Automatic Wall Painting Using Lead Screws

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Abstract: The aim of the project is to design, develop and implement Automatic Wall Painting Using Lead Screws which helps to achieve low cost painting device. The chemicals used in painting can be hazardous to human health, eye and skin infections. Also conventional painting is time and effort consuming, and also the method of operation (rising hand again and again for painting) makes it boring. These factors motivate the development of an automated painting system.

Keywords: construction, design, lead screw, safety, spray painting.

I. INTRODUCTION

Despite the advances in the robotics and its wide spreading applications, painting is also considered to be the difficult process as it also has to paint the whole building. To make this work simple and safe and to minimize the number of labour automation in painting was introduced. The painting automation for the exterior wall in buildings has been proposed. All these predominate the interior wall painting has shared little in research activities. The chemicals in painting can cause hazards to the painters such as eye and respiratory system problems. Also overall nature of the painting procedure that requires repeated work and hand rising makes it boring, time and effort consuming. These factors motivate the development of an automated painting system [1].

When construction workers and robots are properly work together in building tasks, the entire construction process can be better managed and savings in human labour and timing are obtained as a consequence. In addition, it would offer the opportunity to reduce or eliminate human exposure to difficult and hazardous and harmful environments, which helps to solve most of the problems related with safety when multiple activities carried at the same time as well [2].

II. LITERATURE REVIEW

For a minimizing the cost and also the complexity, the support system selection must have simple configuration, a scalable work area and requires less complex control system [3].

Development of the support system forms the most inventory part of automated wall painting. A suitable support system must be selected from various alternatives for suspension of various kinematics mechanism, path planning and motion tracking. The path traversed by the paint head is distorted and needs improvements in velocity control [3].

Above two of the previous wall painting robot mechanism have been analyzed here. In that first method uses a robotic arm which carries a roller. This method is very used to paint interior walls of buildings. The roller comes in contact with the wall and it is fed with painting liquid. The control panel system of the robot not able to the robotic arm to cover the entire plane of the wall through both of the axis vertical as well as horizontal movements. It also enables the robot to maneuver itself and automatically adjust its position appropriately. The specification of the robot has been given below. This system has been practically tested to work fine for interior painting of the wall. However, there is numerous scope for system improvement in the future to increase the painting rate and simplify the system design [4].

Fig 1. Existing Mobile Robot
Another method of wall painting employs a similar mobile platform along with a belt and pulley mechanism and a spray gun. The spray gun is mounted on the belt which moves up and down based on the rotation of two pulleys mounted vertically on the platform. The spray gun - pulley arrangement provides the vertical movement and the movement of the platform provides the horizontal movement. The painting arrangement is as shown below. This method is also appropriate to work only for indoor painting.

Based on the analysis of the results of the above two methods, it is observed that the spray painting method is more reliable and efficient compared to the roller painting mechanism, from a robotic automation standpoint. Hence, spray painting is used in this proposed method. There are two types of sprayer units, air-powered units and airless ones. Air-powered units can be costly (the price of compressor will be vary depending upon the size and specification of the compressor, but a basic unit will cost nearby $200) because they require an air gun and a compressor unit. By using air-powered sprayers give you to spray a variety of fine finishes and are a better options for fine work. Airless sprayers are considerably cheaper than the air units, but they produce sprays with large, heavy paint particles so they are not good for laying down a really smooth finish [4]

III. WORK STUDY

The basic procedure is a complete fundamental to the whole work study. The examination of the process follows the following sequence of phase in that order.

a. Select the work which is to be study.

b. Record all the facts related to the problem.

c. Examine the facts critically but impartially.

d. Develop the most practical, economic and effective method.

e. Define the new method so that it can be always being identified.

f. Install that new method as standard practice.

g. Maintain that standard practice by regular routine checks.

In India, the apartment housing has spread to the suburbs of the large cities, where gardens, tennis courts, and children's playgrounds are included for communities. A phenomenal increase in construction of apartment housing has taken place since 1991 in all large cities, reaching a peak in Seoul, where many individual houses are largely replaced with apartments (Kim, Y. Et al., 2007). The Korean national statistical office (2005) reported that the total amount of contracts in apartment housing construction was 84 billion dollars which was 62% of the total residential building construction cost in South Korea in 2005, while it was only 42 billion dollars for home building construction. Because of such a strong demand and preference, there currently exists over 6,000,000 dwelling units living in apartment buildings and approximately 412,100 dwelling units of apartment buildings are being annually constructed in South Korea. When considering the exterior walls in both new and existing apartment buildings needed to be newly painted or periodically maintained, and painting volumes in other architectural and civil structures, it is expected that the demand of exterior wall painting would be very high. In such apartment housing construction and maintenance, the conventional exterior wall painting is a relatively simple task that various colours are applied to four-sided exterior walls of the building. Some graphic works such as drawings, contractors’ logos, and texts (e.g., building numbers) are also added to the painted wall. However this conventional exterior wall painting is costly and labour-intensive, and especially workers are exposed to significant health and safety risks. In the conventional exterior wall painting, a painter is hanging down from a rope fasten to somewhere in the rooftop and paints the wall with a spray gun or a roller while swinging from side to side like a clock pendulum and coming down from top to bottom. In such a high altitude with a simple connection to a single rope, the painter can be led to a fatal accident even with a small mistake.

