Position Control and Performance Analysis of Experimental Fully-Automated Electro-Mechanical System in Inra-Oral Photography

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Abstract: - In spite of advanced and high technology, there are still some problems for positioning head and chin of patients during photographic recording in dentistry. Furthermore, it is very important to get reproducible photographic images for the evaluation of the intraoral treatments. In this experimental and simulation studies, a new designed system method is introduced for complex through collection of standardized intraoral photographs and computer assisted measurement of reproducible data. However, PLC based fully automated a photograpic device for fully automated intraoral photography and standart protocol for the esthetic of the crown-mucoginvigal complex is also presented. On the other hand, to test the proposed system a neural network was used to predict real time measured values.

Key-Words: -Electro-mechanical system, PLC controller, dental patients, oral photographs, photograpic device, neural predictors

1 Introduction

Nowadays, there have been some reseach work which have been invesitagted by some reseachers. Some papers were published concerning DC motor actuated machines controlled by PLCs. They have been invesitagted both the implementation of the fuzzy method for speed control of a DC motor/generator set using a PLC to change the armature voltage [1], and the incorporation of an adaptive controller based on the self-tuning regulator technology into an existing industrial PLC [2]. Also, other types of machines were interfaced with PLCs. Thereby, an industrial PLC was used for controlling stepper motors in a five-axis rotor position, direction and speed, reducing the number of circuit components, lowering the cost, and enhancing reliability [3]. For switched reluctance motors as a possible alternative to adjustable speed ac and dc drives, a single chip logic controller for controlling torque and speed uses a PLC to implement the digital logic coupled with a power controller [4]. Other reported application concerns a linear induction motor for passenger elevators with a PLC achieving the control of the drive system and the data acquisition [5]. To monitor power quality and identify the disturbances that disrupt production of an electric plant, two PLCs were used to determine the sensitivity of the equipment [6].

Since there are more prone to gum edge, fine; It is important to think of the Phenotype in the planning of treatment [7, 8]. This situation primarily dental

implant after [9], less stable in the long term of the gum margin related to dating [10, 11]. Also, the thin edge of the gums periodontal treatment post higher withdrawal rate [12] and restoration shows less stability in relation to the edges [13, 14]. Healthy periodontal tissue clinical image shows a structure that varies from person to person [9]. The natural tooth Crown length extension after "thick-flat" gum biotype in patients with "thin-curvy" biotype shows more soft tissue generation according to patients [12].

2 PLC Based Morphometric Measurement System

Nowadays, human operated systems are used to make position of head of dental patiens. In this section, the proposed fully automated and standarized oral phtography system is described. The proposed and designed system is consisted of two main positioning apparatus. The first one, the patient is sitting or standing position and puts his/her head in a head holader. The chin is placed on a chin rest and the forehead rests against a traversal forehead holder. The chin rest height can be adusted fully automatically from patient's pervious positions (see Figs. 1,2).

Second one, the camara is fixed to stands with quick mount attachment and can be moved along a circumferential quide rail at a range of 210^0 arround virtual center in the patient's mount by a servo motor and driver equipment. On the other hand, for eccentric and lateral ptotographs with mirror the camara poisition can be changed, recorded and seen at a scala undermeat the camara stand by a servo motor and driver using PLC. In addition to these developments, by using PLC based automation, height and rotation of camara position as well camara object distance can be changed automatically as previous measurements. The images are to be held on the measurements of clinical records by comparison with measurements of "reliability", repeated measurements with measurements on the display "consistency" to be tested. In addition, observer variation in determining deviation of repeated measurements is to be calculated, and these variances which occurred in the area of the teeth will be analyzed.

2.1. Evaluation of the fully automated system

Clinical recordings

For the determination of clinical healthy situation of each volunteer and evaluation of photographic analysis, the following clinical recordings were done by an experienced clinician:

I) Periodontal parameters:

a- Plaque index* (Pl) (Silness ve Löe 1963)
b- Gingival index* (GI) (Löe ve Silness 1963)
c- Periodontal sulcus depth* (PSD): Distance between gingival margin to bottom of sulcus. Dişeti kenarı periodontal cep/sulkus tabanı arası mesafe.
(*: Mesio-vestibule, mid-vestibule ve disto-vestibule surfaces of each tooth

II) Soft tissue parameters:

a- Width of keratinized gingiva (WKG): Distance between gingival margin and mucogingival junction.
b- Papilla dimensions (PD): Width (PD-W) and height (PD-H) of papilla of each papilla.

