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SMART TESTING ARM FOR AUTOMOBILE DISPLAYS

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Abstract— This paper deals with building of a robot to test the touch screens used in automobile industries and in vehicles. This achieved using 5-bar mechanism. Stepper motors are used as actuators and the solenoid is used for touching the screens. So, this is very cheap for industry to buy when compared to the other robots in the market.Night time is very useful for testing touch screens since there will be no workers to test the robot can incorporatethis work very cheaply. The control system that we designed is very cheap and simple so this can be sold cheaply.

Keywords— Five bar mechanism, stepper motor, linear actuator, slot sensor, Human machine interaction

1. INTRODUCTION

The need for the current study is to bring about movement of test actuator in X, Y, Zaxis within definedlimits using serial ascii interface for easy control. The industries currently use several robotic applications in order toautomate several processes with higher efficiency. The previously designed prototype has certain processes containseveral design and process constrains .Despite they result in high cost and manufacturing expenses. The need forcurrent project is to aut omate the process of screen testing with reduced costs and comprises of certain cons whichare required to be overcome. The major components used in the system are a five-bar linkage mechanism, steppermotors, ball bearings, controllers, injection plastic parts, opto - slot sensors and suitable drivers. The speed ofoperation, accuracy and lifetime of the system needs to be maximized. The current project is developed usingsimpler concept of linkages This system is expected to have a wide scope in the automated touch screen testingtechnology once the concepts of pinch-zoom, gesture control and voice recognition systems are integrated with thedeveloped Bot. This is expected to be of very high demand in the near future in all the touch screen testing firms.

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2. LITERATURE SURVEY

The industrial robots are widely used in automobiles[1].the measurement of driver fatigue levels are measured by an embedded system[2]. Two popular cases of mobile applications for automotive testing, sample regression test cases on real devices, Framework for handling complex automotive test cases, and an example automated test is done[3]. An automated testing framework has been designed to test services which communicate between mobile application and real vehicles (cars) using different technologies web services and mobility testing tools[4]. Display Test Automation aims to fully automate testing and to solve all the problems and limitations involved in display testing[5]. A method brings out a low cost automated test framework for testing touch screen devices screen transitions is discussed[6]. A method of handling the IBM Rational Robot to record, edit, and execute functional tests [7]. A model that reduces accidents on the road and preserve the lives of human beings is discussed[9]. The Robotic Tester is to automate manual testing routines required as part of the system validation tests. Currently after flashing the display unit, manual testing of the software functionality is done. The existing robots in the market include the robots such as the DexTAR Robot, Plot clock Robot, Quanser Robot, Intel screen tester and the Bitbeam robot. The DexTAR robot, costs about $6000 which is not affordable to each work desk for each tester. Despite its weight and huge size becomes a constraint in case of transportation of the robot. Figure 2.1 shows the DexTAR robot. The Quanser Robot shown in the figure 2.2, which has a two Degree of freedom provides the required variable motion of the system but the work volume is very less when compared to the other systems. In case of the Intel a complex articulated system is being used which adds up a huge cost to the system making it unaffordable.

Fig. 2.1 DexTAR Robot

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Fig. 2.2 Quanser- 2 DoF Robot

The Intel robot shown in the figure 2.3 is an articulated robot in a compact lab at Intel’s Silicon Valley headquarters, Oculus the robot is playing the hit games like cut the Rope on a smartphone. Using two fingers with rubbery pads on the ends, the robot crisply taps and swipes with micrometer precision through a level of the physics-based puzzler. It tracks up a perfect score.

Numerical scores are converted into a rating between one and five using data from cognitive psychology experiments conducted by Intel to discover what people like in a touch interface. For those experiments, hundreds of people used touch screens set up to have different levels of responsiveness.

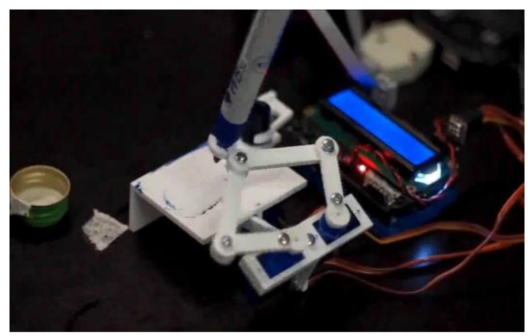

Fig. 2.3 Intel Screen Tester Fig. 2.4 Plot Clock

The Plot clock system as shown in the figure 2.4 is a system used to validate the time on a board at every fixed interval of times and rub it with a duster at a predefined interval of time. The system looked simpler than any other system which are being used in the industries both in terms of construction and the mechanisms.The Bitbeam Robot, shown in figure 2.5, looks feasible in design but involves more complex construction than it looks. The design is more similar to that of the delta robots which are available in the markets. The control over the three motors mounted over the base of the system has to be made more precise and accurate in order to place the end effector or the plunger tip in the screen surface.

