TryStrokes: Learning on a Digital Canvas to Paint in the real world

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***Abstract*–In rural and tribal communities, producing handicrafts act as a source of supplementary income and a means to preserve the uniqueness of their arts and craft forms. Developing skills requires practise and knowledge of native techniques. In activities such as painting, skill in application of pressure and tilt of the brush are very important parameters that contribute to creating beautiful artwork. Technology can play a vital role in aiding to preserve traditional techniques and skills. In this paper we discuss the design of a software application that contains a skill database that stores expert brush stroke techniques and help the novice learn to apply the brush strokes by providing feedback based on the expert stroke. This computerised training solution is scalable, portable and cost effective.**

Index Terms – brush strokes, stroke comparison, skill training, custom brush attachments, fabric painting, vocational education, ICT.

I. Introduction

Women in rural India play a dual role; as producers of goods and services and as wives and mothers managing their domestic chores [1]. They play an influential role in their family with an ability to supplement the income of their household and to mould their children by imparting gainful social value-rich informal education. Yet provisions for creating opportunity for their contribution to economic development have been neglected. The workforce participation rate of Indian women in 2005-2006, was about 31 percent in rural areas and 14 percent in urban areas as opposed to 56 percent for males in both rural areas and in urban areas [2]. By 2010, this further deteriorated when the total work force participation rate of women above the age of 15 dropped to 29 percent [3]. The most cited inhibitors to the inclusion of women in economic development activities in rural communities are malnourishment, frequent child-bearing and lack of education and skill training [1].

Training in income generating activities is critical in order to increase women's participation in economic development. Vocational education and training (VET) holds the potential to remedy the plummeting rate of workforce participation of women in the country, but the conventional training system has been increasingly unsuccessful in attempting to reach the rural areas where the majority of the economically marginalized populations reside [4]. Initiatives such as the Grameen Shakti provide access to renewable energy income and renewable energy-related education as a means to empower rural people, have demonstrated success in Bangaladesh and emphasise the need for training to produce technicians and entrepeneurs [5]. The lack of trainers and increased cost of raw materials and tools required to impart VET, contribute to limited scalability and higher course fee structures in training institutes that operate using conventional training methods. As pointed out by Cheng et al., a system following the traditional model of education suffers knowledge transfer stagnation as impoverished populations have limited time to devote to education [6]. Hence, it is essential to develop systems that facilitate flexible timings and self paced learning.

Fig.1 Women in Kerala receiving training in painting skills on the computerized vocational training application using a tablet and stylus

The Ministry of Human Resource Development, Government of India seeks a solution to the afore mentioned problems that plague conventional VET in the use of emerging technologies such as computerized vocational training and the use of haptic simulators for hands-on training and skill development through the Sakshat Amrita Vocational Education project [7]. The open source courseware developed by this project for humanitarian socio-economic development has been deployed in the South Indian states of Kerala and Tamil Nadu by the Women Empowerment (WE) project, a United Nations Democracy Fund and Amrita University joined initiative. The project has by the first quarter of 2013, trained over one thousand two hundred impoverished women, providing computer based vocational courses such as plumbing, fabric painting, ornamental jewellery making, soap making, flower arrangement and organic vegetable cultivation.

From our experience with the WE project deployment, we reflect Patel's observation [8], that adult women bear the capacity to draw inspiration from their family and everyday experiences and acquire new knowledge and skills when provided with the time and a less restrictive and more creative setting. Products created after taking the fabric painting course act as income generating part-time activity to the women, that they can take up in addition to their primary responsibilities of providing nourishment to their children and tending to household chores. The women are taught in pairs using computerized courseware and a painting application that uses the Wacom tablet and stylus with a custom made brush tip, as shown in figure 1. The application is used to teach precise brush strokes and styles, line tracing, color shading and the effect of mixing different colors in a palette [9]. Skill acquisition in applying brush strokes requires practice and consistent performance feedback [10]. Greater the skill at fabric painting, the better the quality of the products produced by the women.