Berardo Naticchia, Alberto Giretti and Alessandro Carbonari [2] designed the experimental setup as follows:

1. The whole Set up of the spraying parameters:

Even if the system has been designed for five colors, however all the experiments have been performed with four colors: cyan, magenta, red and mercury gray We know that in this case a narrower range of colors can be reproduced, but it is much enough for our experimental result.
Preliminary experiments to set the opportune spraying parameters have been performed as detailed in (Naticchia B., Giretti A. and Carbonari A., 2006). There are two different sets of parameters: those ones which are fixed by standards and by the technology adopted, and those ones depending on the expected quality for the final product. The first group embraces type of paint (in this case waterbase paint), type of application (in this case airmix), spraying pressures (in this case 2.8·10^4 Pa for air and 0.8·10^4 Pa for paint), end-tool trajectories (please refer to Fig. 4), distance from the wall (in this case 0.08 m). Instead variable parameters are given by the distance step between every line of the trajectories and the couple speed-paint flow, which determines the paint thickness on the wall. A detailed study to set the most opportune values for these variables has been carried out in the way already detailed in the aforementioned paper. The quality of the final work has been evaluated using two indicators:
- saturation: indicates color intensity and purity;
- thickness uniformity: evaluates thickness variation on the wall surface, that must be as constant as possible to avoid that visual perception changes with respect to the direction from which the surface is looked at.
- The first was measured using specific software like image processing software, restituting how far from the totally 100% saturated condition is a surface after its coating. The second is important to avoid too big variations of paint thickness on the wall, that could cause a particular reflection of light, that would be perceived by human eyes as a vertical or horizontal stripped surface. The procedure for parameters optimization asks for the collection of one statistical sample (formed by at least 10 measures) whose characteristics vary according to the parameter to be set. In the previous experiments speed of arm motion was left to vary between 0.036 and 0.11 m/s. For our experiments we chose to work at an average speed of 0.073 m/s, as it trades off between a low speed strategy (that reduces the size of the pixel) and the necessity to move fast in order to prevent the formation of droplets (in case too thick paint is sprayed on walls).

At that speed it was found out that the paint flow giving the best results is equal to 3.4·10^-7 m^3/s, as it sprinkles on the wall a paint layer thinner than 0.044·10^-3 kg/m^2, which has been shown to be the maximum allowable limit in (Naticchia B., Giretti A. and Carbonari A., 2006). The distance step between every line of the trajectories was set equals to 0.045 m, as suggested by the results published in the same paper. Once that these parameters have been set, other experiments to verify the accuracy and to table the features of the multicolor system have been perfomed, as explained in the next paragraph.

2. Tests on the four colour spraying device

Given the preliminary experiments of the previous section, the multicolor system has been characterized and tested, in order to infer its features.

Tests have been performed regarding:
- analysis of precision;
- level of resolution;
- accuracy in color reproduction.

The analysis of precision has the main aim of establishing the accuracy of the system when it is asked to paint a given shaded rectangular portion of wall. First, the behavior of the ball valve has been analyzed: its characteristic curve describing the paint flow rate (Q) with respect to its rotation around its axis (measured in percentage) from the closed position has been drawn. The valve has been turned on through steps of 15 degrees, and the corresponding flow rate has been measured as pictured in Fig. 3. The relation coming out from Fig. 3 is of basic importance: thanks to that, the controller will be able to compute the paint flow sprayed by the gun, starting from the opening of each valve of the mixing board (which is equipped with four identical ball valves). Working the relation in the opposite way, it is possible to compute the percentage opening required for each ball valve if a pre-established paint flow is required. This information has been used to compute the relative opening of each valve when a known color mixing is required. Once we know the value of the total flow (Q = 0.34·10^-3 l/s), it is necessary to work out single values for each primary color. The following relation must hold, meaning that the sum of all the paint flows cannot exceed the maximum:

\[1=(Q_c/Q)+(Q_m/Q)+(Q_y/Q) \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots 

Fig. 3. Characteristic curve of the ball valves.
From the theory of colors explained in the next paragraph it is possible to compute every relative flow rate and then the relation in Fig. 3 can be used to compute the required opening for each valve. At this stage it is possible to perform analysis of precision. It has been made by generating a sample of size 9, formed by nine shaded portions of walls of the kind in Fig. 4, changing from magenta to yellow and other 9 shaded from cyan to magenta. Through a software for imaging processing, the saturation of each sample on a 14 equally spaced column grid has been measured. In Fig. 4 we can appreciate that on each point of the grid, standard deviations measured for magenta on the selected points are low, and on the average equal to 8%. Even better results have been obtained for the other two primary colors, where cyan deviation from the mean are on the average equal to 5.5%. Table 1 sums up the first set of those results. The time delay has been measured by filming the movements of the servos on the mixing board and the colors sprayed on the walls: the time difference between color switching of the ball valve and the time when it is observed on the wall is the unknown time delay. One of these tests is shown in Fig. 5. It has been found out that the switching time is equal to 3 s, corresponding to one pixel (0.13x0.20) m wide, which is the finest resolution feasible with this system.

