Visual Feedback for skill acquisition in cataract surgery

Group 22
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Critical Paper Review

Introduction:

My cis-2 project aims at developing a system which can be used to distinguish between experts and novices with the help of visual feedback and help train them for real operations.

Paper 1:
Kinematic Analysis of Surgical Dexterityin Intraocular Surgery

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Motivation:

Surgical training and assessment is becoming increasingly better with better computing systems and smaller tracking systems and utilities. Several useful techniques exist but most of them retain a degree of subjectivity[1-6]. This paper discusses a technique which involves evaluation of the movements of the surgeon's hands, using various parameters leading to a purely objective and numerical outcome. This paper uses highly sensitive optoelectronic motion capture system to certain steps of phacoemulsification procedure.

Technical Approach:

Experimental Setup:

To track the motion of the hands, a 6-camera Qualisys ProReflex system (Fig.1) was setup with motion capture units carefully positioned to cover the measurement volume and minimize occlusion due to body parts, tools, and instruments in the environment.

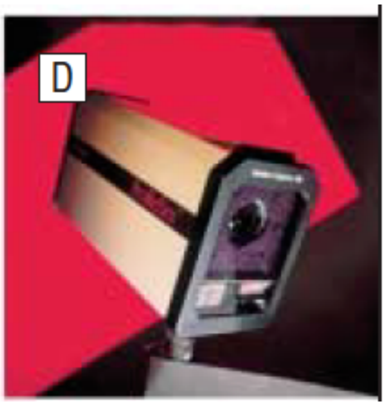

Fig. 1 Qualisys ProReflex camera

Each motion capture system had a low-noise high-speed sensor, built in microprocessor and a 250 infrared light emmiting diodes. Retrospective markers (Fig. 2) are attached to the body segment namely, hands to track their motion (Fig. 3). The marker locations were selected to track both finger and hand
segment motion in 3 dimensions. Size and placement of markers were determined following extensive pilot laboratory work calibrating the instrument for ophthalmic use.

(Fig.2 Retrospective markers)

(Fig. 3 a test subject performing phacoemulsification with handmarkers in situ)

Simulated Surgical Tasks:

The idea is to simulate parts of phacoemulsion. The following three tasks were performed by the people participating in the test:

- Task 1: Construction of a standard 2-step incision using a 3.2-mm keratome blade.
- Task 2: Anterior chamber reformation of the artificial eye through the previously formed incision and constructing a curvilinear capsulorrexis (CCC)

- Task 3: Complete removal of the nucleus using the “divide and conquer technique”

All subjects undertook each of the tasks in a standardized wet laboratory environment with the same prepositioned instruments and artificial eyes.

Participants:

The procedure consisted of twenty-four participants recruited from ophthalmic training hospitals in the greater London area. Participants were divided into 3 groups based on their experience:

- Novice (performed less than 10 independent procedures)
- Intermediate (10-150 procedures)
- Expert (more than 150 procedures)

Data Processing:

The 3 dimensional co-ordinates of individual markers were recorded in high detail at a sampling rate of 100Hz. The data was then filtered to remove lag. Three parameters were analyzed to evaluate surgical dexterity:

- The time taken,
- The total path length covered,
- The total number of movements taken to complete the surgical task.

Results:

The table (Fig 4.) summarizes the results for time, number of movements and total path length covered. The results demonstrate significant differences in path length, number of movements, and time taken, with the more experienced surgeons demonstrating greater efficiency in completing the given tasks.

Table. Surgical Task Performance per Group

Parameter by Stage and Skill Level	Time Taken, min		Path Length, m		Subjects, No.	
	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)
Incision						
Expert	1.05 (0.50)	0.95 (1.53)	3.83 (1.41)	3.87 (4.23)	6303 (3003)	5656 (9169)
Intermediate	1.57 (0.34)	1.60 (1.12)	4.47 (1.12)	4.43 (3.39)	9377 (2074)	9604 (6719)
Novice	3.15 (1.68)	2.89 (5.45)	7.60 (5.22)	6.57 (16.41)	18 901 (10 069)	17 329 (32 673)
P value	.001		.05		.001	
Continuous curvilinear capsulorrhexis						
Expert	1.85 (0.96)	2.02 (2.88)	3.11 (0.96)	3.18 (3.28)	11 141 (5748)	12 145 (17 268)
Intermediate	2.53 (1.14)	2.15 (3.41)	4.15 (2.43)	3.13 (7.09)	15 170 (6858)	12 867 (20 431)
Novice	3.69 (1.43)	3.01 (3.64)	5.28 (2.49)	4.49 (6.94)	22 156 (8560)	18 042 (21 843)
P value	.03		.08		.03	
Phacoemulsification						
Expert	3.51 (1.01)	3.42 (3.04)	1.66 (0.40)	1.53 (1.09)	21 047 (6062)	20 484 (18 236)
Intermediate	4.10 (0.82)	4.11 (2.53)	2.61 (2.57)	1.78 (7.62)	24 593 (4897)	24 663 (15 181)
Novice	5.63 (1.72)	5.78 (4.77)	5.48 (3.47)	4.73 (11.14)	33 787 (10 295)	34 701 (28 638)
P value	.04		.02		.04	

