2019 16th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE)
Mexico City, Mexico. September 11-13, 2019

# Three-dimensional recording system of the path of the surgical instrument type Jarit; Metric dispersion

Daniel Lorias Espinoza
*Electrical department*
*Bioelectonic section*
*Cinvestav*
Cd Mx, México
dlorias@cinvestav.mx

Vicente González Carranza
*Department of neurosurgery,*
*Hospital infantil de México*
*Federico Gómez*
Cd Mx, México
drvicentegonzalez@me.com

Fernando Pérez Escamirosa
*Instituto de Ciencias Aplicadas y Tecnología*
*UNAM*
Cd Mx, México
fernando.perez@icat.unam.mx

Jose Antonio Gutiérrez Gnecchi
*Department of engineering electronic*
*Instituto Tecnológico de Morelia*
Morelia, México
angugi98@netscape.net

Arturo Minor Martinez
*Electrical department*
*Bioelectronic section Cinvestav*
Cd Mx, Mexico
aminor@cinvestav.mx

Jonadab Ignacio Hernández Popo
*Instituto Nacional de Rehabilitación LGII*
Cd Mx, México
yo38@hotmail.com

**Abstract— the aim of the present work is to present the partial results of a three-dimensional recording system of the Jarit surgical instruments. The 3D record was made by processing images in Matlab and passive markers in the instruments. Coordinates home and end of the path was determinate. And through two web cam the registration of the instrument path was made.**

**The records of the neurosurgeons are shown and the concept of the metric dispersion is introduced. As a partial result we can conclude that it was possible to measure the metric dispersion. The record was made in different planes (X-Z) superior view, (X-Y) lateral plane and (Z-Y) Frontal view. Also, the main characteristics of the proposal were determined.**

***Keywords—minimally invasive surgery, tracking systems, motion analysis***

## I. Introduction

There are different proposals to evaluate minimally invasive skills. The majority registers the end of the execution of the task and does not take into account the development or execution of the same [1]. In different areas, the analysis of the movement has allowed to offer a different analysis to evaluate the performance. In medicine it has been applied in several aspects, for example in gait analysis, kinetic records, in rehabilitation and sports medicine. In minimally invasive surgeries, the literature has shown that movement analysis provides important information about the development of laparoscopic skills [2, 3].

The motion record systems employ passive or active systems. The main characteristic of the active system is that they connect electromechanical transducers, or sensors to the instrument to register kinematic variables. This information is sent to a data acquisition system for further analysis. A passive system adds to instrument a marker of distinctive color which reflects light, or a luminescent marker with LED, electromagnetic or ultrasonic basis. One or more electronic units monitor the marker [2].

In different hospitals surgical training is principally in the operating room or physical simulators that lack of metrics. The use of metric allows objective feedback of developing skills, otherwise the evaluation depends on the person who are evaluating [4].

Minimally invasive surgery demands very specific advanced skills and neurosurgery demands very precise movements. Aspects that the learners have to be developed despite the limitations of training systems and evaluation.

Several authors have presented different proposals for training systems and models, for example; Endo-Trainer [5], Neurosurgical Endoscopic Trainer [6], practice model for Neuroendoscopy [7], novel neuroendoscopic model [8], simulator for neurosurgery [9]. These proposals have been increasing, but none seems to be better than another, Likewise, the increase in proposals demonstrates the need for objective metrics to measure the development of neuroendoscopic skills.

This paper shows a 3 Dimensional record system of the position of the surgical instruments. The metrics to be registered are; dispersion and the metric time. Also shows the obtained records and the use with surgeons of the specialty [10,11]. The system is passive type, uses a web cam and a marker on the instrumental.

## II. Material and Methods

A box trainer was developed. To record the dispersion metric the Jarit surgical clamp was used and a passive marker was placed on it. The spatial position was performed using two web cam located inside the box trainer. The cameras were distributed in orthogonal mode. The box trainer is connected to the computer via an arduino nano. The graphical interface or GUI was developed in Matlab. Fig. 1

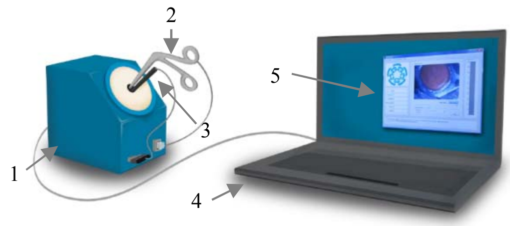


Fig. 1. General scheme of the training system. 1 training box, 2 Jarit clamp, 3 Neuroendoscope, 4 computer, 5 graphic interface.

