robot was telemanipulated by a remote surgeon by wiring 10 mts away of the operating room. Since 1998 at the CINVESTAV it was built the first Mexican Surgical Robot to hold a laparoscopic. The human surgical experience began in November 2001. This research will be concluded in 2004. A third device with the same tasks but with a new concept in laparoscopic navigation was designed and built the CINVESTAV. An electromechanical harnes mounted on the surgeon's thorax helps surgeons to hold laparoscopes with hand free navigation.
Conclusions: With these three experiences since June 12 1996 to 2003 we demonstrated the feasibilities to design and built surgical assistant robots to hold laparoscopes in Mexico. Our participation is limited in endoscopic surgery. No complications were presented on humans in surgical procedures.

1 Introduction

After the Scott Fisher publications about Virtual reality and robots telemanipulation in th of the eighty (1986)[1], The Surgeon and Ex Colonel Richard M. Satava[2] of the USA Arr the Unites States of America, he involved the experience of the spacial technology o Nasa-Ames and Stanford University International experience to the operating rooms. T technologies were related with robotic telemanipulation to explore planets like ma visualize its surface and spatial simulation in a virtual reality field. These associa between operating rooms and the spacial technology impacted the international society were the motivation to apply surgical robotics in the battle field to treat the bleedings i war since a remote site by a remote surgeon who telemanipulated[3] robots in an ope field. These technological impacts generated many projects in many countries England, France, Japan etc. Reseachers in many countries developed robots to specialties. The first surgical speciality was the war surgery (Green Telepresence Sys followed by orthopedic surgery (Orthodoc and Robodoc[5]) and neursorugery (Neuromate[6])

In 1991 AESOP 1000 Robot in laparoscopy was designed and built by Jonathan Sackier Yulung Wang[7]. Up to day each speciality shares surgical robots to assist or to perf surgical procedures. For instance, important developments are the different internati socities to promote and discuss the current developments in Computer Assisted Surg Medical Robotics such as: International Congress and Exhibition on Computer Radiology, Medicine Meets Virtual Reality MMVR, Computer Maxilofacial Congress, International Workshop. Computer Assisted Surgery CAS, Rapid Proto Medicine, Annual Conference of the International Society for Computer Aided ISCAS, International Conference on Medical Image Computing and Computer-Assis

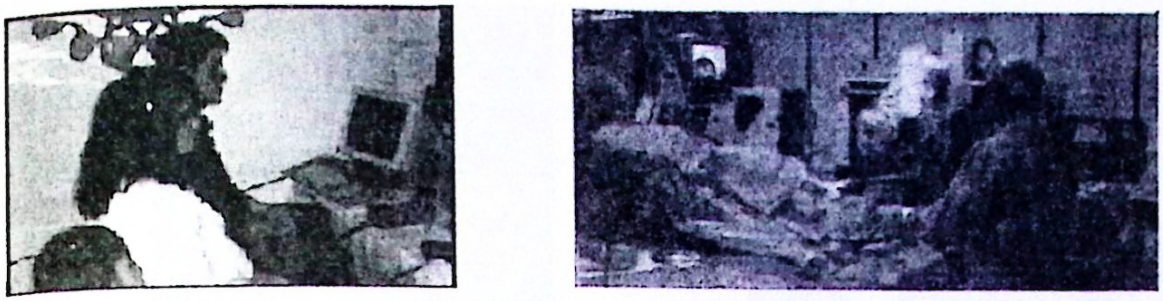
icture 1. Robot Puma de Unimation 6000, 1995. Escuela Superior de Ingeniería Mecánica, Eléctrica y Robótica Unidad Azcapotzalco IPN, Computer Integrate Manufacture Laboratory

Items	Puma	Tonatiuh
Reach (mm)	400	40
Payload (kg)	6	0.3
Axes	6	4
Applications	Industrial purpose	Surgical assistance
Electrical leakage protection	None	Yes
Clean room dedicated	No	Yes
Surgical ergonomics	No	Yes
Surgical security	No	Yes
Reverse engineering	No	Yes
Manipulation	Manual	Manual, pedal
Mechanical weight (kg)	Over 200	18

able 1. Robot specifications. Puma Robot 6000 of Unimation description vs Tonatiuh Robot ESIME Azcapotzalco 1996/ CINVESTAV 2003

ention MICCAI, Israeli Symposium on Computer-Aided Surgery, Medical Robotics, edical Imaging ISRACAS, International Workshop on Computer- Aided Diagnosis, International Symposium on Cardiovascular Imaging, Mexican Symposium on ter Assisted Surgery and Medical Images Mexican CAS, Mexican Symposium on ter Assisted Orthopedic Surgery Mexican CAOS, etc.

