Tilting-Twisting-Rolling: A Pen-based Technique for Compass Geometric Construction

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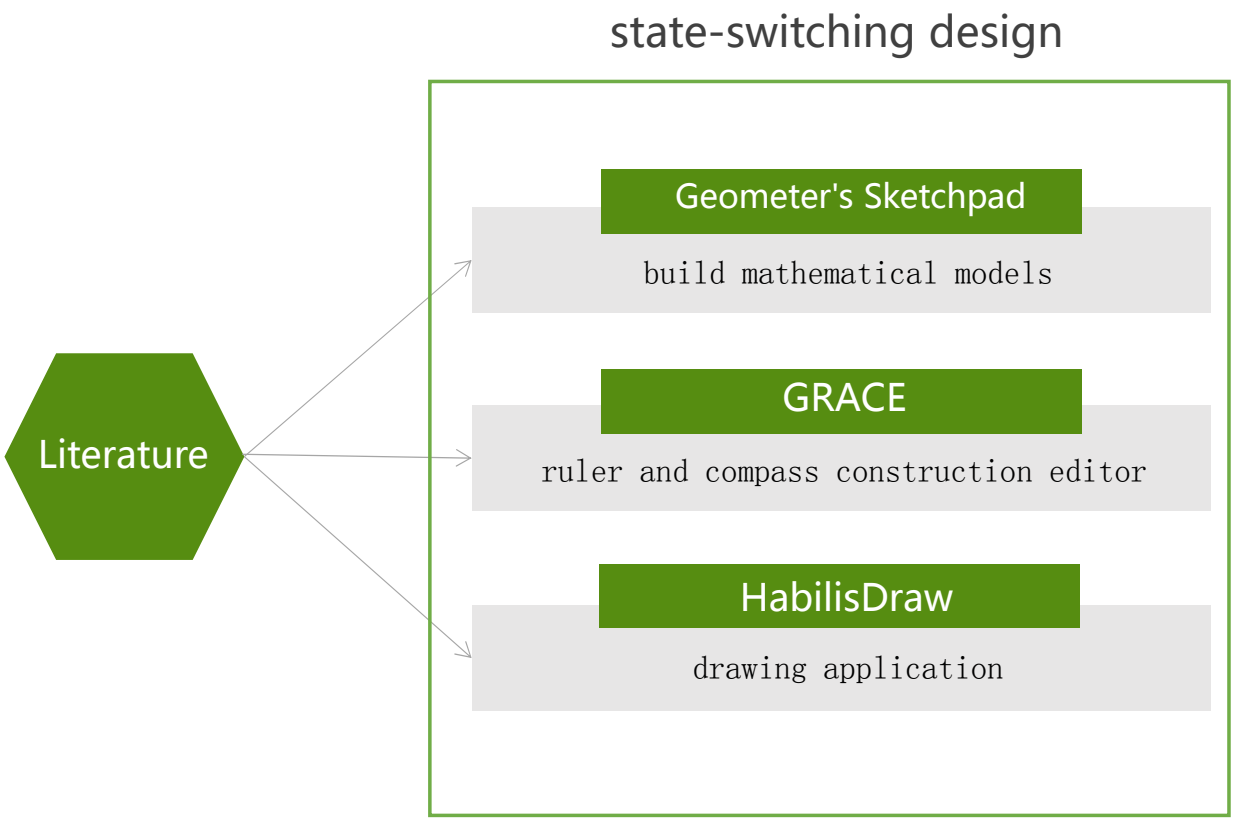
Outline

1. Introduction
2. TTR Technique
3. Experiment
4. Conclusion

Background

- Pen-based devices offer a direct way to construct geometry
  - Rough sketches
  - Precise geometry
- One common approach to create precise geometry: Free stroke beautification
  - However, in areas like education, it is necessary to present precise geometry during the drawing process
  - E.g. geometry classes where geometry construction with ruler and compass is used to understand fundamental concepts

Related Work



Our idea

- To better support geometry construction with a pen, we propose a Tilting-Twisting-Rolling (TTR) technique to facilitate constructing geometry like arcs through an uninterrupted pen action.