In this paper, we describe the architecture and discuss the implementation of the application named TryStrokes used to teach accurate brush strokes applied to painting on fabrics and handicrafts. Several paint applications exist in the market, all of which teach the use of brush strokes for digital painting on a digital canvas. Our application is novel in its approach to teach brush stroke styles and painting skills required to paint on real fabric. The application achieves this by providing corrective feedback on the student's brush strokes by comparing it with pre-recorded expert brush strokes.

II. RELATED WORK

The advent of the first digital paint application, a brain child of Alan Kay in 1971 [11] came with Steve Purcell, who created it in 1972 on some experimental hardware built at Xerox PARC that could sustain a bit-map display. Later Dick Shoup at PARC with Alvy Ray Smith, created the first color painting program, SuperPaint [12]. Since then, digital paint programs have found application in professional artwork, school education and other creative applications such as calligraphy[13] and three dimensional painting[14].

In order to improve on the realism of the artwork, Baxter et al. [15], Suguru Saito et al. [16] and Xu et al. [17] have discussed designs for virtual brushes with bristles that can deform, flatten and spread increasing the user's natural control over complex brush strokes. Vandoren et al. have created FluidPaint, naturally integrating interface elements such as wet brushes of traditional painting in a digital paint system[18]. All these programs are aimed at either increasing the naturalism of digital paintings or attempting to provision use of real life brush stroke methods on the digital canvas.

Much work can be done to use digital painting programs to teach brush strokes that can be applied to real life painting. The closest attempts would be by Yin et al. who have developed a calligraphy- brush application that can be used to teach calligraphy strokes on paper [19]. We have developed an application that holds pre-recorded expert brush strokes which is compared with the user's strokes and provides information on deviation and stroke angle, and helps the user make multiple attempts to improve their skills in the use of paint brushes. In order to accomplish this we use a custom brush attachment to a stylus similar to that developed by Vandoren et al. [20]

III. SYSTEM DESIGN

The TryStrokes system primarily consists of four major components as shown in figure 2.

A. *Input device*

The TryStrokes application uses the WACOM Intuos3 tablet with stylus and custom made bristles module as its preferred input device. It has a touch sensitive area, customizable express keys and customizable touch strip controls. Intuos3 tools have unique IDs for each tool permitting collaborative learning. This also enables usage of multiple tools and customization of each tool. The Intuos3 grip pen is sensitive to pressure and is popularly used as a freehand tool for image editing and creating naturalistic pen and brush strokes.

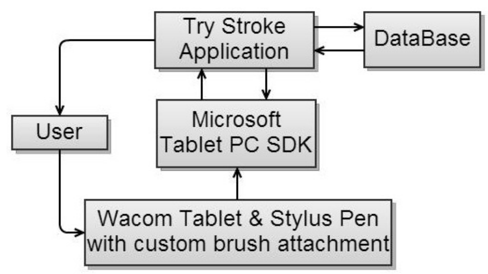

Fig.2 Block diagram describing the TryStrokes training system

We designed a brush end attachment for the stylus pen that contained a tuft of bristles of flat type and round type bristles and in different sizes and thicknesses. The brush end attachment facilitates a more realistic haptic sensation during contact with the flat surface during painting. Here on the system is explained taking the example of a stylus pen with flat type brush attachment with a randomly selected bristles width and length of 10mm and 13mm respectively.

In the system, the Wacom tablet acts as the fabric canvas and the stylus with brush attachments acts as the real brush. The length of the bristles in the brush attachment is designed to fall within the range of maximum height of the stylus that can be detected by the tablet. The position and tilt angles (azimuth, altitude) of stylus pen are provided by the tablet.