Mexico since 1995 Mosso et al performed the first Robotic surgical procedures in a niversity. Undergraduate students created a specific computer program to change the dustrial tasks of a Puma Robot. The goal of this project was to design motions that permit



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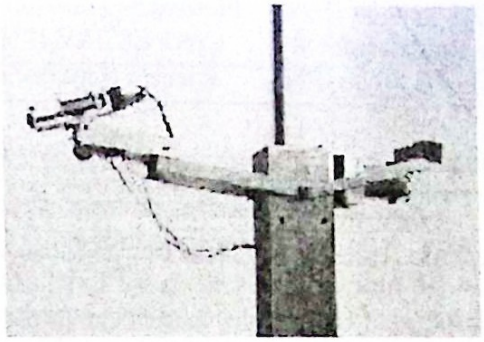
Picture 2. Puma Robot Unimation 6000. June 12, 1996 ESIME Azcapotzalco of the IPN. a) Remote room b) Operating room in the Manufacture Computer Integrate Laboratory.



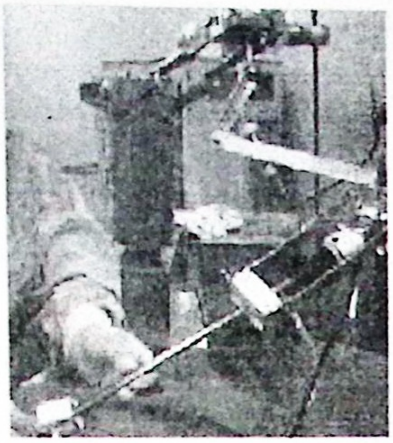
Picture 3. Tonatiuh Robot, first version.1997. Centro de Investigación y de Estudios Avanzados of the CINVESTAV IPN Bioelectrónic Laboratory.

the end effector of the PUMA navigate in abdominal cavities with a laparoscope in laparoscopic surgical procedures.[8,9] . After these experiences in 1996 we had the purpose to built a specific manipulator to hold laparoscope and the first design was Tonatiuh. It was created from 1997 to 2003. The first robot built in Latin America. It was built by Mosso and Minor at the CINVESTAV in Mexico City[10]. In 2000 we designed a third electromechanical with a new concept in endoscopic navigation. All robotic systems are installed around the patients, over the patients and inside patients. This new models is mounted on the surgeon's thorax. The harness is light, and easy to manipulate and with all possibilities to be robotized. The last two manipulators are been improved to obtain better clinical overcomes.[27-31].

2. Material and tools

Puma Robot (1995)

Four undergraduate students of the ESIME Azcapotzalco in 1995 were coordinates to develop a computer program to manipulate an Industrial Puma Robot to perform surgical tasks in laparoscopy, see picture 1. In 1996, Puma manipulator has six degrees of freedom and was teleoperated 15 m. away by a remote surgeon by wiring. See picture 2. Industrial robots were like robot a prototype to designs surgical robots. Puma characteristics are in table 1.



Picture 4. Tonatiuh Robot , 2th versión 1999. CINVESTAV IPN, Surgery Departament at the Escuela Superior de Medicina of the IPN

Picture 5. Tonatiuh Robot, 3th versión 2000. CINVESTAV IPN, Surgery Departament, Escuela Superior de Medicina of the IPN

3 Pigs	Laparoscopic cholecystectomies assisted by a teleoperated robot

Table 2. Puma Robot of Unimation. Surgical procedures in animals ESIME Azcapotzalco June 12 1996

Tonatiuh Robot (1997-2003)

Mosso and Minor in the Bioelectronic Laboratory at the CINVESTAV began to design a surgical robot in 1997. This project was accepted by CONACYT (Consejo Nacional de Ciencia y Tecnología). We modified five times the first version (see table 1) to improve motions, accuracy with surgical procedures in laboratory with experimental animals[12.] , The Tonatiuh Robot (Sun God in Aztec civilization, and founded in the center of the Aztec Calendar) has 18 Kg of weight and the computer is included inside the base of the robot. The first interface to manipulate the robot was a Keyboard. Currently is a manual control.

Hand Free Navigation System (2000 – 2003).