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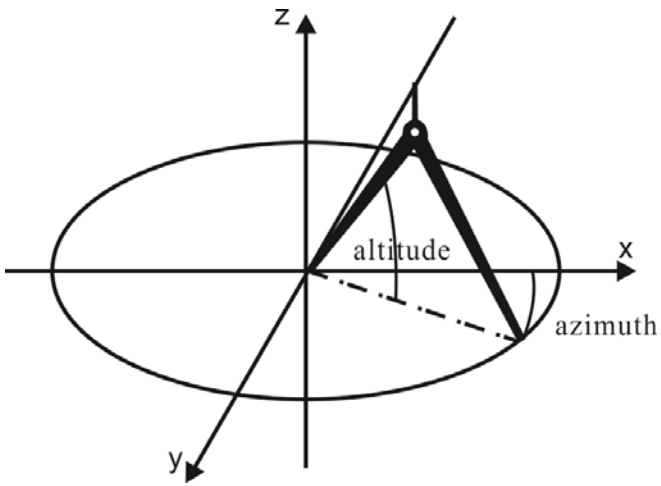
Virtual Compass Design

- Our design is based on a virtual compass metaphor



the drawing leg of the compass

$$\Delta x = \left(\text{altAdjust} - \frac{|\text{altitude}|}{\text{altF}} \right) \times \sin\left(\frac{\text{azimuth}}{\text{aziF}} \right) \times \cos(\text{altitude})$$

$$\Delta y = \left(\text{altAdjust} - \frac{|\text{altitude}|}{\text{altF}} \right) \times \cos\left(\frac{\text{azimuth}}{\text{aziF}} \right) \times \cos(\text{altitude})$$

$$Mx = Ox + 2 * \Delta x$$

$$My = Oy - 2 * \Delta y$$

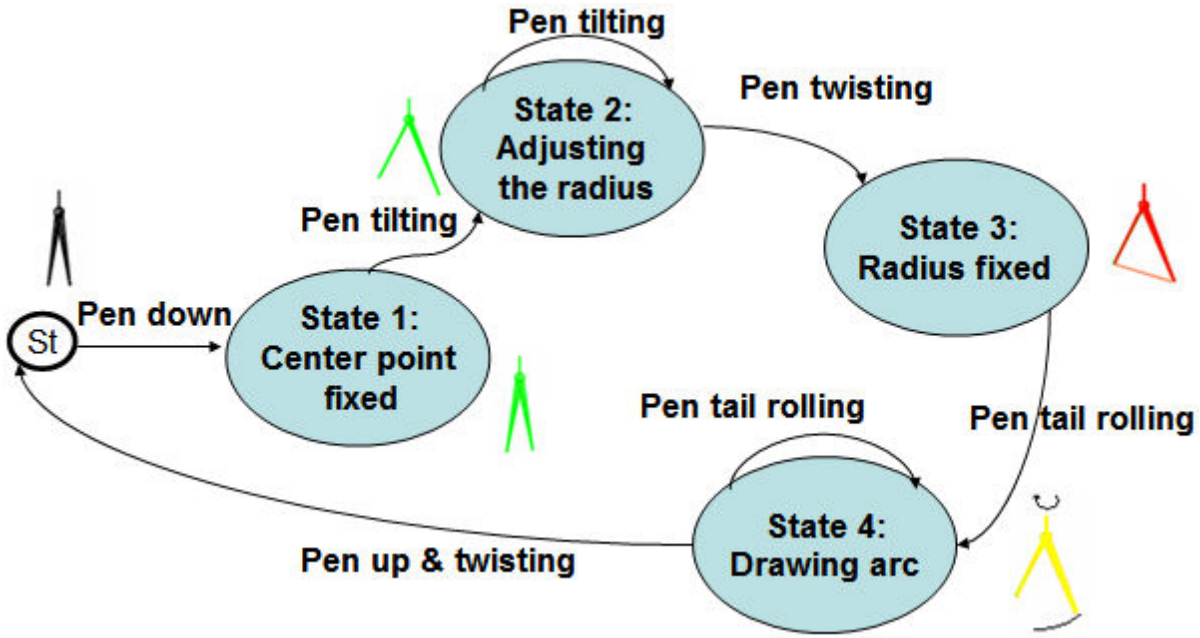
the position of the top point of the compass