3. Procedure for colour reproduction

One of the most important requirements for such a system is that it can accurately reproduce the colors of every pixel of drawings. For that purpose a general procedure for color reproduction has been set, that is based on the theory of colors in (Perrin, H. and Zanaszi, R., 1982). As we are dealing with a system working like printing machines, every color can be thought as composition of the three primary ones: cyan, magenta and yellow (generally also black is included to obtain a wider range in the visible spectrum, however in this experiment it was neglected).

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<th>% s.d</th>
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<td>2.9</td>
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<tr>
<td>35</td>
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</tbody>
</table>

We will explain the general procedure while applying it to one real case. First of all one color belonging to the visible spectrum has been generated with the help of a software for image processing (Fig. 6- a), having the following normalized coordinates

\[(C, M, Y) = (0.43, 0.06, 0.51)\]

and the same holds for magenta and yellow. Then it must be considered that the primary colors used by our system are not the same primary colors considered by the image processing software. Hence three wall samples have been painted using these primary colors and obtaining the following normalized coordinates:

1st primary color \((C^*) = (0.67, 0.2, 0.13)\);
2nd primary color \((M^*) = (0.12, 0.80, 0.08)\);
3rd primary color \((Y^*) = (0.05, 0.00, 0.95)\).

The relative amount of the system’s primary colors \((C^*, M^*, Y^*)\) to be used for the reproduction of the original color \((C, M, Y)\) have been computed by solving the following system:

\[
\begin{align*}
C^* + \alpha C + \beta M^* + \gamma Y^* &= C \\
\alpha C^* + M^* + \beta M + \gamma Y &= M \\
\alpha C^* + \beta M^* + \gamma Y &= Y
\end{align*}
\]

Where the coefficients \(\alpha\) and \(\beta\) allow for the non purity of our primary colors.

Table 1.

Precision evaluation at each point of the grid superimposed to sprayed samples like in Fig. 4.

![Fig. 4. One of the samples for precision evaluation.](image)

![Fig. 5. System resolution.](image)
For instance, if we know that the system must spray a certain amount of cyan (C), we know that it is present not only in its cyan (C*) but has also other contributions in its magenta and yellow (α_c=12% and β_c=5%), as suggested by eq. (3), from which all the other coefficients have been determined. The unknown variables have thus been determined to be

\[(C^*, M^*, Y^*) = (0.476, 0.025, 0.54).\]

Then applying eq. (1) in the following form:

\[1=C^*+M^*+Y^*=(Q_C/Q)+(Q_M/Q)+(Q_Y/Q)......(5)\]

And by the knowledge of the optimum flow rate Q, it was possible to compute the single flow rate values QC, QM and QY; from these values and from the diagram in Fig. 3, valves’ openings were determined and the final color was sprayed on a plaster wall sample (Fig. 6-b), and in Fig. 7.

![Fig. 6. Original color (a) and its reproduction (b).](image)

![Fig. 7. Four clockwise directed snapshots of the miniature robot’s spray painting on a plaster wall.](image)

Observing the two figures it is possible to appreciate that they look very similar. But this check has been performed also using a scanner acquisition system: it gave back the normalized values (0.53, 0.58, 0.31) for Fig. 6-b, which have been corrected by the knowledge of the shift introduced by that scanner (previously determined scanning pure primary colors from (Perrin, H. and Zanassi, R., 1982)), that is (+0.20, +0.06, -0.26). Hence the corrected value of the color sprayed by our system was (0.33, 0.1, 0.57), whose difference with the original one is (-0.1+0.04, +0.06), that is the approximation introduced by the whole mechanical system.

**IV. CONCLUSION AND FUTURE RESEARCH**

From the above research paper we studied that automated painting can be not only aimed at improving productivity, but also quality & reduce human effort. The robot eliminates the bad effects caused due to the painting chemicals to the human painters such as skin infections, eye and respiratory system problems and also the nature of painting procedure that requires continuous work and hand rising makes it monotony, time and effort consuming.

In future research we can use lead screws in place of Robots on which the spray gun will move and perform the operation of painting. We may place a trolley below the lead screw setup to maximize its range in X-direction. By doing this we may reduce the cost of the automatic wall painting.

**REFERENCES**


