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Adapting Surface Sketch Recognition Techniques for Surfaceless Sketches

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Abstract

Researchers have made significant strides in developing recognition techniques for surface sketches, with realized and potential applications to motivate extending these techniques towards analogous surfaceless sketches. Yet surface sketch recognition techniques remain largely untested in surfaceless environments and are still highly constrained for related surfaceless gesture recognition techniques. The focus of the research is to investigate the performance of surface sketch recognition techniques in more challenging surfaceless environments, with the aim of addressing existing limitations through improved surfaceless sketch recognition techniques.

1 Introduction and Motivation

People frequently employ sketches on surfaces as a powerful medium to express ideas and concepts, and researchers have made significant strides in developing surface sketch recognition techniques for a wide range of domains. Not limited to surfaces, sketches can additionally extend beyond physical surface environments, with both realized and potential applications for surfaceless sketches that are performed in the air using wireless devices or from limb motions using motion-tracking sensors. Unlike for surface sketches though, recognition techniques for analogous surfaceless sketches are largely unexplored and also highly constrained for similar surfaceless gesture recognition techniques. Furthermore, developing robust recognition techniques for sketches in surfaceless environments are further complicated with challenging properties not inherent with sketches made in surface environments including less precise motion-tracking sensors, unclear states of when sketches begin and end (i.e., the Midas touch problem), physical fatigue in prolonged sketching (i.e., the gorilla arm problem), and so on. Yet in order to develop recognition techniques that perform robustly for surfaceless sketches, they must adequately address the additional challenges posed with the corresponding surfaceless environments.

Since surfaceless sketches share analogous core properties with surface sketches, developing recognition techniques for surfaceless sketches may strongly benefit from taking cues from corresponding surface sketch recognition techniques. In the initial stage of conventional surface sketch recognition, corner-finding recognizers process the raw strokes in the sketch and rely on features and heuristics to locate the corners within those strokes (e.g., ShortStraw [Wolin *et al.*, 2008]). The subsequent stage involves low-level recognizers using information from these located corners to recognize primitive shapes (e.g., PaleoSketch [Paulson and Hammond, 2008]). In the final stage, high-level recognizers make use of the information of these primitive shapes to recognize the larger sketch (e.g., LADDER [Hammond and Davis, 2007]).

While research work for surfaceless sketch recognition techniques are largely lacking, there has been further research work done in different aspects of recognition techniques for related surfaceless gestures. Such research works included directly extending existing gesture recognition from surface environments into its surfaceless analog (e.g., Protractor3D [Kratz and Rohs, 2011]) or recognizing dynamic hand gestures expressed in the air (e.g., Bag-of-Gestures [Ponce *et al.*, 2011]), but such recognition techniques are highly constrained to a limited number of gestures.

2 Accomplishments and Results

In researching the development of robust recognition techniques for surfaceless sketches, I was strongly motivated in exploring the limitations of naïve implementations of existing surface sketch recognition techniques on surfaceless sketches [Taele and Hammond, 2012]. As a result, I utilized a Microsoft Kinect motion-tracking sensor to record surfaceless sketches performed with a user's dominant hand and interactive editing cues performed by the spatial location of the user's non-dominant hand.

Taking analogous cues from surface sketch recognition techniques, I first explored the performance of corner-finding approaches on raw sensor readings of those sketches with state-of-the-art naïve surface sketch corner-finding algorithm ShortStraw and two prevalent naïve corner-finding metrics curvature and speed [Wolin *et al.*, 2008]. I additionally proposed two new corner-finding algorithms that were specifically designed for surfaceless sketches: the BestFit (BF) corner-finder, which is a simplified version of the Sezgin corner-finder [Wolin *et al.*, 2008] that was tuned to noisier motion-tracking data, and the Extended BestFit (BF-E)

	ShortStraw	Curvature	Speed	BasicFit (BF)	BasicFit Ensemble (BF-E)	NDDE	DCR
Arc	25.0%	0.0%	47.5%	70.0%	20.0%	35.0%	72.5%
Circle	0.0%	0.0%	27.5%	57.5%	7.5%	15.0%	72.5%
Curve	17.5%	0.0%	20.0%	55.0%	15.0%	20.0%	77.5%
Ellipse	5.0%	0.0%	2.5%	70.0%	7.5%	35.0%	85.0%
Line	100.0%	10.0%	100.0%	100.0%	100.0%	65.0%	17.5%
Polyline(2)	95.0%	17.5%	90.0%	97.5%	100.0%	77.5%	47.5%
Polyline(3)	95.0%	27.5%	85.0%	92.5%	97.5%	80.0%	60.0%

Figure 1: Corner-finding and primitive shape extraction accuracies for surfaceless sketches.

corner-finder that uses an ensemble approach of the BF and ShortStraw corner-finding algorithms.