$$Height = \sqrt{ArmLen^2 - \Delta x^2 - \Delta y^2}$$

$$Tx = Ox + \Delta x$$

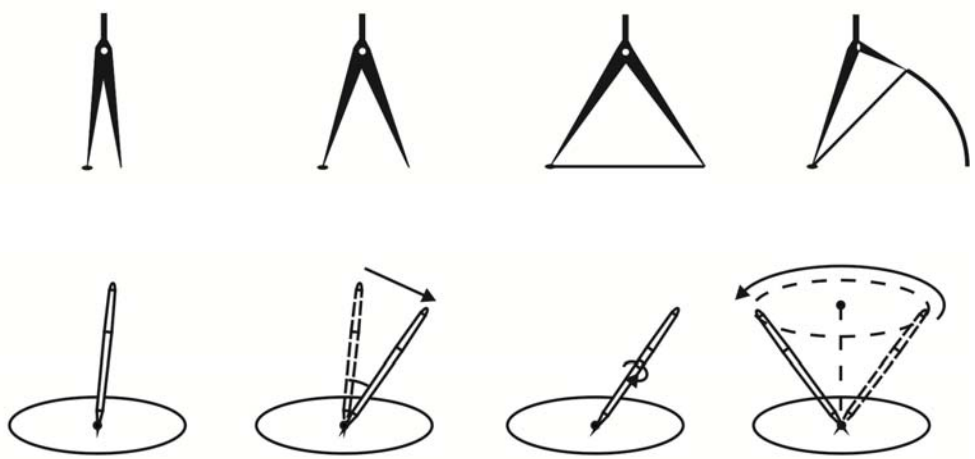
$$Ty = Oy - \Delta y - Height$$

Interaction State Transitions



Visualization Techniques

- real-time visual feedback of the drawing action



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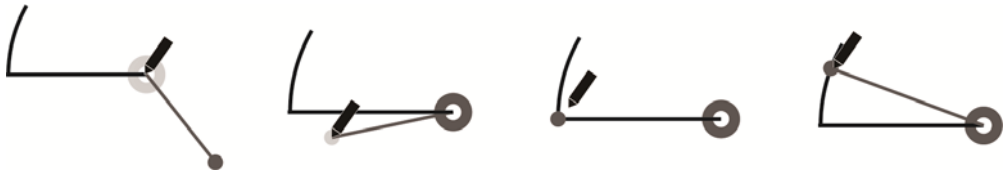
Experiment

- We conducted an experiment to compare user performance in drawing arcs between the Tilting-Twisting-Rolling (TTR), and traditional state-switching tool, like HabilisDraw (HD)

TTR

HD



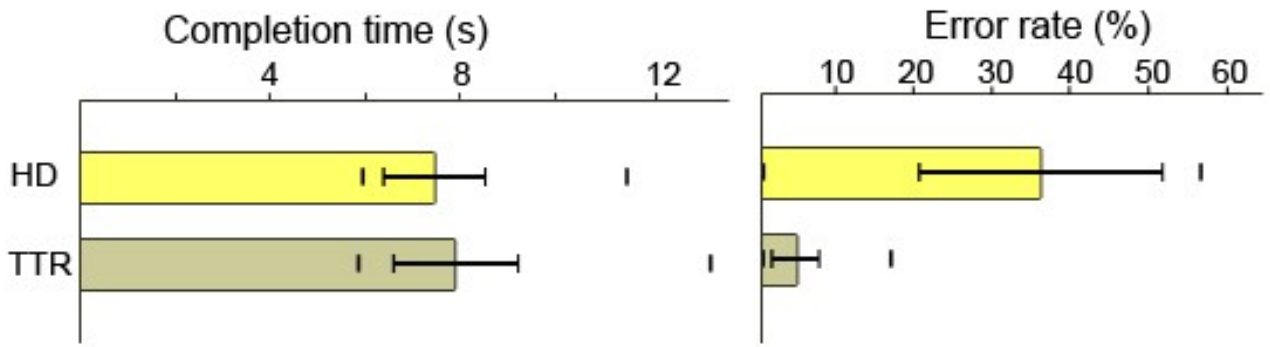
Experiment Design

- 12 subjects, within-subject design
- In each trial, a template arc was displayed on the screen, and subjects were told to replicate the arc with the given tool, the TTR or HD tool, as quickly as possible. Nine different arcs were used in the study, and each arc appeared twice during 18 trials. The order of the experimental conditions was counterbalanced using a Latin square control for order effects.