The downward pressure on the tablet is calculated as a function of the pressure applied by the user while drawing on the work area and the height of the stylus tip. The pressure variation on the stylus results in changes in the ink width. The tilt of the stylus is captured and the variation manifests in the form of line width variation. In case of brushes with increasing tilt, larger area is covered by the brush resulting in rendering more ink. The azimuth and altitude values of the stylus are important for the performance of a flat brush. Flat brushes render thin ink when the direction of the stroke is perpendicular to the azimuth of stylus. The thickness thus varies in accordance with the azimuth of the stylus and the direction in which the brush draws a stroke.

B. *Microsoft Tablet PC SDK 1.7*

The Windows Tablet PC Edition Software Development Kit (SDK) facilitates building ink-enabled, pen-enabled, and speech-enabled applications and supporting hardware for the tablets and tablet PC. The combination of software and hardware in a Tablet PC enables these methods of user interaction and allows for a rich, interactive, and productive computing experience for users. The Tablet PC platform encompasses Windows OS that enable input and output of handwriting and speech data on a Tablet PC as well as interchange of this data with other computers. We used the Windows Tablet PC Edition Development Kit 1.7 for the TryStrokes application.

C. *The TryStrokes application*

This application has been developed for the evaluation of brush stroke for our computerized fabric painting course. The application has been developed using Microsoft Visual C#.

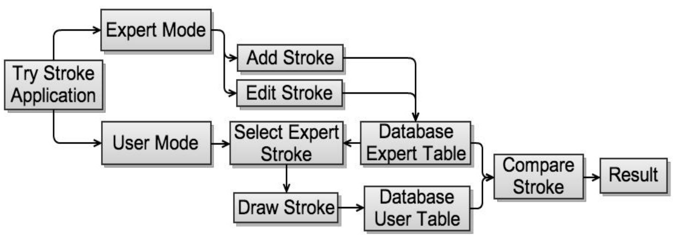

Fig.3. Block diagram representing application use case

TryStrokes application consists of two modes expert and user, as illustrated in figure 3. The expert mode provides the ability to add, edit or remove an expert stroke. Experts can paint reference strokes and it is then stored in the Database Reference Table.

User mode interface shown in figure 4, comprises of three portions: the left hand portion of the UI that shows the list of expert strokes used as reference by the novice user, the central draw area for practicing the strokes and the right portion of UI that displays the evaluation details and guidelines based on the performance. The brush strokes made by an expert are saved in the database, both the 2D image and brush orientation and position parameters, as an Expert stroke for reference. Several of expert strokes are saved in the database and displayed in the UI. The novice user has to select any one Expert stroke for practicing. After selecting the expert stroke, the selected stroke is displayed in top portion of the work area. Then the user has to choose the appropriate brush attachment following which she or he is asked to attempt the same stroke in work area. According to the position and tilt angles the application calculates the pressure, width, opacity and velocity of stroke and one 2D stroke texture is generated in the work area. The user stroke is then stored in database with its respective parameters. The next step is to compare the user strokes with expert stroke in order to evaluate the user's brush stroke. For this purpose, the user stroke is divided into three portions;

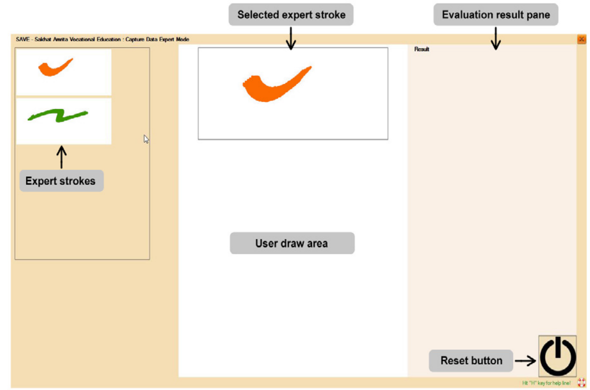

Fig. 4.User Interface for the TryStrokes application

First, middle and end portions. In each portion, the algorithm takes ten rows of data with equal intervals. The user stroke parameters are compared with the expert stroke reference table, assuming a deviation tolerance of ±10. Based on this evaluation, the system displays the results and guidelines for performance.