I additionally explored the performance of surface-based primitive shape recognition approaches from the collected corner information of the raw surfaceless sketches, which rely on two key metrics used in state-of-the-art naïve surface-based primitive shape recognizer PaleoSketch [Paulson and Hammond, 2008]: *normalized distance between direction extremes (NDDE)* and *direction change ratio (DCR)*, which are effective features in classifying curves (e.g., circles, arcs) and polylines on surface sketches, respectively.

In order to evaluate the performances of corner-finding and primitive shape recognition for surfaceless sketches, I conducted a preliminary study on four engineering graduate students with prior exposure to current-generation motion-tracking sensors but no research background in using such sensors. Each user was tasked with naturally sketching ten iterations of seven basic geometric shapes in the air with their dominant hand: arc, circle, curve, ellipse, one-, two- , and three-stroke line. Prior to performing the study, users were given several minutes to familiarize themselves with the sketching and interaction cues. Corner-finding performance was evaluated with both the previously-described conventional and modified corner-finding approaches, while primitive shape extraction was evaluated from the previously-described conventional surface-based metrics. Accuracies of the users' collected surfaceless sketch data were calculated with all-or-nothing recognition using leave-one-out cross-validation (Figure 1).

3 Discussion and Future Directions

From the corner-finding evaluation, the naïve surface sketch recognition techniques performed relatively much poorer to the initial surfaceless sketch recognition ones: the BF algorithm achieved the best performance with a wide margin over the other evaluated corner-finders for curved shapes (i.e., arc, circle, curve, ellipse), with misclassifications stemming from false positives where curved shapes were sometimes approximated as polylines; and the BF-E algorithm performed best for polyline shapes. For the evaluation of the primitive shape extraction, NDDE and DCR features performed with mixed results compared to very high accuracies for surface sketches [Paulson and Hammond, 2008]. While these preliminary findings strongly suggest that low-level surface sketch recognition techniques and features for surfaceless sketches perform poorly in corner-finding and with mixed results for primitive shape extraction, better accuracy results from the proposed basic surfaceless counterparts demonstrated strong potential in instead adapting surface sketch recognition techniques to surfaceless environments.

Motivated by these findings, one future research direction involves a more expansive collection of surfaceless sketch data. Data repositories currently exist for surface sketches, but is lacking for sketches made in surfaceless environments, so it would be greatly beneficial to create such a repository incorporating more diverse users performing surfaceless sketches in greater quantity, in wider variety, and with different input methods (e.g., with a wireless device, with motion-tracked limbs). A related follow-up research direction involves developing more refined proposed surfaceless sketch recognition techniques that would be evaluated on this expanded data collection for corner-finding, primitive shape extraction, and compound shape recognition. One additional research direction would also involve addressing indirect sketch recognition issues in surfaceless environments such as the Midas Touch and gorilla arm problems.

References

[Hammond and Davis, 2007] Tracy Hammond and Randall Davis. Ladder, a sketching language for user interface developers. In *ACM SIGGRAPH 2007 courses*, SIGGRAPH '07, New York, NY, USA, 2007. ACM.

[Kratz and Rohs, 2011] Sven Kratz and Michael Rohs. Protractor3d: a closed-form solution to rotation-invariant 3d gestures. In *Proceedings of the 16th international conference on Intelligent user interfaces*, IUI '11, pages 371–374, New York, NY, USA, 2011. ACM.

[Paulson and Hammond, 2008] Brandon Paulson and Tracy Hammond. Paleosketch: accurate primitive sketch recognition and beautification. In *Proceedings of the 13th international conference on Intelligent user interfaces*, IUI '08, pages 1–10, New York, NY, USA, 2008. ACM.

[Ponce *et al.*, 2011] Victor Ponce, Mario Gorga, Xavier Baró, and Sergio Escalera. Human behavior analysis from video data using bag-of-gestures. In *Proceedings of the Twenty-Second International Joint Conference on Artificial Intelligence*, IJCAI '11, pages 2836–2837, Palo Alto, CA, USA, 2011. AAAI Press.

[Taele and Hammond, 2012] Paul Taele and Tracy Hammond. Initial approaches for extending sketch recognition to beyond-surface environments. In *Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems Extended Abstracts*, CHI EA '12, pages 2039–2044, New York, NY, USA, 2012. ACM.

[Wolin *et al.*, 2008] Aaron Wolin, Brian Eoff, and Tracy Hammond. Shortstraw: A simple and effective corner finder for polylines. In Christine Alvarado and Marie-Paule Cani, editors, *Sketch Based Interfaces and Modeling, Annecy, France, 2008. Proceedings*, pages 33–40. Eurographics Association, 2008.