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User Identification by Means of Sketched Stroke Features

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Abstract

We present preliminary results of using physical features of a user's sketching style, such as pen tilt and pressure, to identify a user from their sketched strokes.

Introduction

Forensic documentation examination attempts to determine the creator of a hand-written document by examining the document image (Koppenhaver 2006). Global and local stylistic features of the image are gathered from the image as a whole to determine a single owner of the entire document. However, imagine a collaborative document, where two people are working on the same document, both drawing and editing text and images. We would like to know unobtrusively who drew which stroke on the page. This would be quite difficult using standard image processing techniques, which tend to rely on more global stroke properties. Our goal is to identify the creator of each stroke on a stroke by stroke basis, using as little external contextual evidence as possible.

The rise in the availability of Tablet PCs, as well as SmartBoards and multi-touch displays, has encouraged many people to work collaboratively on hand-drawn documents containing both hand-drawn text and images. Collaboration is commonplace for designers of technical documents, such as mechanical engineering systems, software architecture specifications, circuit diagrams, and chemical compositions. Sketch recognition can be used to help identify and recognize which objects have been drawn for automatic animation, simulation, or other processing. Several sketch recognition techniques do take advantage of stylistic drawing features to recognize objects, such as average speed, max speed, overall curvature, etc (Rubine 1991). Many of the systems using such algorithms require users to provide several drawing samples to train the system on their drawing style (Sezgin & Davis 2005). None have yet incorporated pen tilt or pressure to help recognition. More importantly none have yet used these features to help identify who is drawing. Rather, users are required to use separate devices, or otherwise overtly specify who is drawing. We want to use pen tilt and pressure information to identify who is drawing, even when the sketcher changes on a stroke by stroke basis, without requiring any modal interaction from the user.

User Consistency							
User	$Study$	$\overline{P}$	σ_P	$\overline{T}x$	σ	$\overline{T}y$	$\sigma_T y$
One	1	0.744	0.237	0.372	0.036	-0.017	0.045
	2	0.763	0.213	0.381	0.031	-0.043	0.063
	3	0.785	0.209	0.382	0.041	-0.056	0.050
Two	1	0.527	0.167	0.365	0.068	-0.344	0.051
	2	0.484	0.163	0.390	0.061	-0.376	0.049
	3	0.537	0.163	0.287	0.069	-0.414	0.050
Three	1	0.543	0.166	0.469	0.036	0.001	0.051
	2	0.434	0.149	0.508	0.040	-0.010	0.076
	3	0.455	0.148	0.450	0.036	-0.032	0.048
Four	1	0.477	0.106	0.119	0.051	-0.468	0.034
	2	0.611	0.179	0.099	0.088	-0.440	0.094
	3	0.686	0.220	0.116	0.084	-0.434	0.135
Five	1	0.577	0.179	0.371	0.031	0.003	0.053
	2	0.616	0.197	0.351	0.036	-0.009	0.053
	3	0.582	0.169	0.354	0.032	0.007	0.051
Six	1	0.478	0.152	0.283	0.063	-0.222	0.062
	2	0.491	0.162	0.279	0.054	-0.185	0.010
	3	0.525	0.166	0.287	0.072	-0.159	0.072

Figure 1: Results of the first portion of the study. $\overline{P}$ = average pressure. σ_P = standard deviation of the pressure. $\overline{T}x$ = average x tilt. $\sigma_T x$ = standard deviation of the x tilt. $\overline{T}y$ = average y tilt. $\sigma_T y$ = standard deviation of the y tilt

The ability to non-intrusively distinguish users has three benefits. First, a collaborative sketching environment can identify a stroke's owner automatically on a shared sketching surface. Research has shown that collaborative sketching improves idea generation and design feedback (Shah *et al.* 2007). Automatic labeling of who drew what would provide interesting information about the design process. Second, user identification can be used as part of a security mechanism, providing a guarantee of who drew what stroke and that their document was not modified by an unintended user (Jain, Ross, & Pankanti 2006). Third, identifying a user or their sketching style, can provide additional context for a sketch recognition system. A sketch recognition system which knows who is drawing which stroke could react differently depending on who is drawing, allowing people to interact collaboratively but in their own drawing style, improving both recognition rates and usability.