II) Tooth morphology parameters: (Cuny-Houchmand et al. 2013)

1- Crown width (CW)
2- Crown height (CH)

Measurements for the soft tissue and tooth morphology parameters done by using a gauge ruler of 0.1 mm precision and the rest of the clinical parameters were recorded by using a Williams periodontal probe.

Study group

The participants of the study were grade III undergraduate students of Faculty of Dentistry, Erciyes Üniversity. Inclusion criteria were as follows;

1- Systemically healthy, non-smoker and over 18 years old
2- All participants were unaffected of dental or periodontal disease in the evaluated region maxillary anterior teeth
3- No missing or filling teeth for maxillary
4- No history of antibiotic or anti-inflammatory drugs within the previous 6 months

The study details were explained to all participants, and then written informed consent was received from each participant before initiation of the study protocol.

The patient group consisted of three female and two male students with an average age of 21,4 years.

2.2. Intraoral photographic records

The camera was fixed to a arm connected that its movements were controlled by the software and can be moved along a circumferential orbit at a range of 210° around a virtual center in the volunteer's mouth. For the photographs of anterior teeth, a fixed central camera position directed at a straight angle to the mid-facial line was available. In addition, height and rotation of the camera position can be arranged individually by adjusting the head and chick holders. Additionally, each positional change of the camera within the 210° of movement was recorded by a computer-assisted system with specially written custom-made software.

Standardization of photographing was achieved by using a laser beam directed to mid-facial line. After positioning of the mouth, photographs of each anterior tooth including canines and lateral and central incisors directed to mid labial and mid-papillary region were obtained. The same procedures were repeated one week later in order to evaluate the reproducibility of imaging. At each imaging, camera was positioned at 90 to the longitudinal axes of each tooth and its lateral papillae.

Total of 11 photos comprising of both mid-labial and mid-papillary areas of each six teeth were obtained from each volunteer.

Room illumination

The system was placed in the photographic archive room of Dept. of Periodontology where the room illumination was arranged to CRI 95 which was close to the Calvin values obtained by using a standard ring flash in order to have the closest ones to the natural colors.

Evaluation of intra- and interobserver variations

All the photographic recordings of the fully automated system and manual were done by a professional photographer.

Measurements on the photographic records were separately done by two clinicians with various levels of experience. For each clinician, the mesurements were repeated in two weeks interval in order to evaluate the intra- and interobserver variations.

3 Testing Hypothesis

This section describes main hypotesis of the propose fully automated PLC based ssytem in the following;

1-Reliability: the accuracy of measurements with direction, clinical measurements with digital photographic images, computer-aided with standardized measurements will be assessed the relationship between. 2-Consistency: Photographic records are made on the measurement repeatability of measurements to be made at different times will be revealed with the determination of deviations. In particular, the data of a sensitive measurement of patient positioning and image effect technique is attaching great importance.

In the case of healthy conditions and disease tissues will be used to evaluate the relationships between computer-aided standardized digital photographic image analysis is the closest to the reality of clinical results and those results under the same conditions that may occur during repeated deviations < 0.01 mm in dimensions and future research as well as a clinic for routine applications and the difference between them in terms of the assessment of great importance. Designed and produced the fully automated patient jaw snapping, positioning the image due to the nature of the system with the system of non-invasive soft tissue by using a method associated with the gum edge thickness, including almost all of the measurements you can easily and very largely aimed at fine-tuning with hassasie. To be evaluated in the gum areas of macro photography without any angular deviation of the recording, as the photographic records received error-free and the minimum error of measurement and evaluation system that will be used to make (additional: 1, will be used as the basis of the system project details) consists of five main parts (Fig. 1,2):

Part 1: the head and the Chin still placed, for each individual location as the original adjustable forehead and jaw snapping (jaw snapping part of vertical direction moving) parts. **Part 2**: digital camera image of the rear area of the oral cavity and can be saved in

the desired angle of the mirror inside the mouth (0-180 ° angle within the limits of the width) moving in the horizontal plane rail system and offers these tracks on the vertical direction moving mirror and camera connections. **Part 3**: Jaw snapping, intraoral mirror and camera placed in the mechanisms used to control the movements of the joystick. **Part 4**: all auto mobile parts and running them with the engine table. **Part 5**: CPU and graphics processing capabilities and in our study, both photographic and digital radiographic image is to be used in the analysis of OsiriX can operate in compliance with the program and the high resolution images in the computer system even higher performance and mechanical mechanism is automatic and repeatable way to use software to function.