### A. Calibration

The calibration of the box trainer was made using a milling machine. The trajectory of the instruments was made with the milling machine and a vector that represents the ideal path of the instruments was determined. The ideal route is the average of several repetitions with the milling machine. The calculated relative error is equal to 2%. Fig 2.

Fig. 2. Calibration of the training module, with the milling machine the ideal path of the instruments was determined.

### B. Metrics

These are quantitative values that allow us to objectively observe the evolution of the development of surgical skills.

#### 1) *Instrumental path*

The total distance traveled by the instruments is determined by the Euclidean equation (1) which determines the distance between two points in three-dimensional space.

$$P_2 = \int_0^T \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2}\, dt \qquad \text{[cm]} \qquad (1)$$

#### 2) *Smoothness of movement*

It is based on the measurement of instantaneous tremor or jerk. It represents the change of acceleration (2) and is measured in $cm/s^3$ (3).

$$j = \frac{d^3x}{dt^3} \qquad (2)$$

$$J = \sqrt{\frac{1}{2}\int_0^T j^2 dt} \qquad (3)$$

#### 3) *Time*

It is the time in which the surgeon performs the task. The units are in seconds (4).

$$t = T[s] \qquad (4)$$

#### 4) *Dispersion*

In our case, the dispersion is the term used to refer to the area that has been between the ideal trajectory and the path of the instrument. The ideal trajectory has been taken from the linear displacement obtained from the start of the path at the end of the same. The path of the instrument is performed by the surgeon. Our hypothesis is that a smaller area indicates that the surgeon is very close to the ideal route. On the contrary, a larger area indicates that the instrumental route and the ideal route are different.

The area is obtained by an algorithm developed in matlab, the function used is "trapz" this function allows to know the integral from a vector known without knowing the characteristic equation. The trapezoidal rule is a technique for approximating the definite integral (5). The trapezoidal rule works by approximating the region under the graph of the function f(x) as a trapezoid and calculating its area (6).

$$\int_a^b f(x)\, dx. \qquad (5)$$

$$\int_a^b f(x)\, dx \approx (b-a) \cdot \frac{f(a)+f(b)}{2}. \qquad (6)$$

To obtain the total dispersion, dispersions are calculated by each plane, lateral view (X, Y) and frontal view (Y,Z). First is calculated the dispersion that exists in the path of *A-B*. Where *A* ($x_A$, $y_A$, $z_A$) is the starting point, *B* ($x_B$,$y_B$, $z_B$) the end point of the path. Then the dispersion that exists in path *B-A* is calculated. Later the dispersion of each trajectory is added and the average is obtained. Finally, a function is used to obtain the absolute value. A larger area indicates that the instrument path with the ideal path has a great difference, while a smaller area indicates that the instrument path and the ideal path are very close. See fig 3.

After engineering tests, records were taken with physicians of the specialty of Neurosurgery and Otolaryngology.

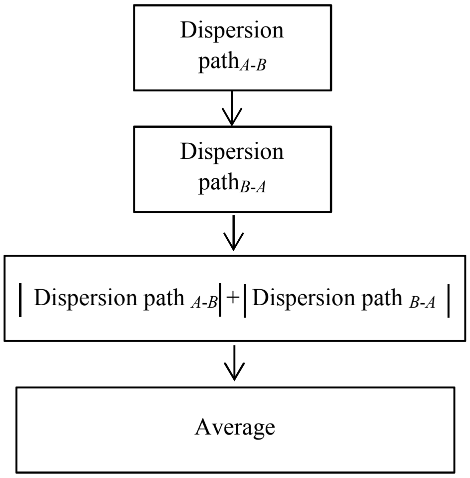


Fig 3. Flowchart of the calculation of the metric dispersion.

## III. RESULTS

After having completed the trajectory *A-B-A*, with the obtained data the graph representing the movement of the Jarit clamp in a three-dimensional space is generated. Fig 4. The fig 5 shows the side and front view. When comparing it with the ideal path, the dispersion metric was obtained. With the data obtained we obtain the vector of movement in the XY plane (Representing the lateral dispersion) and the vector of movement in the ZY plane (represents the frontal dispersion).