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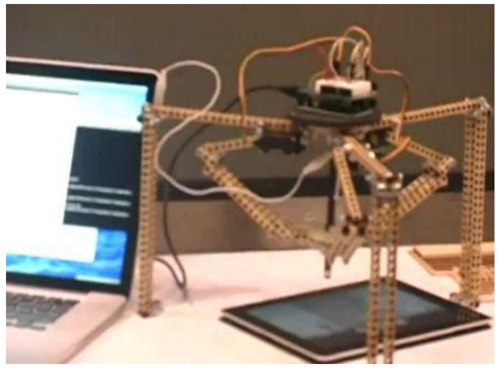

Fig. 2.5 Bitbeam

The National journals that employ similar concepts are Automated Functional "Testing Using IBM Rational Robot" by A.Chakrapani, K.V.Ramesh by the Department of Computer Science and Engineering, GITAM University, Visakhapatnam, India and Cost Effective Automated Test Framework for Touchscreen for HMI Verification by, Sajan Kumar, P. Sreekalesh, S. Arathy, Assistant Professor, R .V.S College of Engineering, Dindigul, Tamilnadu, India and TATA Elxsi, Trivandrum, Kerala, India The international journals include "Cognitive Human-Machine Interface Applied in Remote Support for Industrial Robot Systems" by Tomasz Kosicki and Trygve Thomessen of Norwegian University of Science and Technology (NTNU) in Trondheim, Norway and "Touchscreen Display Enhancements for Flight Deck Applications and Touchscreen Display Enhancements for Flight Deck Applications" Robinson, T., Grabski, G., Yugawa, K., Jeffers, J. Germany.

3. METHODOLOGY

The construction of the system involves combination of several complex systems with electrical, mechanical and software constrains. The various phases of the Automated HMI Test System project are shown in the Fig. 3.1.

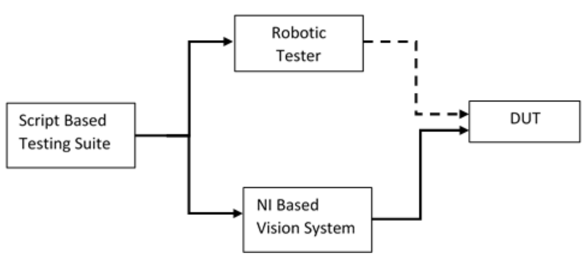

Fig. 3.1 Block diagram

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To study and understand the working of HMI Test systems we need to do, study of the various linear actuator systems, Learning the type if linear actuator used in the current industry, to design a suitable mechanical model to test the touch screens system, to select the required components to be used to build the system, checking out the possible combinations of the studied actuators to obtain a stable System, working on the concepts of 5 bar mechanism, to study programming using C#, to formulate a method for efficient and consistent accessing the screen to design an Electronic circuit board for the system ,to fabricate a mechanical structure for holding all the components and the circuit Board, to test and troubleshoot the problems faced during touch operation, to validate the system operation using several trial runs and routines, to capture the touch and the success of touch using a NI based vision system which will be integrated with the robot system, to fabricate a suitable enclosure system to make the product complete

4. MATHEMATICAL MODELING:

The formation of the equation governing the system was not as simple as it seemed. It involved a lots of efforts and research. The Equation governing the system is the most critical and innovative part of the system. It should be having inputs of coordinates X, Y and the outputs angle1 and the angle 2. The process of documenting the equation was the tricky part. Though the equation could be scanned and stored as an image (viz.jpeg or .png format), efforts were taken inorder to make it using Microsoft Word, since it would be easier in case of any future modification or rectification by experts.

4.1 THE EQUATION GOVERNING THE SYSTEM-PHASE I:

The figure 4.1 shows the five bar mechanism using graphical representation during phase I of the system designed.