D. *MySQL Database*

In order to store the expert strokes and user strokes, a local database system is designed using the MySQL Server 5.5 and MySQL Workbench 5.2 CE and all data manipulation and data definition activity is performed using SQL.

TABLE I
DATABASE TABLE STORING STROKE INFORMATION

User tables for storing the data from user		**Expert Reference tables for storing the data from expert**	
Stroke_User		**Stroke_Expert**	
PK	Stroke_ID	PK	Stroke_ID
	Stroke_Name		Stroke_Name
	Stroke_Time		Stroke_Time
Stroke_User_Details		**Stroke_Expert_Details**	
PK	Stroke_Details_ID	PK	Stroke_Details_ID
	Stroke_ID		Stroke_ID
	Stroke_Position		Stroke_Position
	Stroke_Tilt		Stroke_Tilt
	Stroke_Pressure		Stroke_Pressure
	Stroke_Width		Stroke_Width
	Stroke_Opacity		Stroke_Opacity
	Stroke_Time		Stroke_Time

Two separate tables are created for expert mode and user mode as shown in Table I, Stroke_Expert reference table for Expert mode and Stroke_User table for User mode. All the strokes and its parameters are stored in this local database. A bi-directional communication socket is established between user interface and database.

IV. SYSTEM ARCHITECTURE

The layered view of the system architecture is depicted in figure 5. The Wacom tablet captures the events from the stylus and the packets are sent from the tablet to the SDK when stylus is placed within sensing range of the tablet. This data is sent to the tablet pc event handler platform and to the application UI by the Microsoft SDK.

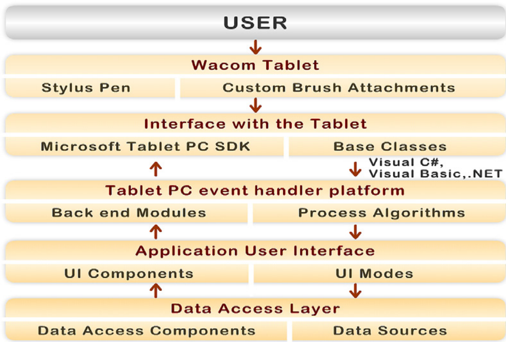

Fig. 5. Schematic of the layered System Architecture

The SDK acts as a library resource for all the in built functions. It has built-in APIs defined to recognize the occurrence of stylus events pertaining to changes in pressure and tilt. The algorithms for graphical rendering of the brush stroke and for comparison and evaluation of the strokes are implemented in the TryStrokes application. The data from the interface is stored to and retrieved from the data base by the data access layer.