The proposed system's block diagram as outlined in Figure 3, will be employed with computers, Apple iMac and IOS operating system. Apple iMac, it uses the operating system stability, high resolution screens with fast processors and radiology and digital imaging is one of the preferred hardware.

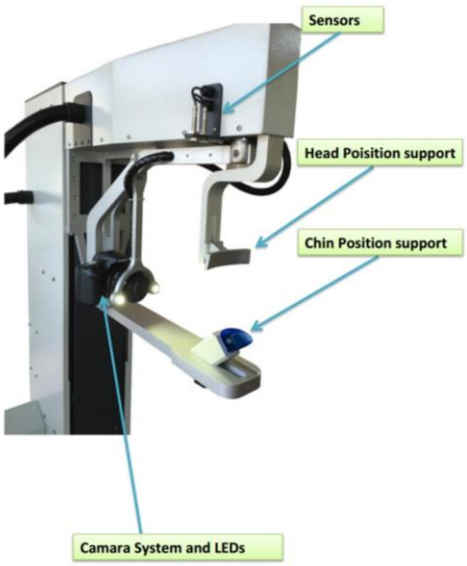

Fig. 1. Camara and chin position apparatus

Fig.2. General view of the proposed system

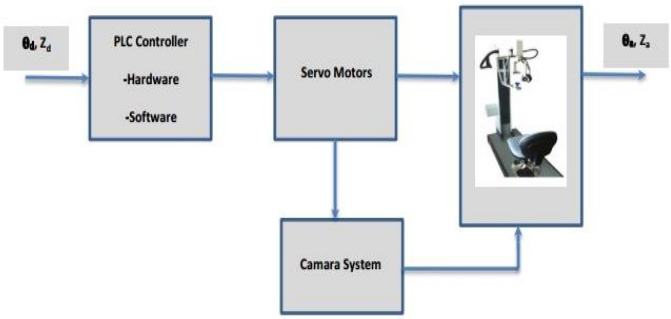

Fig.3. Position control system

4 Neural Network Predictor

This section describes the feedforward neural networks (FNN). An artificial FNN's neurons are arranged in a feedforward manner (usually in the form of layers, i.e. each neuron may receive an input from the external environment and/or from other neurons, but no feedback is formed. A standard feedforward neural network consists of simple processing. A feedforward network computes an output pattern in response to some input pattern. Once trained (with fixed connection weights) the output response to a given input pattern will be the same regardless of any previous network activity. This means that the feedforward neural network does not exhibit any real dynamics, and there are no stability problems in such networks. For feedforward networks the dynamics are often simplified to a single instantaneous nonlinear mapping. Some learning algorithm of the ANN can be described in the following [15, 16]. The schematic view of the proposed neural predictor is given in Fig.4. As

can be seen from the figure, the network has three layers with bias.

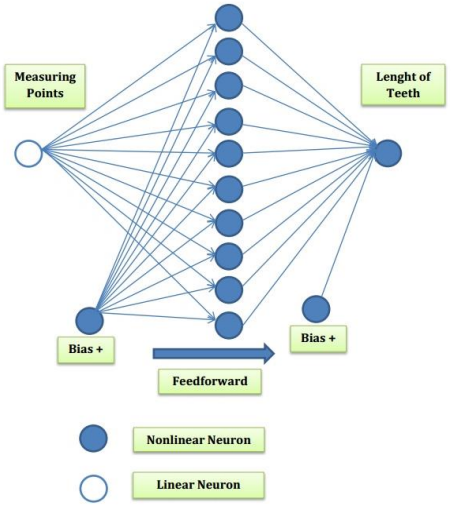

Fig. 4. The proposed feedforward neural network

4.1 Quickpropagation (QP) learning algorithm

This section describes the learning method which has been used as learning algorithm of the feedforward neural network predictor. The used QP is a kind of training method based on the following assumptions, E(w) for each weight can be approximated by a parabola that opens upward and the change in slope E(w) for his weight is not affected by other weights that change at the same time. The weight update rule is;