Fig. 4 Tabulation of Surgical Task Performance per group

Also Fig. 5, Fig. 6 and Fig. 7 show a graphical representation for the three tasks given. Fig. 8 shows the whole result in a short table.

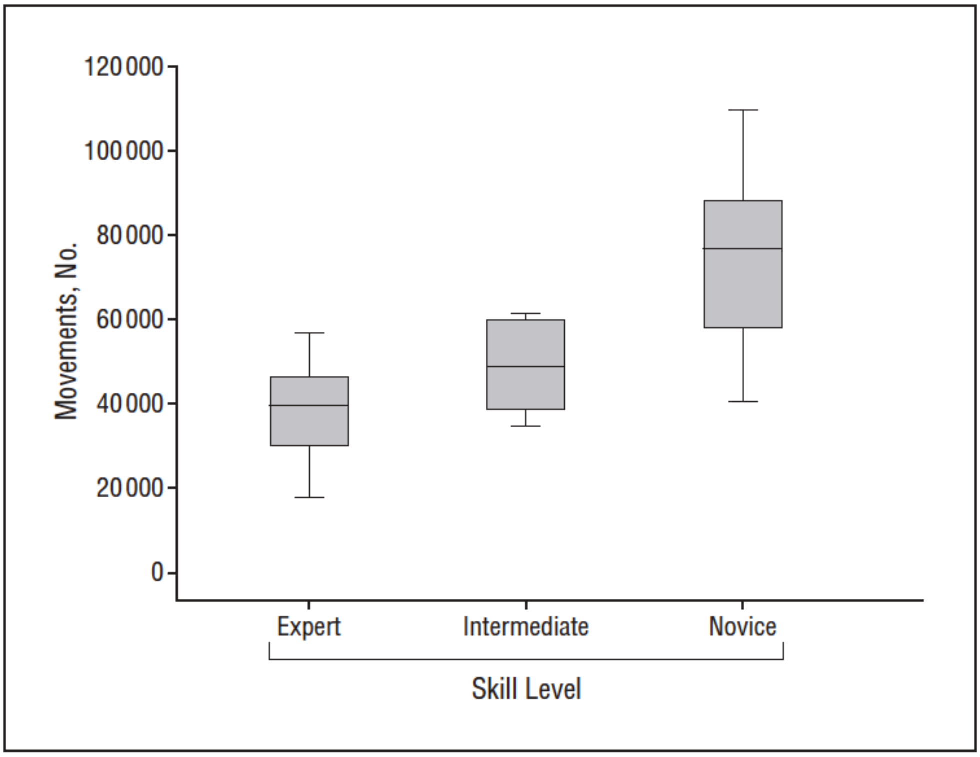

Fig. 5 Box plot showing the overall number of movements used by each of the 3 groups to complete the 3 tasks.