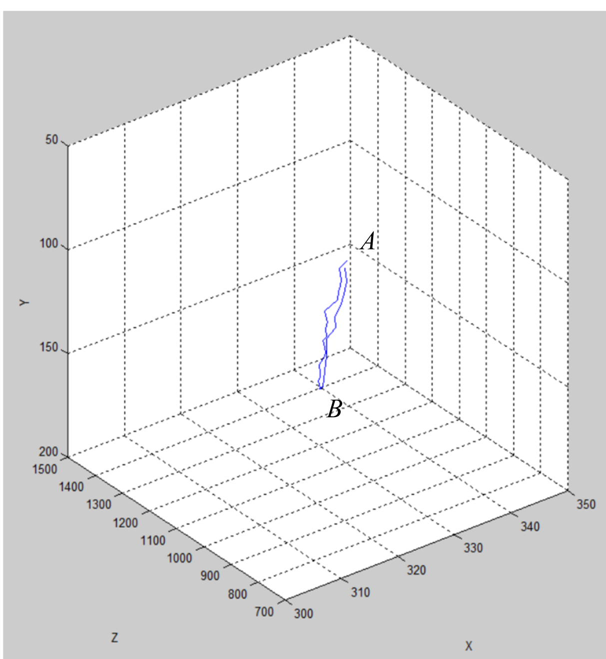


Fig. 4. Three-dimensional record (XYZ) of the path of the surgical instruments. Point *A* is the beginning of the path and point *B* is the end of the path. Trajectory of an expert surgeon.

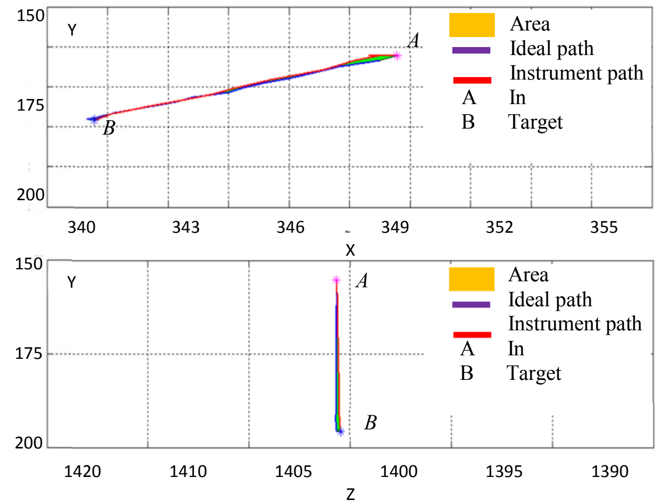


Fig. 5. Lateral and frontal view of the path of the instrument. *A* start of the path. *B* end of the path.

Records were taken with physicians of the specialty of neurosurgery and otolaryngology (of the hospital infantil Federico Gomez de la ciudad de Mexico), the metrics recorded were time (t) and the variable dispersion. Fig. 6. The movement of the instruments could be recorded. The XYZ record allowed to show the movement not desired during the path; like the tremor, changes of position and adjustment of the path. Aspects that helped doctors to improve the technique of approach.

The system allows the movement of the instruments in four degrees of freedom (4 DOF) (1 Inside-out, 2 left-right, 3 Forward -backward and 4 turn on their own axis) but the registration system can capture only the first three DOF.

After having carried out the initial tests, the following characteristics were determined:

- Viable technological principle.
- Portable low cost and weight digitalization system.
- No data lost.
- Passive registration system.
- USB Communication.
- 3 DOF.
- Sampling frequency 30 fpm.

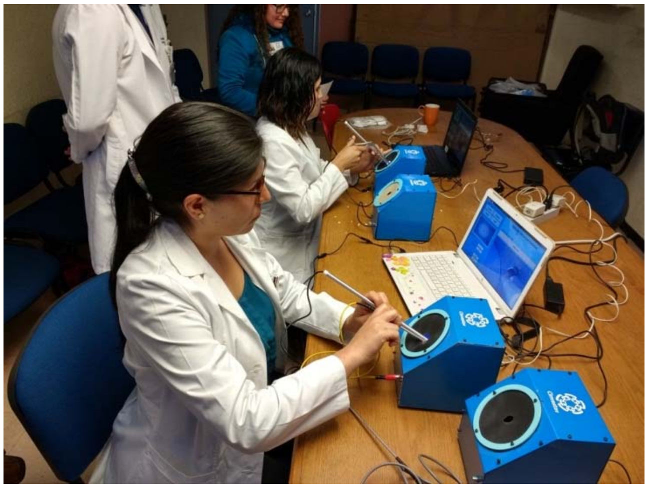

Fig. 6. Records with surgeons of the specialty of neurosurgery. Equipment developed in the CINVESTAV in the Bioelectronics section.

## IV. Discussion

The three-dimensional record of the surgical instruments was possible. And was possible to obtain the components of the movement in the frontal (Z-Y plane) and lateral plane (X-Y plane). The operating principle of the movement record system is through a passive system. The record was without altering or limiting the natural movement of the surgeon. One of the strategies of design is that the normal movement of the surgeon is not restricted or limited.

Transducer type Gimbal has a resistive operational principle, which together with the mechanical combination, reduces or limits the natural surgical movement. In addition there is a loss of data due to the wear of the resistive device, or when the instrument is moving quickly. This is a great restriction and needs constant calibration. This is solved using web cam to record the path of the instrumental.