$$\Delta w(t) = \frac{S(t)}{S(t-1)-S(t)}\Delta w(t-1) - \eta\, S(t) \qquad (2)$$

Where $S(t-1)-S(t)$ The numerator is the derivative of the error with respect to the weight and is a finite difference approximation of the second derivative. Together these approximate Newton's method for minimizing a one-dimensional function . To avoid an infinite backward step, or a backward uphill step, a maximum growth factor parameter μ is introduced. No weight change is allowed to be larger than μ times the previous weight change. Furthermore, QP has a fixed learning parameters, η ,that needs to e chosed to suit the problem.

5 Experimental and Simulation Results

In experimental work, some patients's teets were photographed at two different times for comparison. These results are shown in Figs. 5(a)-5(b). From the results, there are some small errors because of mechanical equipments set of the system.

Fig. 5(a). First measurements of the patient's toots

Fig. 5(b). Second measurements of the patient's toots

On the other hand, simulation study has also been carried out for predicting measurement of length of teeth of two patients using neural network predcitors. In this section describes, two types approaches. First approach is related to experimetal work with the proposed fully automated camara based measuring system. Two patients' teeth poistions are photograped at two stages firt and second times. However, Table 1. shows training, structural and RMSE (root mean square error) parameteres of the neural network for the cases of 1-2. The results of this stage is shown for patient 1 in Figures 6(a) and for patient 2. As can be seen from figures, there is some errors between first stage measurement and second stage measurement. However, this problems has been accured by chin supporting equipment.

Fig. 6 (a). First patient teeth positons with two photos match (Case 1)

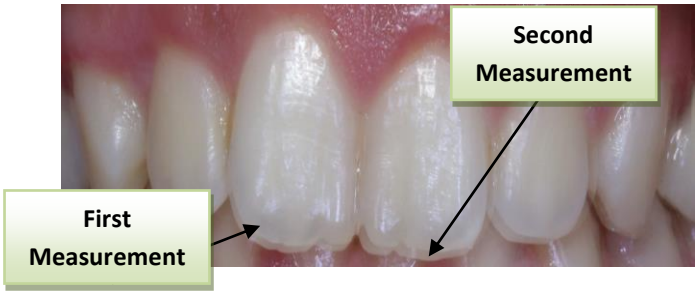

Fig.6 (b). Second patient teeth positons with two photos match (Case 2)

On the second approach is consisted simulation based neural netwoks (NNs) results for both patients. Two types of neural network based algorithms were employed to predict each patients length of teeths variations. Furthermore, Quick-Propagation Neural Network (QP-NN) was used to predict two patients' length of teeths variations for first and second stages measuremets.

Table 1. Strucrural, training and RMSEs of the proposed neural network with two algorithms

Cases	NN type	Learning rate	Training numbers	Algorithms	RMSE (First Stage)	RMSE (Second Stage)
Case 1	1-10-1	0.01	100.000	QP	0.2144	0.0410
Case 2	1-10-1	0.01	100.000	QP	0.0545	0.0508

QP-NN approach for patient 1's lengh of teeth variations is represented in Fig.7. As can bee seen on the figure, measuring points 3 and 4 have some errors to predict.

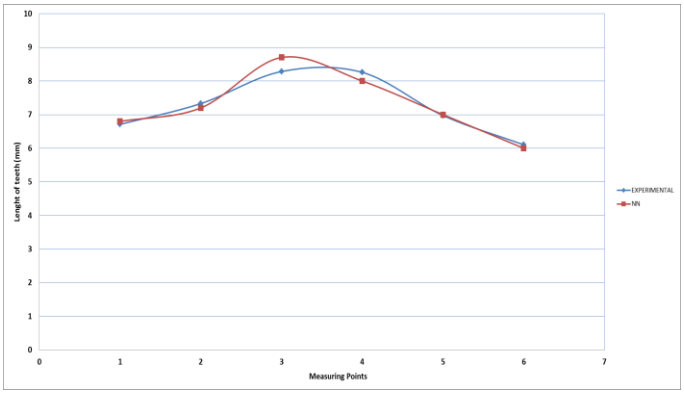

Fig.7. First stage measurement of patient 1's teeth length variations with QP-NN

Fig. 8, is indicated the results of the second stage of patient 1 with QP-NN. The results showed that the proposed NN perdictor has good performance to predict experimental results.