V. ALGORITHM AND FLOWCHART

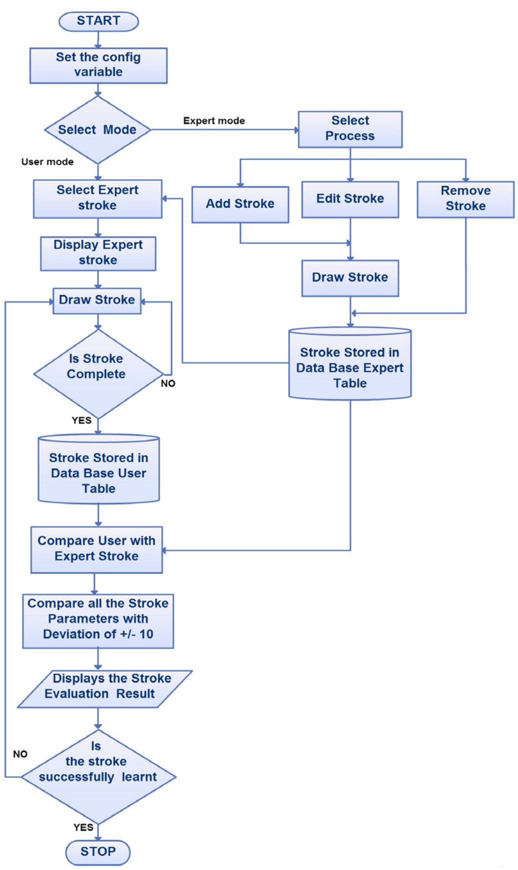

Fig.6. Flowchart of the TryStrokes application

The algorithm has been designed to draw the brush strokes, compare and evaluate user strokes with experts and to provide real-time feedback to the user, consistent with the extent of deviation and guidelines for better skill development.

As shown in the flow chart in Fig. 6, the user has to first set the configuration variable for mode selection; expert mode or user mode. Once the mode is selected, the corresponding UI is displayed and then the training can begin.

When expert mode is selected, the application shows the expert mode UI. In the expert mode there are three functions; Add, Edit and Remove strokes. When 'Add stroke' is selected, the expert is then asked to perform the brush stroke. The stroke parameters including position $S(x, y, z)$, azimuth θ, altitude φ as shown in figure 7, and time t are aquired from the tablet using the Microsoft Tablet PC SDK. The position of the stroke is obtained from the stylus position $S(x, y, z)$ in time t as shown in figure 7, and time t is acquired from the tablet using Microsoft Tablet PC SDK. The stroke is obtained from the change in stylus position $S(x, y, z)$ over time t.

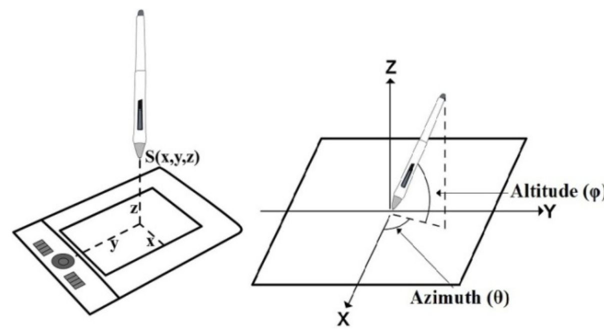

Fig.7. Position of pen $\boldsymbol{S(x, y, z)}$ and Tilt of pen $\boldsymbol{T(\theta, \varphi)}$.

The velocity of the stroke during time t_i to t_{i+1} is

$$V_i = (S_{i+1} - S_i)/(t_{i+1} - t_i)$$

where S_i and S_{i+1} are the positions of stroke point at time t_i and t_{i+1} respectively.

The average velocity of the stroke is $V = \frac{\sum_{i=1}^{n} V_i}{n}$

$T(\theta, \varphi)$ represents the tilt of the brush where θ is the azimuth and φ is the altitude of the stylus. The pressure of the stroke is calculated from the z value of position.

$$P = (L - h)/L$$

where P is the pressure of the stroke, L is the length of bristles and h is the height of the stylus from the surface.
When h is maximum(h=L), pressure is minimum (P= 0).
When h is minimum(h=0), pressure is maximum (P= 1).

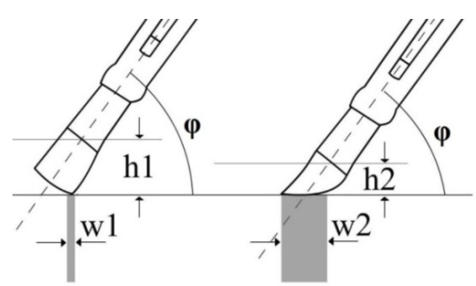

Fig. 8. Illustration depicting Width and Height of the stroke.

So the pressure is maximum when the stylus drawing tip is touched on the tablet surface.The opacity of the stroke ‘α’ is directly proportional to the pressure of the stroke. From the tilt angles $T(\theta, \varphi)$, the direction of stroke at each point is calculated. Based on the stylus position $S(x, y, z)$, pressure P and tilt angles $T(\theta, \varphi)$, the width of the stroke W, shown in figure 8, is calculated.

$$W = Wb * P * \sin\theta$$

where Wb is the selected brush's width.

