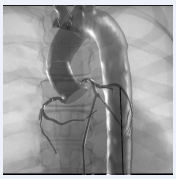

Development of a Virtual Simulator for Endovascular Catheterization Training

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Introduction

- A virtual endovascular catheterization system that simulates the characteristics of catheters and vasculature can provide cost-effective and safe training for cardiologists. State-of-the-art virtual systems lack either real-time deformations of vessels or the catheter's steerability and flexibility.
- In this work, a modeling and simulation framework for endovascular catheterization training is introduced. The framework enables user specifications on procedures, devices, and starting sites. Cardiologists evaluated the validity and visual authenticity of the virtual system.

Method

Vasculature:

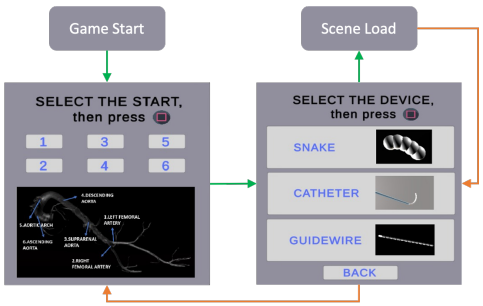
- We proposed a vasculature deformation model that relies on a Position-based Dynamics (PBD) approach [1].
- The users can choose starting sites to explore the navigation at specified routes.
- A simulated movement of the vessels caused by the heartbeat is generated to make it close to the real-life scene.

Devices:

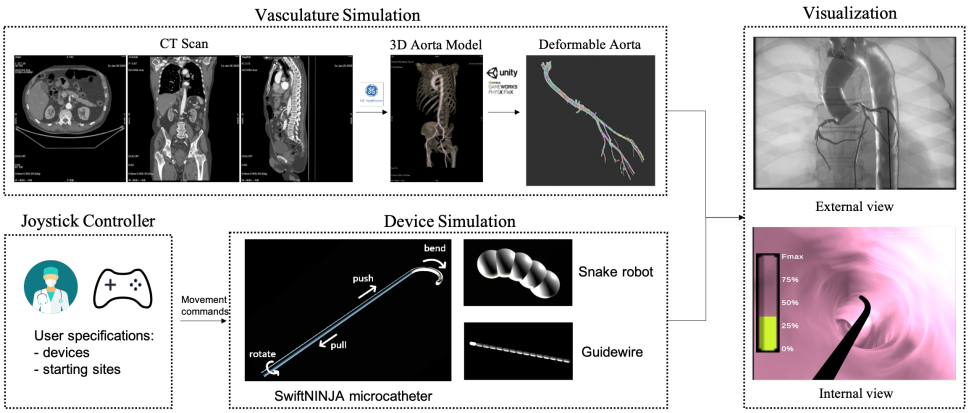
- We introduced a catheter model which consists of a flexible body and a steerable tip, modeled via PBD and constant-curvature, respectively.
- We provided other device options, such as an autonomous follow-the-leader snake robot and a guidewire simulated using Mass Spring Model.

Visualization:

- Simulated fluoroscopy view and internal view are provided to the user who controls the catheter traveling through the aorta via a Joystick.
- Force feedback is provided to users in real-time via a bar graph.



The Graphical User Interface (GUI) provides user specifications on devices and starting sites.

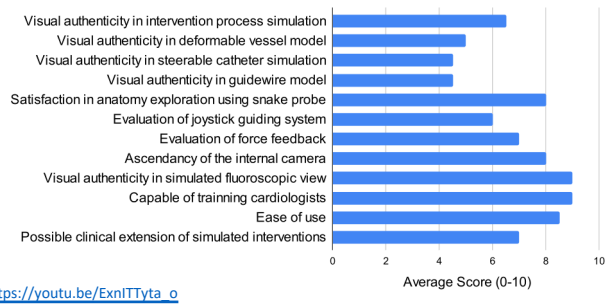


The overview of the proposed system presents

- the workflow from the extraction of the patient-specific deformable vessel mesh model (top left)
- and the device simulation procedure (bottom left)
- to the visualization of the simulated training environment (right).

Results

- A demo of the intervention process is made available[1], which simulated the advancement of the devices in a TAVI procedure.
- The virtual system were evaluated by two cardiologists.



[1]https://youtu.be/ExnITTyta_o

Discussion and Conclusions

- Encouraging feedbacks are provided by user-end evaluation:
  - The internal view could provide information about the lumen 3D structure and reduce complications.
  - The force feedback is essential for users to determine catheter manipulation.
  - The system is capable of training practitioners.
- Future works will validate the virtual system via quantitative evaluation by learning to follow a reference trajectory [2] and add radial access option.
- Furthermore, we will integrate the system with augmented reality interface.

References & Acknowledgment

[1] Zhen Li, Federica Mechelli, Guido Evangelisti, Angelos Theoharis, Cristina Espinosa Jiménez-Carlés, Giovanni Monizzi, Angelo Mastrangelo, Maria Elisabetta Mancini, Daniele Andreini, Jenny Dankelman & Elena De Momi (2021) Modeling and Simulation of Steerable Catheters and Deformable Vasculature for Endovascular Catheterization Training. *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* . [Under Review].

[2] Zhen Li, Jenny Dankelman and Elena De Momi, Path planning for endovascular catheterization under curvature constraints via two-phase searching approach. *International Journal of Computer Assisted radiology and surgery (IJCARS).* 16 (4), 619–627 (2021). https://doi.org/10.1007/s11548-021-02328-x

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