The final Equation involving the input variables: The lengths of the links a,b,c and the co-ordinates (x,y)

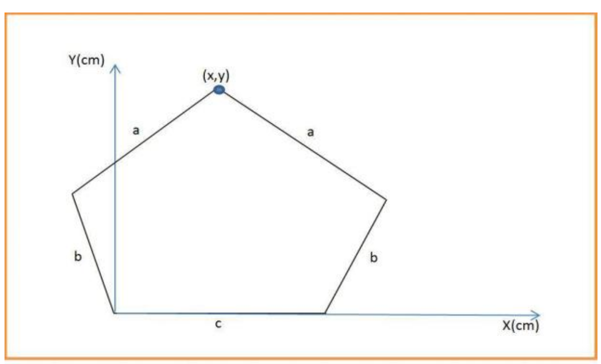

Fig. 4.1 Five Bar mechanism using graphical representation (PHASE-I)

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The output of the system is the The degrees of rotation of motor θ_{m1} &The degrees of rotation of motor

$$\theta_{m1} = \left[\tan^{-1}(\frac{y}{x}) * (\frac{180}{\pi}\right) + \cos^{-1}[\frac{b^2+x^2+y^2-a^2}{2b\sqrt{x^2+y^2}}] * (\frac{180}{\pi})$$

$$\theta_{m2} = 180 - \left[\tan^{-1}(\frac{y}{c-x}) * (\frac{180}{\pi}\right) + \cos^{-1}[\frac{b^2+y^2+(c-x)^2-a^2}{2b\sqrt{(c-x)^2+y^2}}] * (\frac{180}{\pi})$$

4.2 Derivation for equation governing the system:

The figure 4.2 shows the five bar mechanism with required angles using graphical representation at phase- I of the system designed

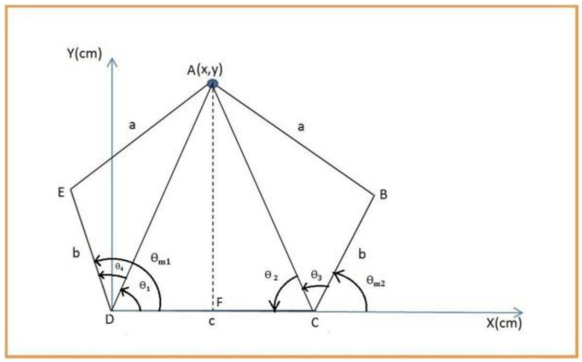

Fig. 4.2 Five Bar mechanism with required angles using graphical representation (PHASE-I)

Join the lines AC and AD to get triangles AED & ABC,

Draw a perpendicular from base a to the vertex A(x,y),

Let ∠ADC =θ_1, ∠ACD= θ_2, ∠ACB =θ_3, ∠ACB =θ_4. Let the degrees along which the motors m1 and m2 must move along be given by, value of θ_{m1} incase of motor 1 & incase of motor 2. Since it's a right-angled triangle we obtainθ_1

& θ_2 as follows:

Consider the △ADC wherein ∟ADF $\tan\theta_1 = \frac{y}{x}$, where $\theta_1 = \tan^{-1}\frac{y}{x}$.

Consider the △ACF wherein ∟ACF $\tan\theta_2 = \frac{y}{c-x}$ where$\theta_2 = \tan^{-1}\frac{y}{c-x}$. By figure, we find that $\theta_{m1} = (\theta_1 + \theta_4)$ & $\theta_{m2} = 180 - (\theta_3 + \theta_4)$.

Applying Pythagoras theorem in the right triangle △ADC we obtain, AD=$\sqrt{x^2 + y^2}$.

Applying cosine law in the △AED we obtain, $\cos\theta_4 = \frac{b^2+x^2+y^2-a^2}{2b\sqrt{x^2+y^2}}$ .This implies that, $\theta_4 = \cos^{-1}\frac{b^2+x^2+y^2-a^2}{2b\sqrt{x^2+y^2}}$.

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Applying Pythagoras theorem in the right triangle △AFC we obtain, , AC=$\sqrt{x^2+(c-x)^2}$.

Applying cosine law in the △AED we obtain, $\cos\theta_3 = \frac{b^2+(c-x)^2+y^2-a^2}{2b\sqrt{(c-x)^2+y^2}}$. This implies that,$\theta_4 = \cos^{-1}\frac{b^2+(c-x)^2+y^2-a^2}{2b\sqrt{(c-x)^2+y^2}}$ $Then, \theta_{m1} = \theta_1+\theta_4$ & $\theta_{m2} = 180-(\theta_3+\theta_4)$.

