Guiding with touch: Haptic cueing of surgical techniques on virtual and robotic platforms

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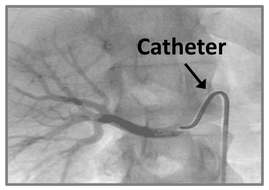
IIS-1638073

OBJECTIVE: To improve the efficacy of endovascular surgery skill training by providing real-time, objective performance feedback through informative haptic cues

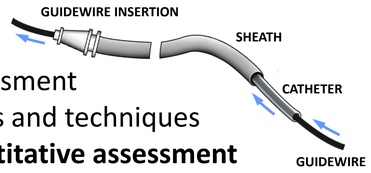
BACKGROUND

Traditional assessments lack specificity & objectivity

- **Endovascular surgery:** a minimally-invasive procedure that requires manipulation of flexible guidewires and catheters to reach target locations within the vascular system
  - Can be done manually or on robotic platform



- Current training paradigm is **subjective** and **imprecise**:
  - Trainee performance evaluated through observation by expert surgeon
  - Feedback provided using structured assessment tools; trainees are graded on general skills and techniques
  - Limited tools exist for objective and **quantitative assessment**

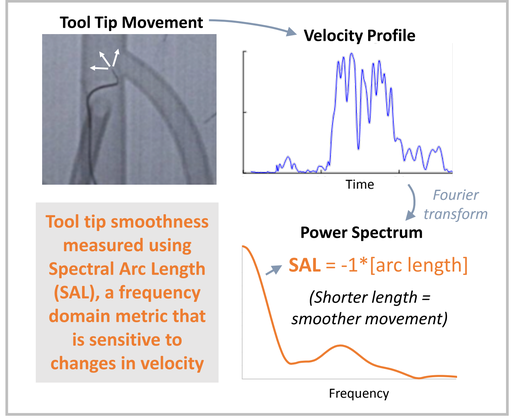


PRIOR WORK

Tool tip movement smoothness correlates with skill

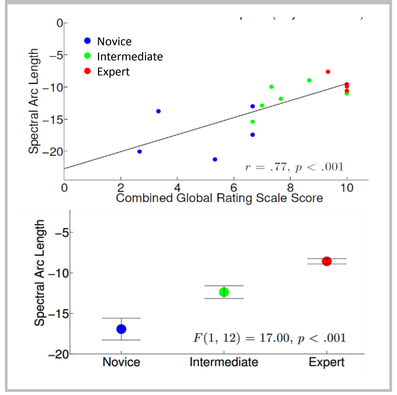
- Previous study revealed strong relationship between **smoothness** of tool tip movement and **surgical expertise** *(Estrada et al. 2016)*

SPECTRAL ARC LENGTH CALCULATION



Tool tip smoothness measured using Spectral Arc Length (SAL), a frequency domain metric that is sensitive to changes in velocity

TASK PERFORMANCE
(Manual Catheterization of Model)

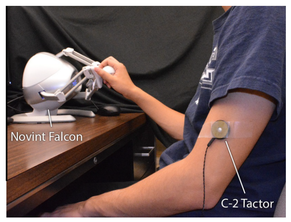


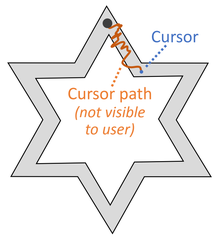
- SAL correlates with Combined Global Rating Scale scores and differentiates novice, intermediate and expert skill groups

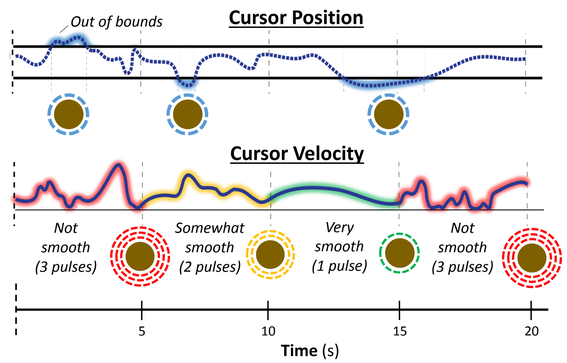
VALIDATION

Haptic feedback influences motor strategy

- Mirror trace task used as a proxy task to validate effect of smoothness-based haptic feedback
  - Objective: trace shapes as **quickly** and **accurately** as possible
  - Control input from a Novint Falcon is inverted along both the x and y axes
  - **Vibrotactile feedback** provided with C-2 tactor





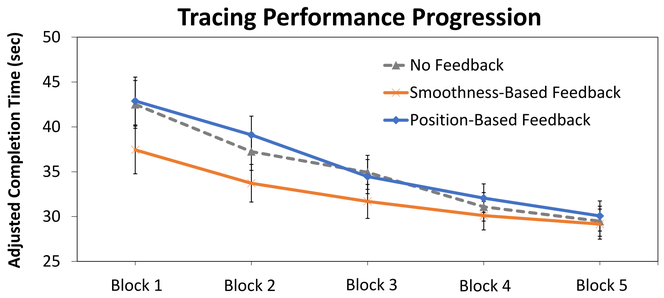


3 Feedback Groups

Position-Based: Tactor vibrates continuously while cursor is outside of shape boundaries

Smoothness-Based: Every 5 sec, tactor renders 1, 2, or 3 pulses based on SAL (smoothness) value

No Feedback: No haptic feedback provided



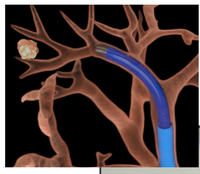
- Tracing performance assessed using **adjusted completion time** metric, which penalizes time out of bounds: $t_A = [time\ in] + 5*[time\ out]$
- Subjects receiving smoothness-based feedback improved in speed and accuracy more than subjects in other feedback groups

NEXT STEPS

Implementation on surgical training platforms

- Provide real-time haptic feedback on tool tip smoothness during typical training tasks on simulation and robotic platforms

3D Systems
ANGIO MENTOR
Simulator



Auris
MONARCH
Robotic system