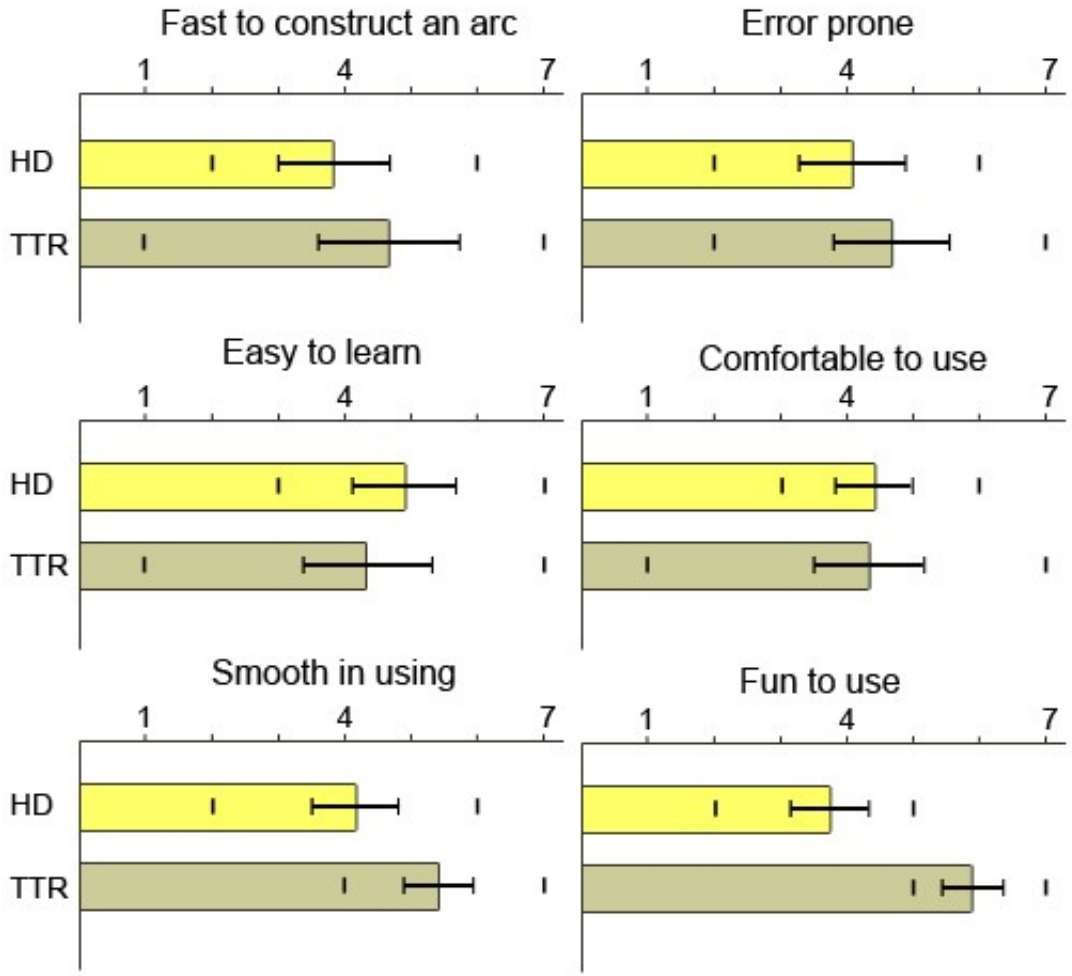
Measurement

- task completion time
- error rate
- questionnaire
  - fast to construct an arc
  - error prone
  - easy to learn
  - comfortable to use
  - smooth in using
  - fun to use

Result



Result



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Discussion

- Results of the experiment demonstrate that in arc constructions, TTR technique can significantly reduce the error rate
  - most errors in HD were related to subjects' misconception of current states
- Our results also indicate that TTR technique improve the user experience in geometry construction
- Error rate vs. Error prone

Future Work

- Our research can be extended in two ways
  - study the integration of tilting, twisting, and rolling and investigate how they may be better combined and how they may interfere with each other
  - go beyond geometry drawing and design tilting, twisting, and rolling tools for more generic multi-state interaction

Thank You!

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