By digitizing the movement it is possible to objectively quantify the learning performance, which allows to record and measure the performance evolution, nevertheless, through figure 4 it is also possible that the apprentice can see qualitative aspects such as the tremor in the instrumental path. In other aspects see that in the middle of the route there is a greater dispersion in the entry and exit route.

Regarding metrics, the metric dispersion alone does not represent the development of surgical skills, however combined with other metrics, for example metric time, smoothness of movement and precision generates a more reliable index. The metric precision is indirect, since at the end of the route, the surgeon had to touch a small push button that indicated the end of the route.

For the moment, the units are considered dimensionless. For the purpose of this first evaluation, the dispersion value is normalized as a percentage, where a large dispersion is considered as a large deviation from the original route.

The surgeon's visual feedback is two-dimensional and works in a three-dimensional space. The visual feedbacks by planes allow analyzing in which plane the surgeon is more inclined to leave the ideal path.

After using our proposal the physicians have accepted in a more objective way the comments of the development of their surgical skills. Currently working on the validation of the equipment (Face, Content, and Construct Validity)

Referring to the digital processing of the images and the amount of data it can handle, we believe that matlab is a good platform. This is due to its toolbox of image processing and open architecture for communication with components such as web cam.

## V. Conclusions

It was possible to record the trajectory of the Jarit clamp, the displacement was linear. The linearity of the displacement is being used as a metric to determine the precision of the neurosurgeon's movement. This shows that with basic tasks we can infer in the development and evolution of the neuroendoscopic skills of neurosurgeons in training.

## References


[1] Oropesa I, Sánchez-González P, Lamata P, Chmarra MK, Pagador JB, Sánchez-Margallo JA, et al. "Methods and Tools for Objective Assessment of Psychomotor Skills in Laparoscopic Surgery," Journal of Surgical Research., Vol 171 ,pp., e81 - e95, 2011

[2] Lorias ED, Gutierrez-Gnecchi JA, Minor MA, "Is the digitization of laparoscopic movement using accessible alternative technologies possible?," Minimally Invasive Therapy.21:135–141, 2012

[3] Egi H, Okajima M, Yoshimitsu M, Ikeda S, Miyata Y, Masugami H, et al. T. "Objective assessment of endoscopic surgical skills by analyzing direction-dependent dexterity using the Hiroshima University Endoscopic Surgical Assessment Device (HUESAD)" Surg Today, 38(8), pp705-10. 2008

[4] Singapogu RB, DuBose S, Long LO, Smith DE, Burg TC, Pagano CC, et al. "Salient haptic skills trainer: initial validation of a novel simulator for training force-based laparoscopic surgical skills," Surg Endosc 27: 1653, 2013

[5] R. Singh, V. K. Srivastav, B. Baby, N. Damodaran and A. Suri, "A novel electro-mechanical neuro-endoscopic box trainer," 2015 International Conference on Industrial Instrumentation and Control (ICIC), Pune, 2015, pp. 917-921.

[6] Waran, Vicknes; Narayanan, et al Neurosurgical Endoscopic Training via a Realistic 3-Dimensional Model With Pathology Simulation in Healthcare 10(1):43-48, February 2015.

[7] Bajaj J, Yadav YR, Pateriya A, Parihar V, Ratre S, Dubey A. Indigenous Inexpensive Practice Models for Skill Development in Neuroendoscopy. J Neurosci Rural Pract. 2017;8(2):170–173.

[8] Jaimovich SG, Bailez M3, Asprea M4, Jaimovich R Neurosurgical training with simulators: a novel neuroendoscopy model. Childs Nerv Syst. 2016 Feb;32(2):345-9

[9] Weinstock P, Rehder R, Prabhu SP, Forbes PW, Roussin CJ, Cohen AR. creation of a novel simulator for minimally invasive neurosurgery: fusion of 3D printing and special effects J Neurosurg Pediatr. 2017 Jul;20(1):1-9

[10] Choudhury N, Glinas-Phaneuf N, Delorme S, Del Maestro R," Fundamentals of neurosurgery: Virtual reality tasks for training and evaluation of technical skills" World Neurosurg 80:e9-19, 2013.

[11] Lorias ED, González-Carranza V, Chico-Ponce de León F, Minor MA, "PsT1: A Low-Cost Optical Simulator for Psychomotor Skills Training in Neuroendoscopy," World Neurosurg. 2015 Jun; 83(6): 1074–1079.

[12] Bright E, Vine S, Wilson MR, Masters RS, McGrath JS. Face validity, construct validity and training benefits of a virtual reality turp simulator Int J Surg. 2012;10(3):163-6.