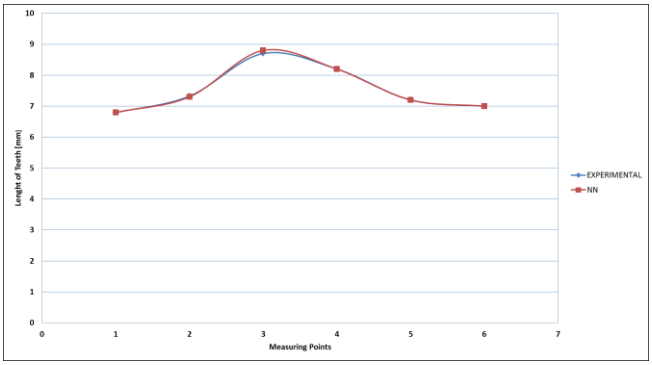

Fig.8. Second stage measurement of patient 1's teeth length variations with QP-NN

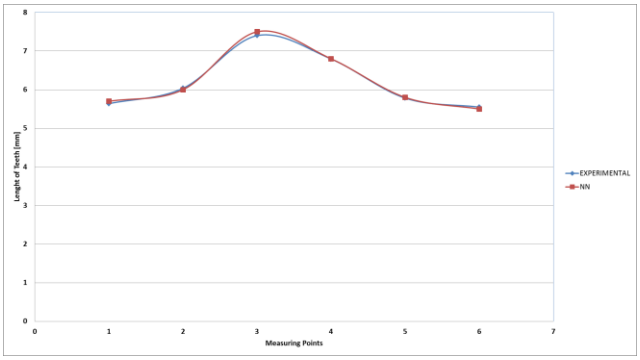

Fig. 9. First stage measurement of patient 2's teeth length variation with QP-NN

Figs. 10 shows the case of 2 for patient 2's teeth length variations. QP-NN have similar results to predict for both cases.

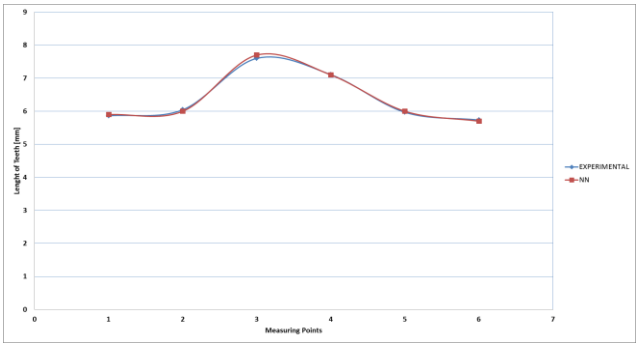

Fig. 10. Second stage measurement of patient 2's teeth length variations with QP-NN

6 Conclusions and Discussion

Hand setting when shooting with, 1. with 2. and even framing your shift occurred in the next shoot pictures taken from being difficult or even impossible to be taken for evaluation and measurement of becoming. Device, joystick and forwarded to the desired angle and a photo with machine inspection appropriate frame provides the setting. Digital camera is to be used when the desired angle of the image because it can not be both the camera screen and in the system can be controlled from the value of the angle on the Rails. This adjustment during the frame line and location information recorded in the computer through touch screen and the next shot from the same individual according to the values that made the shooting for standarizasyon are provided.

The main outcome expected from this designed system, computer aided aesthetic and photographic records, standardized phonetic problem as important as periodontal disease will be held in the area inside the mouth front assessments. It can be made as close to the truth, and most clinical investigations and surgical treatment to be applied routinely in both the results of accurate and repeatable way.

On the other hand, a proposed of neural predictor was employed to predict experimatal results of two cases. However, the proposed QP-NN has superior performance to adapt the experimetal results of the fully automated dental patient chin positioning system. Finally, the neural netwok based predictors can be employed this kind of system as intelligent measuring and poistioning systems.

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