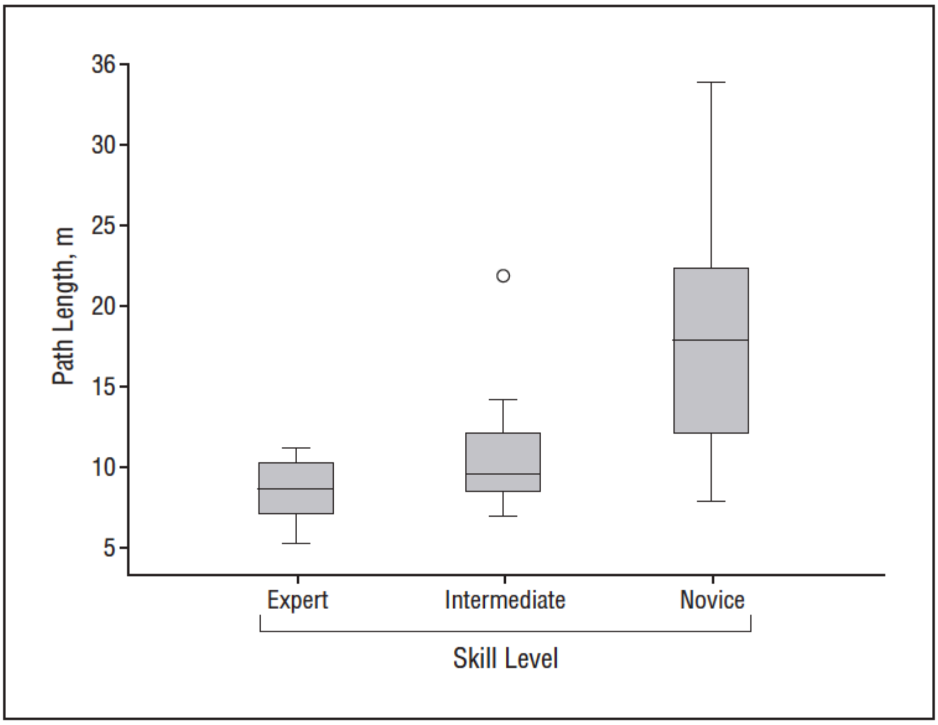

Fig. 6 Box plot showing the overall path length (in meters) covered by each of the 3 groups to complete the 3 tasks. The circle indicates an outlier

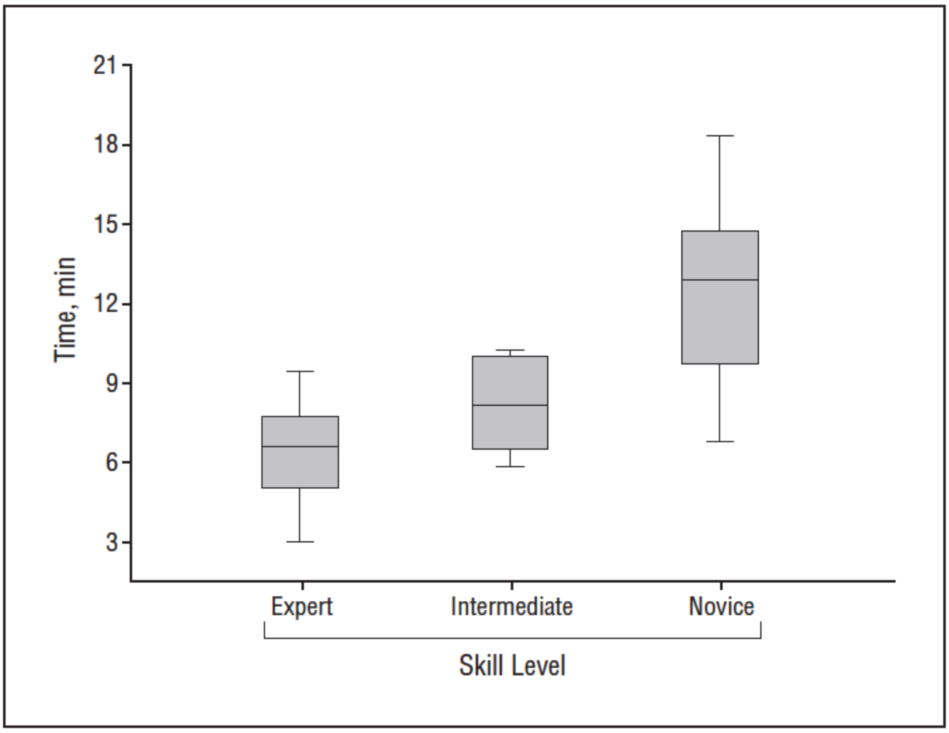

Fig. 7 Box plot showing the time taken (in minutes) by each of the 3 groups to complete the 3 tasks.

P value	Criteria
0.01	Time
0.01	Movements
0.05	Path length

Fig. 8 P values for each criteria

Conclusion:

Authors of the paper do a really good job in recording data. The paper summarizes that as surgeon's expertise increased, less surgical time, shorter path lengths and fewer hand movements were required to complete the given task. This suggests an increasing efficiency in task execution with greater surgical experience.

