Guide wire Modeling for the planning of catheterization

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Abstract. The course and the success of an endovascular intervention can be influenced by the choice of the guide wire and primarily by its ability to access to the lesion. We propose a new approach for the modeling of guide wire.

1 Introduction

In minimally invasive endovascular surgery, the advances in instrumentation technology result in the use of a great number of devices among which guide wires are of particular importance. Due to the multiple characteristics of the available guide wires (shape, strength, torque, elasticity), the pre-operative selection of ones which best fit the patient anatomy is a difficult task requiring strong clinical expertise that have a great impact on the success of catheterism procedure. We propose a virtual environment dedicated to the simulation of the guide wire navigation within patient-specific vascular structures considering its physical parameters.

2 Method

Following the "multi-body" representation [1], the guide wire model is discretized as a chain of small and rigid segments connected to their neighbors at joints. The artery is represented by a polygonal mesh. The joints present two degrees of freedom in rotation limited by a maximal angle characterizing the maximum radius of curvature of the guidewire (fig.1-left). This method provides a means for modeling the heterogeneous properties of guidewires, since we can easily define different local strengths at joints.

Insertion of the guide wire is simulated by adding a new segment to the distal extremity of the model. Under the assumption of fairly rigid artery walls, cancellation of artery walls crossing is managed by a retraction process deforming the guide wire. The segment which collides the artery wall rotates through an incremental angle computed from relative local wall orientation. If the maximum angle is reached and collision remains, the angular constraint is iteratively propagated along the pivots of each segment of the guide wire to the proximal extremity until the collision is cancelled.

To represent the elastic property of guide wire, a relaxation process is implemented following the "home springs" model [2]. It connects springs between the current position and the virtual zero-bending energy position of each joint (fig.1-middle). The relaxation process solved by the explicit Euler method integrates a penalty force in case of wall crossing and leads the system to pull back toward its equilibrium shape.

3 Results and Discussion

The general behaviour of our model has been validated in a phantom representing a vascular tree structure. The simulation takes place in a virtual environment implemented using *WorldToolKit* C libraries and interfaced with a 6-DOF controller. Experiments demonstrate the realistic behaviour of the physically different guide wires interacting with the phantom wall (fig.1-right) and the potential of the simulation in assessing the ability of particular guide wires to reach a target. Nevertheless, the proposed catheterism simulation is not yet able to deal with real time interactions. Since collision detection requires about 99% of the total computation time by using polygons intersection functions of WTK, it could be improved by using a camera based method to satisfy real-time constraint. Moreover, since the computational time of this technique is independent of the number of polygons, the use of complex vasculature presented in patient CT data with a lot of polygons is permitted. Further work will compare simulated and real guide wire behaviours within a physical phantom and will evaluate the simulation within surface models of patient vasculature.

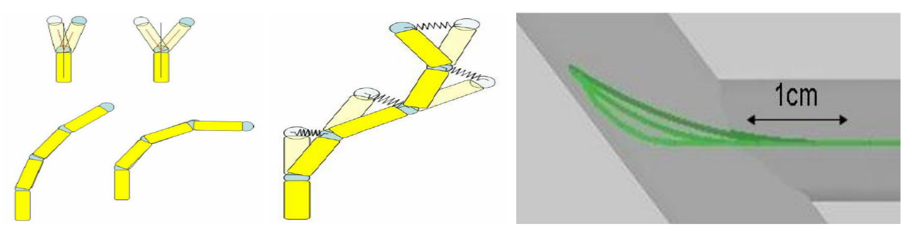

Fig. 1. (left) Discrete models of guide wires for different strengths, (middle) relaxation process, (right) view along Z axis of the simulation in a phantom model using three guide wires (represented by 0.3mm radius 3mm diameter segments) presenting three different radius of curvature (0.03, 0.1 and 0.3 rad maximum angles).

References

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