By using the available data we find the values of θ_{m1} & θ_{m2}

$$\theta_{m1} = \left[\tan^{-1}(\frac{y}{x}) * (\frac{180}{\pi}\right) + \cos^{-1}[\frac{b^2+x^2+y^2-a^2}{2b\sqrt{x^2+y^2}}]$$

$$\theta_{m2} = 180 - \left[\tan^{-1}(\frac{y}{c-x}) * (\frac{180}{\pi}\right) + \cos^{-1}[\frac{b^2+y^2+(c-x)^2-a^2}{2b\sqrt{(c-x)^2+y^2}}$$

We obtain the θ_{m1} & θ_{m2} values in radians when we multiply the obtained values by$\frac{180}{\pi}$**, t**hus, the generalized equation for the system is obtained.

4.3 Derivation for equation governing the system:

The previously derived equation was feasible only at minimal work areas. So we had to work on the derivation of the equation which would completely satisfy the requirement. The figure 4.2 shows the five bar mechanism mathematically depicted with the used angles and length.

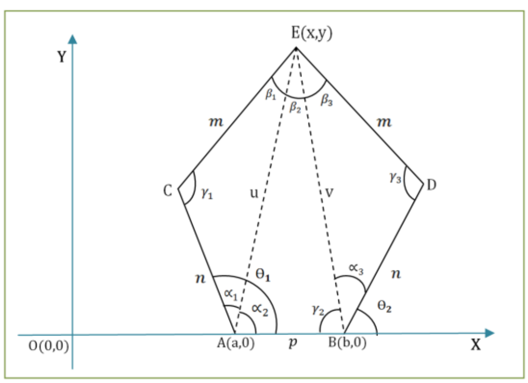

Fig. 4.2 Five Bar mechanism with required angles using graphical representation (PHASE-II)

From the Figure Above, $u = \sqrt{(x-a)^2-y^2}$, $v = \sqrt{(x-a)^2-y^2}$. Let ∠CAB =θ_1, Let ∠DBX =θ_2. In △ACE,$m^2 = u^2+n^2-2un\cos\alpha_1$, $\cos\alpha_1 = \frac{u^2+n^2-m^2}{2un}$. $\alpha_1 = \cos^{-1}\frac{u^2+n^2-m^2}{2un}$. Similarly, for finding ∠CEA, $\gamma_1 = \cos^{-1}\frac{m^2+n^2-u^2}{2mn}$. As we know that sum of the angles of a triangle is 180

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To find ∠CEA, $\beta_1 = 180 - (\alpha_1 + \gamma_1)$. Therefore the required θ_1 is given by, $\theta_1 = (\alpha_1 + \alpha_2)$. Similarly, in ΔAEBto find ∠EAB, $\alpha_2 = \cos^{-1}\frac{u^2+p^2-v^2}{2up}$. To find ∠EBA, $\gamma_2 = \cos^{-1}\frac{v^2+p^2-u^2}{2vp}$. $\beta_2 = 180 - (\alpha_2 + \gamma_2)$. Similarly, in ΔBED, $\alpha_3 = \cos^{-1}\frac{n^2+v^2-m^2}{2nv}$.$\gamma_2 = \cos^{-1}\frac{m^2+n^2-u^2}{2mn}$.$\beta_3 = 180 - (\alpha_3 + \gamma_3)$. θ_2=180-(α_3+γ_2).

5. RESULTS AND DISCUSSION

5.1 PRE-CALIBRATION PROBLEM DEFINITION:

The system requires a positional status feedback in order to initiate the system using stepper motors. As the final/initial value of the system is unpredictable, unlike servo motors, a pre-calibration system is mandatory in order to initialize the system and to perform the necessary activities using the stepper motors and the controller.

5.1.1Solution:

The combined use of “Hall effect sensor and magnetic field using a magnet can help in achieving the aim and solving the problem by indicating the user about the zero position of the stepper motors as shown.

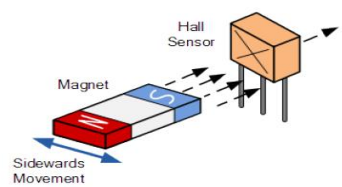

Fig. 5.12 Hall effect sensor

The figure 5.12 shows a simple schematic of an Hall effect sensor. This is also achievable using the opto slot sensors. Two optosensors are used along with each motor for greater control and accurate feedback responses (since usage of just one sensor is not much accurate and vulnarable to errors)

5.2 PROBLEM FACED WITH POSITIONING OF THE STEPPER MOTORS

There were several possible positions in which we could place the two steppers in order to achieve the required motion control task such as. The The figure 5.13 shows a simple schematic of the possible orientations of