References:

[1] Cremers SL, Lora AN, Ferrufino-Ponce ZK. Global rating assessment of skills in intraocular surgery (GRASIS). Ophthalmology. 2005;112(10):1655-1660.

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Paper 2:
"PhacoTracking"
An Evolving Paradigm in Ophthalmic Surgical Training

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Background:

Evaluation of skill is essential for training of surgeons. Previous studies have shown that a good surgeon will display a quick, economic and precise movements [1]. Using metrics such as path length, time of procedure, and number of movements, others have shown that the level of surgical skill could be discriminated for cataract surgical tasks in a wet laboratory environment. [2-4]. Surgical recording devices are already installed in ophthalmic operating rooms and data is generally collected. This paper aims at using these video data collected to estimate parameters which can aid in discriminating experts from novices and also guide in skill acquisition.

Technical Approach:

Phacotracking: "PhacoTracking" is defined as the application of tracking methodology to phacoemulsification cataract surgery with the purpose of analysis of instrument movement during the procedure. (Fig. 9).

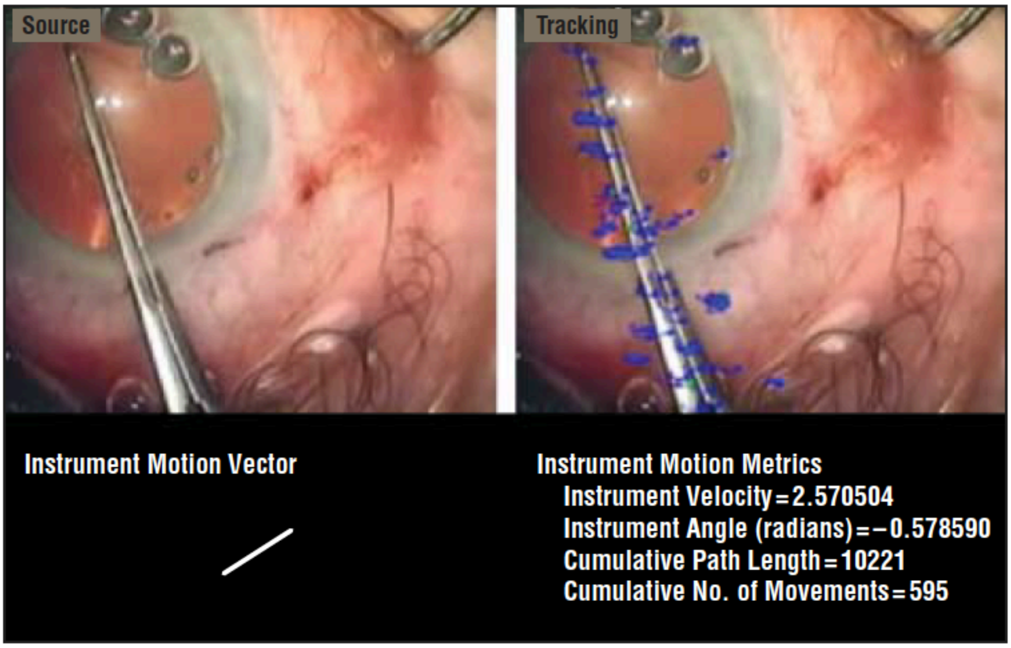

Fig. 9 Output from instrument tracking system. The top portion of the output shows the input video and the result of computer vision tracking. The lower portion shows the metrics that are measured by the system.

Method:

To perform the procedure, a cohort of 2 groups of surgeons was formed- one group of expert and other of novices. The surgeons were classified based on the number of cases they have operated on. Novice was less than 200 cases and experts were more than 1000 cases. 10 videos were recorded from each group. Each surgeon contributed one video in their cohort. The authors of the paper included only those videos of procedures performed under regular conditions namely: patients whose pupils dilate fully, mild to moderate cataract, were able to lie fully flat and stable during the duration of the surgery. The authors have claimed to have recorded the whole procedure in contrast to the previous paper which just focuses on some key steps in the procedure.

Parameters compared:

This paper compares the same parameters between experts and novices.

- Time,
- Path length,
- Number of Movements

Object Tracking:

The authors of the paper do not go into the details of how the performed tracking of the tool. They have mentioned that they used a combination Speeded Up Robust Features [5] and optical flow (Luccas Kannade) [6]. They have also mentioned that the application of feature detection with motion analysis enabled them to measure instrument motion without initialization.