We describe the third navigation system developed in Mexico, a novel device to hold the laparoscopic camera during surgery (It is not a robot). Unlike other systems, it is worn by the surgeon on his thorax and its position is controlled directly by the surgeon´s body movements or by a joystick. The laparoscope holder consists of two parts: An electromechanical arm and a harness to hold it and mounted on the surgeon's thorax. In the last extreme of the portalaparoscope is installed manually, the laparoscope with a clasp and in the other extreme it has a spherical joint that provides a circular motion to the laparoscope.

Instituto Politécnico Nacional	Escuela Superior de Medicina 2001	Dogs 1 Left Hemicolectomy 1 Laparoscopy 1 Thoracoscopy 1 Transthoracic Vagotomy	4
ABC Hospital	Centro de Investigación y capacitación quirúrgica. Brimex II 2003	Rats 2 Uterine anasthomosis 1 Funduplication 360° Pigs 1 Intestine suture 1 Cholecystectomies 1 Gastroyeyuno-anastomosis	6
Total			10

Table 3. Experimental animals with Tonatiuh Robot

We designed and built in 2000 the first model to hold and place the laparoscope, it was built in acrylic, aluminum in the bioelectronics laboratory, and is composed of two parts. The system was designed and built in the bioelectronic laboratory in the Cinvestav and the surgical procedures at the Escuela Superior de Medicina of the IPN (Instituto Politécnico Nacional), on June 21, 2001. In February 2003 we carried out the first surgical experience humans.

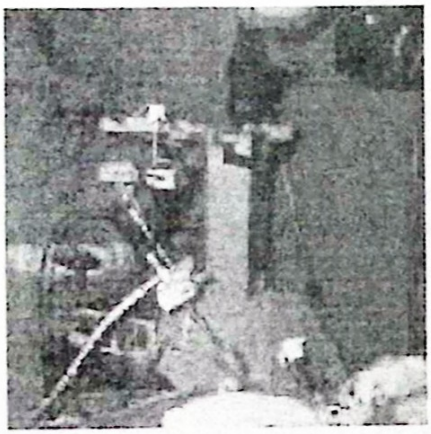
3. Results

Robot Puma (1995-1996).
We performed the first surgery assisted by a Industrial Puma Robot at the Manufactured Assisted by Computer in the ESIME Azcapotzacol of the Instituto Politécnico Nacional México city on June 12 1996. We performed three laparoscopic cholecystectomies without intraoperative complications. The robot was telemanipulated 10 m. away from a remote room. See picture 2. A Surgeon Resident was graduated at the Juárez Hospital SS, with registry number HJM – 221/ 96. Four undergraduate students in electronic engineering were graduated.

Robot Tonatiuh (1997-2003).
In the surgical department at the Escuela Superior de Medicina of the Instituto Politecnico Nacional in 1999. See pictures 4 and 5, and table 1. On November 30 2001, the first human procedure was performed. Tonatiuh Robot assisted a Vaginal Endoscopic Hysterectomy at the Hospital Regional de Troncoso of the IMSS. No complications were presented in the perioperative times[12], see picture 6. With these improvements we continued surgical procedures on humans in gastrointestinal laparoscopic procedures in 2002 at the Hospital

Picture 6. Tonatiuh Robot, 3th version 2001. CINVESTAV IPN Surgery Departament. Hospital Regional de Troncoso of the IMSS

Picture 7. Tonatiuh Robot, 3th versión 2002. CINVESTAV IPN Surgery Departament, Hosp. Fernando Quiroz Gutiérrez of the ISSSTE



Picture 8. Tonatiuh Robot, 4th version 2002. CINVESTAV IPN-ISSSTE. Laparoscopic surgery teleguided via satellite. Hospital Belisario Domínguez Tuxtla Gtz. of the ISSSTE Chiapas

Fernando Quiroz Gutiérrez of the ISSSTE, see picture 7. On Abril 11 2002 two laparoscopic cholecistectomie at the General Hospital in Tuxtla Gutierrez City in Chiapas were teleguided via satellite by a remote surgeon located in Mexico City (National Medical Center November 20 of the ISSSTE), 2400 Km away from the operating room. The remote surgeon gave a second surgical opinion only. The surgeon was assisted by the robot inside the operating room.[14] See picture 8 and 9. At the Hospital general de zona No. 27 of the IMSS we presented the last versión of the Robot Tonatiuh. The particular modifications are been done in the Surgical training and research center Karl Storz Brimex II of the ABC Medical Center, see picture 9b and 10. This robot is the first designed and built in America Latina and was supported by the Consejo Nacional de Ciencia y Tecnología (CONACYT) from Mexico. The Registry Number is 34989-A. The robot is not finish yet. Is necessary to conclude perform