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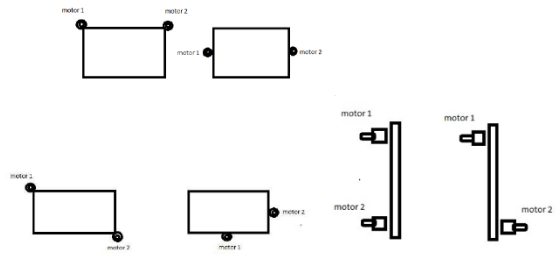

Fig. 5.13 Possible orientations of the motor

the two motors that are to be places across the test screen. The gravity plays a major role in placing the stepper motors along the surface of the system. The stepper motors failed to carry the weight of the linkage mechanism on the whole, which made the system more unstable and vulnerable to damages.

5.3 PLACING OF THE SENSOR & THE FEEDBACK SYSTEM

Placing of the sensor involved much efforts and parameters to be taken into consideration. The positioning should be made in such a way that the rotary mechanism of the system doesn't get affected and such that the feedback is accurate and there is least probability to miss a pulse.

5.4 PROBLEMS ENCOUNTERED DUE TO VIBRATIONS

Since the chosen motor was a stepper motor, due to the reasons like Low cost, easy control, No need for a feedback mechanism, Micro stepping option for more accurate and smoother working

We had to face some other kinds of problems like Excessive vibrations, Instability in the system, Unstable positional reach. Due to the above constrains, we had to go for a servo mechanism temporarily, since the cost of a higher end stepper motor with an opto - sensor was about Rs.18,000 which was beyond the scope of our project in terms of cost. In order to make the system even more smoother in action and response we had to make an axis shift since the usage if the thin shaft of the motor directly would reduce the torque exerted by the motor and there is also a chance of breakage of the shaft. In order to overcome this problem, a gearing mechanism was implemented in the motor shaft. By this process the direct impact of the motor shaft, on the load is deflected to the gear system.

5.4.1 Remedy:

The length of the links was reduced to half of the previous value. As the length was reduced, the system became more compact and stable. Another problem which arose was that, the length of diagonals was not reachable

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by the system. So in order to overcome it, we planned to make the length of the links attached to the end effector, even a bit more longer

5.5 DESIGN CONSTRAINS:

The design of the system involves various constrains such as: Speed of the system, the response time, the time taken for input signal, the time taken for touch, the time taken for response of touch.

5.6 PROBLEM ENCOUNTERED WITH CODING FOR ARDUINO CONTROLLER

The actual equation governing the system control was complex to find. So certain reverse engineering processes were carried out in order to obtain temporary solutions to the system. We obtained fundamental logics using rudimentary equations to achieve the pattern as shown in the figure 5.14.

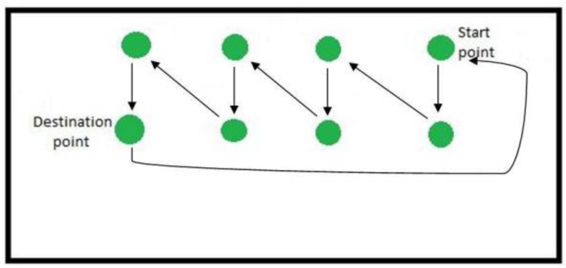

Fig. 5.14 Motion achieved using the screen-tester prototype at PHASE-I

5.7 PROBLEMS FACED WITH THE PLUNGER MECHANISM:

The positioning of the plunger was a tricky part of the system.We made an attempt on the Bell crank mechanism the slider crank mechanism, leadscrew mechanism etc. Finally we found that the Rack & Pinion mechanism suited the system to its best. It was much simple to mount and control and had a lighter weight.

6. CONCLUSION AND FUTURE WORK

This main idea of this project is to reduce the human interference in the testing process of the pump casing in Robert Bosch Engineering and Business Solutions Pvt. Ltd, Coimbatore which could be used worldwide to test any type of touch screen device. By improving the mechanical design it can be made to test any type of touch screen system which is resistive or capacitive in nature and even if the system is mounted vertically. The automated HMI testing process with less human interference results improvement in accuracy and the quality of the testing is enhanced. The number of workers needed per screen and hence the time for testing is reduced since the tester only has to initiate the software. Also the cycle time for the testing operation of a single component is reduced and the

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efficiency of the testing is magnified. The future works of pinch-zoom, gesture control and voice recognition system will add to the credits of the system.

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