Results:

The results showed that novice surgeons used a greater path length to complete the procedure compared to experts. In addition, the variance of the path length among novices was far gretater than experts. (Fig. 10). Similar patterns were observed for number of movements and time taken to complete the procedure. (Fig. 11, Fig.12). The P values are summarized in the table (Fig. 13).

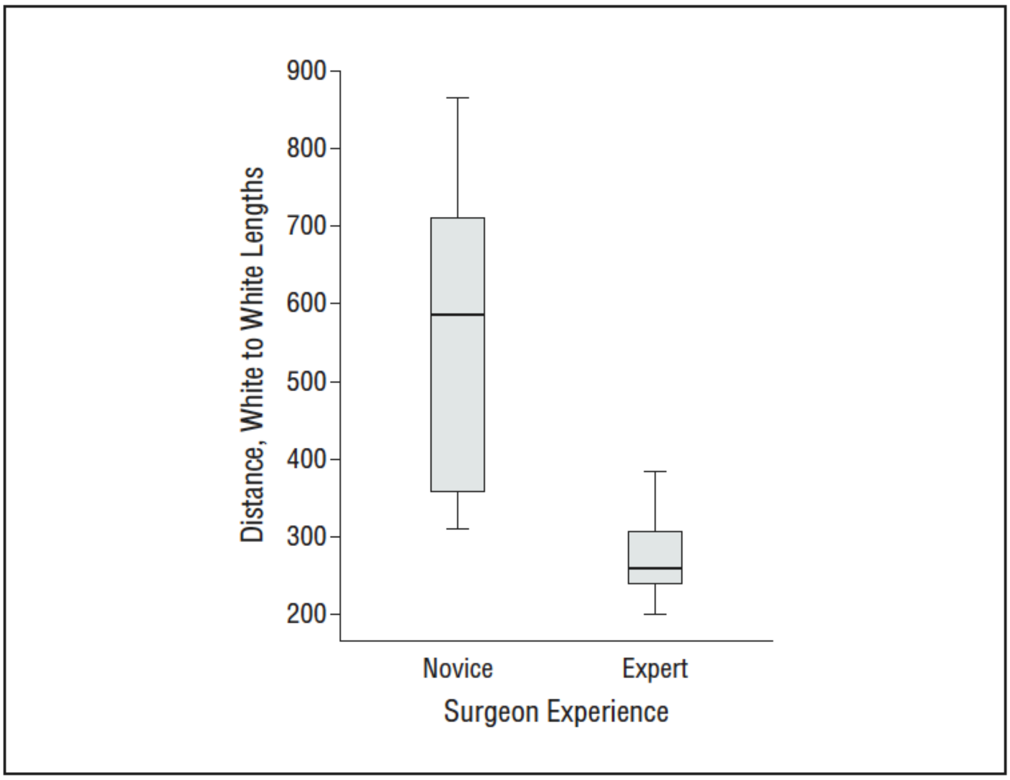

Fig. 10 Box and whisker plot showing the total path length for novice andexpert surgeons. The horizontal line within each box is the median value, and the top and bottom borders of the box are ±1 SD with limit lines showing 95% CIs (±2 SDs).