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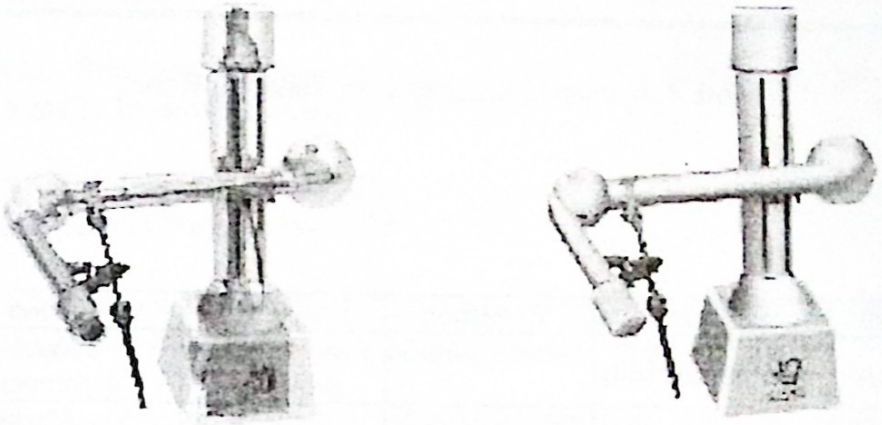
Picture 9. Tonatiuh Robot, 4th version 2003. CINVESTAV IPN. a) Centro Nacional de Rehabilitación. Tirad Mexican Simposium on Computer Assisted Surgery CAS. b) Hospital ABC



Picture 10. Comercial prototype of Tonatiuh 2004. CINVESTAV IPN- SESA DE COMUNICACIONES AC. de CV.

more surgeries to validate its capacity to assist surgeons to move laparoscope. More than 2C Mexican surgeons participated in this project together with anesthesiologists, nurseries residents and Universities students in medicine. All thesis of Engineering area 7 postgraduate students (Master of science) and 1 doctoral student in bioelectronics are in process o graduation.13 publications in Mexican journals and 8 in conference were presented[8-27]. See table 4.

Hand Free Navigation System (2000 – 2003).

A new navigation system was built in laparoscopic surgery to be mounted on the surgeon thorax. The system caused fatigue to the surgeon when he could not obtain a good position t control the scope. The best advantage of the system is the speed to manipulate the laparoscop by the surgeon over the employed with human assistance to hold the laparoscope. The weigh of the system is 2.78 kg without the laparoscope. Total weight is 3.320 kg. The system was tested by surgeon initially in the physical laparoscopic simulator. We followed with surgery on dogs.

IMSS	Hospital Regional Troncoso Hospital General de zona de no. 27	1Vaginal Hysterectomy 8 Cholecystectomy	9
ISSSTE	Hospital Fernando Quiroz Gutiérrez CMN 20 de Noviembre→ Hospital Belisario Dominguez. Tuxtla Gutiérrez Chiapas	2 Cholecystectomy 1 Seromiotomy 2 Funduplication 2 Cholecystectomy	7
SS	Hospital Juárez de México Hospital Infantil de México	1 Laparoscopy 1 Funduplication 1 Gastrostomy 1 Piloroplastie 1 Esplenectomy	5
TOTAL			21

Table 4. Humans Surgeries with Tonatiuh Robot

Year	Thesis	Grade	Profession	Institution	Section	No.
1996	Thesis	Medical speciality	General surgeon	Hospital Juárez de México	Surgery department	1
1996	Thesis	Undergraduate	Industrial Robotic Engineer	ESIME Azcapotzalco	Manufacture Laboratory Assisted by Computer	4
2000	Thesis	Postgraduate	Master in science. in Bioelectrónic	CINVESTAV	Bioelectronic laboratory	1
2003	Thesis	Postgraduate	Master in science and Doctoral science	CINVESTAV	Bioelectronic Laboratory	6 1
Total						12
Journal Publications						13
Conference publications						8
Total						25

Table 5. Scientific production

4. Conclusions

The majority of surgical specialities are supported by robots to assist, or perform specific surgical tasks in operating field. Mexican surgeons, anesthesiologists, nurseries participated. Two universities, four Mexicans Public health Mexicans Institutions and one research center participated. Our principal contribution in endoscopic navigation is the electromechanical devices mounted on the surgeon thorax. This is a real artificial third arm to hold the laparoscope where the man-machine relationship is closer.

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