Implementation and Results

We implemented a drawing application to record pen location (x,y), time, pressure, and tilt information for each stroke point when a user draws on a Wacom Cintiq. We performed two separate studies to determine user consistency as well as

Classifications				
Users	Features	Correct	Tested	Accuracy
User 1,2	All Features	367	372	98.7%
	All Pressure	194	372	52.2%
	All Tilts	362	372	97.3%
	AVG Tilts	359	372	96.5%
	STDEV Tilts	221	372	59.4%
User 2,3	All Features	187	209	89.5%
	All Pressure	150	209	71.8%
	All Tilts	187	209	89.5%
	AVG Tilts	184	209	88.0%
	STDEV Tilts	118	209	56.5%
User 1,3	All Features	358	359	99.7%
	All Pressure	301	359	83.8%
	All Tilts	337	359	93.9%
	AVG Tilts	331	359	92.2%
	STDEV Tilts	238	359	66.3%
User 1, 2, 3	All Features	442	470	94.0%
	All Pressure	232	470	49.4%
	All Tilts	439	470	93.4%
	AVG Tilts	431	470	91.7%
	STDEV Tilts	230	470	48.9%

Figure 2: Results of linear classifier in identifying the creator of each stroke

user identifiability.

Study 1: User Consistency

The first study was to determine if users' pen tilt and pressure information were consistent over a period of time. We wanted to know if this information changed daily or if it was constant, and could thus be used to reliably identify users over a long period of time without retraining the system. Six users were asked to write their daily to do lists on a tablet PC each day over a three day period. Each sample contained between 100 to 200 strokes. For each day we calculated the mean and standard deviation for a user's pen pressure, x-tilt, and y-tilt.

Figure 1 shows that the data from study 1, and from this data we can see two things: 1) Users are fairly consistent with the physical manner in which they go about sketching, 2) sketching mannerisms are distinct from user to user. Some participants were more consistent than others. For instance, on a day-to-day examination, User 1 and User 6 has a fairly consistent daily average x-tilt. We also observe that within a particular day users were fairly consistent, noting the general small standard deviations for the x- and y-tilt. Pressure appeared to be the most inconsistent physical metric, despite this we still find it to be beneficial in helping to identify the stroke owner as we can see in the next section.

Study 2: User Identification

The second study was to determine if the stroke owner could be identified given only a small amount of training data. Three users participated in this study, each providing four different sketching samples. The sketch samples contained a combination of handwritten text and objects. Several linear classifies were constructed to attempt to identify the stroke owner by a single feature, a subset of the features, or all of the features. The classifier was provided all of the strokes from two of the samples from each sketcher. The strokes from the other two samples were used as test data.

Figure 2 shows the results of the second study. We can see that with only pen tilt and pressure, a stroke's owner can be identified fairly accurately. It should be noted that many of the strokes in the sample are quite small, being only a few pixels in length: on par with the dot above an 'i', or the dash used to cross a 't.' Pressure and standard deviation of the tilt of a stroke were the weakest features. Using all tilt values - the standard deviation and the average x/y of a stroke - provided accuracy that closely rivaled using all of the features. Nonetheless, adding pen pressure information does increase identification accuracy. User 2 and User 3 were somewhat similar in drawing style, but the classifier still did quite well with an accuracy of 89.5%. When distinguishing between all three users, the system was able to obtain an accuracy of 94.0%. This is quite impressive when we note that these accuracies were obtained only by looking at the pen tilt and pressure data from a single stroke to identify the stroke owner. The results provide the baseline for what these features can accomplish when included with other contextual information.

Future Work

We would like to evaluate how our features perform when identifying users in a much larger class of users. We plan to build a multi-user sketch system that allows for real-time collaboration on a drawing, and non-invasive identification of each user's contribution. We will also experiment with other classifiers, such as a quadratic classifier, Support Vector Machine, or Bayesian Network to see if that will improve recognition further.

Conclusion

Without using any additional context, pen pressure and tilt information are capable of identifying the creator of an individual stroke given only a small amount of training data. Our study shows that a sketcher's pen pressure and tilt information are consistent over time, and that there is enough distinction between how people physically draw so that the sketch owner can be identified with high accuracy.

Acknowledgments

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