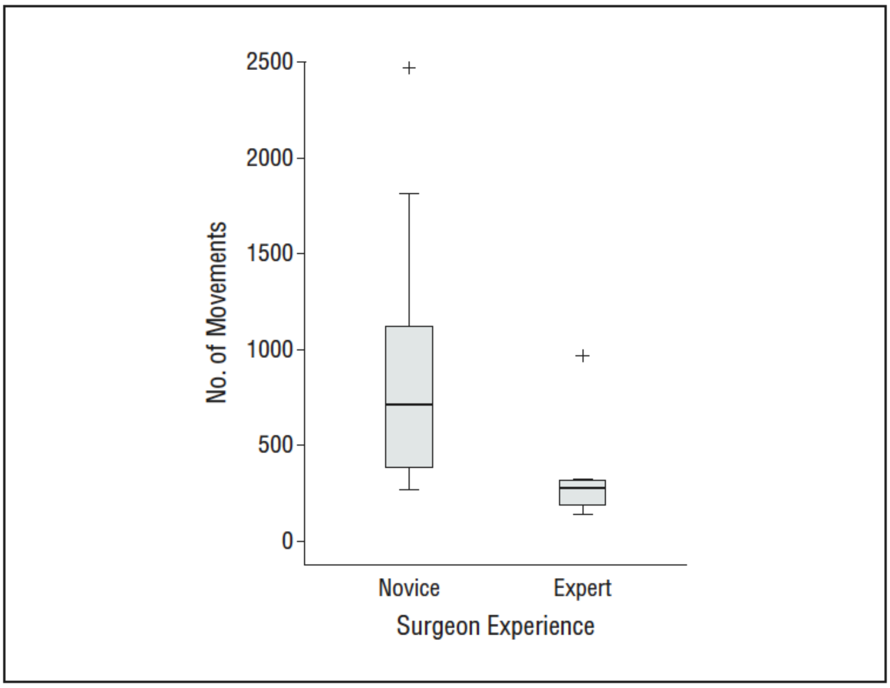

Fig. 11 Box and whisker plot showing the total number of movements for novice and expert surgeons. The horizontal line within each box is the median value, and the top and bottom borders of the box are ±1 SD with limit lines showing 95% CIs (±2 SDs). The plus signs

beyond the whiskers are outliers.

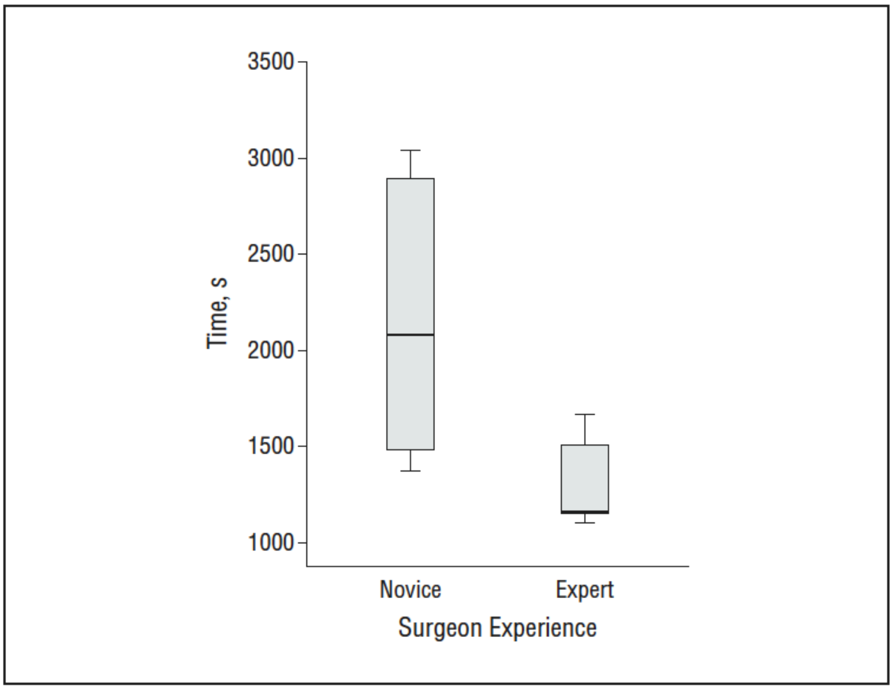

Fig. 12 Box and whisker plot showing the total time taken by novice and expert surgeons. The horizontal line within each box is the median value, and the top and bottom borders of the box are ±1 SD with limit lines showing 95% CIs (±2 SDs).

P value	Criteria
0.002	Distance
0.05	No of Movements
0.004	Time taken

Fig. 13 Summary of P values

Conclusion:

In short, the paper confirms the fact that expert surgeons have lower path length, time of operation and lower movements.

Revelance of both papers with my project:

Both these papers discuss on comparing certain metrics to distinguish between expert surgeons and novices. They also talk about using these metrics as a feddback technique to analyse and improve existing techniques. This is the core idea of my CIS-2 project. However instead of using time, path length or amount of movements, I focus on using tool force patterns to judge expertise.

References:

[1] Ellis H. Famous Operations. Media, PA: Harwal; 1984.

[2] Saleh GM, Voyatzis G, Hance J, Ratnasothy J, Darzi A. Evaluating surgical dexterity during corneal suturing [published correction appears in Arch Ophthalmol. 2006;124(12):1801]. Arch Ophthalmol. 2006;124(9):1263-1266.

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