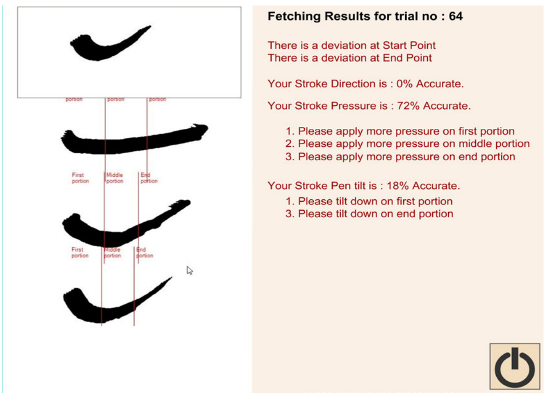

Fig.9. Screenshot of Stroke comparison and evaluation module

Based on the brush width and other measured parameters position $S(x, y, z)$, pressure P, velocity V, width W, tilt $T(\theta, \varphi)$ and opacity of the stroke ‘α’, the stroke is represented at each point of time t.

The Stroke image and its parameters $S(x, y, z)$, P, V, W, $T(\theta, \varphi)$, α are appended to the reference table in the database. Finally the expert stroke M is stored in database reference table. If the expert selects ‘Edit stroke’, the expert can select one previous stroke and edit the stroke. By selecting ’Remove stroke’, the expert can delete a previously created stroke.

In the user mode, the application shows the user mode UI. In this mode, the novice user can select any one expert stroke from the list. The selected expert stroke and its parameters from database are selected and the image of the stroke is displayed in the UI. Then the user is asked to draw strokes in the central draw area. In a fashion similar to that in the expert mode, parameters for the user stroke are calculated. After one user stroke is completed, the user stroke (U) is compared to the selected expert stroke (M) using an image processing algorithm and sample space data comparison. On comparing the points of the reference data with the novice entered data and provisioning a tolerance in deviation of ±10 units, deviation of user strokes from expert strokes is determined. This is obtained by selecting a sample space of 100 points from reference data and user data. In this sample space, the difference between any two concurrent y-axis values is compared. The stroke area is divided into three portions, namely, the First portion, Middle portion and End portion as shown in figure 11. Each portion is further divided into ten sample spaces and all the parameters of the stroke $S(x, y, z)$, P, V, W, $T(\theta, \varphi)$, α are compared with the same sample space values of the expert. Conducting this analysis, the algorithm evaluates the accuracy of the user stroke in three portions and provides guidelines and tips for the better stroke learning as shown in screenshot of application in figure 9.

VI. Conclusion and Future Work

We have implement the TryStrokes application for brush stroke training and evaluation in our ongoing Fabric painting course using Wacom tablet and stylus pen with brush attachments catering to the economically backward, illiterate and neo-literate population of India, primarily focusing on women.

Fig.10. Women practicing fabric painting after training on the computerised VET course

The application takes into account all the features in painting such as tilt of a brush, the pressure applied on bristles, the azimuth of a flat brush and its altitude keeping in mind simplicity and intuitiveness of use required for the HCI application for low literacy users. Once trained on the computer-based course, the women then are provided training on real fabric and other handicrafts to provide skill transfer to the real world and to assess their proficiency, seen in figure 10.

Future work can be focussed on large scale validation studies to study the rate of improvement in performance using such simulation methods to teach brush stroke styles. The fabric painting has many different kinds of strokes styles such as inward stroke, outward stroke which have their own characteristics. We aim to develop effective evaluation algorithms for other stroke styles. Additional progression in the design of other types of custom brush attachments for brushes like round brushes and Filbert brushes that would also enhance user experience.

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