Within the HapCath - haptic catheter - project an assistive system for interventional catheterizations has been developed. Conventional navigation during catheterization is done by direct manipulation of a handle at a guide wire’s proximal end. With the aid of x-ray imaging the corresponding movement of the distal tip within the patient can be monitored. Depending on the practical experience of the medical expert and on the varying complexity of the treatment, the procedure differs in duration and x-ray exposure dose of up to 300 %. The aim of the HapCath-System is to reduce duration and exposure dose by simplifying the procedure. The implemented method is to measure the contact forces at the distal tip (III) of the guide wire (II) and feed these measured forces back onto the proximal end of the guide wire to enable tactile feedback and allow for haptic control of the guide wire. The system gives exact measures for the contact force of the guide wire’s tip and vessel walls (I) to the physician.

The demonstration system of HapCath includes an artificial artery system, within these the user is able to manoeuvre the haptic guide wire and to recognize different types of plaques by touching the calcifications with the guide wire tip. The system is set up to experience different levels of haptic assistance. The different tasks of catheterizations can be performed with visual or haptic feedback either, or with visual and haptic feedback simultaneously.

Minimized Force Sensor

The sensor structures are especially designed for the measurement of axial and also for lateral forces. The new designs facilitate high miniaturization and allow for the integration into a wire with a diameter of 360 µm. The mechanical structures depend on different mechanical principles: Whereas the model with symmetrical deflection body provides one lever arm for every force component, the measurement of the force vector at the sensor element with asymmetric deflection body is done by evaluating the stress distribution in a single measuring plate, which is bended by the load applied through an coupled structure of two lever arms.

An advantage of the element with asymmetric structure mainly depends on the relatively simple manufacturing technology, done by anisotropic-wet-etching with potassium hydroxide (KOH) of the plate cavity and the further structuring by simply sawing out the elements. Nevertheless, the sawing process had to be adapted and optimized by our partner (CiS - Erfurt). The sensor with symmetric structure is manufactured by Deep-Reactive-Ion-Etching (DRIE) and therefore allows for more complex structures. For the application within blood vessels, the packaging of the sensor element is crucial, since a defect sensor cover can lead to serious patient disease or death. The realized method of packaging the sensor is to mold the sensor into a structured elastomer . Even though the mechanical properties of polymeric materials are much less appropriate than silicon to achieve a stable linear stress/strain relation, the degrading effect of the molding compound is very small due to only small deflections of the relatively stiff sensor structure in comparison to the polymeric material.

HapCath: Haptic Guide Wire for Catheterizations of the Heart with a Micro Force Sensor and a Force Feedback System

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Measures

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Actuator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal force: $F_n = 300 \text{ mN}$</td>
<td>Force of actuator: $F_a = 1.3 \text{ N}$ (scalable)</td>
</tr>
<tr>
<td>Measurement dynamic: $f_c &gt; 10 \text{ kHz}$; Output dynamic: $f_c &lt; 300 \text{ Hz}$</td>
<td></td>
</tr>
<tr>
<td>Realtime three component force measurement + temperature, Translational and rotational actuation ec-motor driver, Safety functions e.g. residual-current measurement, sensor damage recognition, etc.</td>
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</tbody>
</table>

Demonstration System

The demonstrator represents the current status of the project. It includes the piezoresistive force-sensor integrated into the tip of a guide wire and packaged for the application in an artificial vessel phantom. An electronic system incorporates the sensor electronic for derivation of the force vector, the haptic controller and the driver for the actuators. Furthermore, the electronic allows to display adjustable levels of haptic support. To depict the use of HapCath for intuitive catheter navigation, a camera system displays the movement of the guide wire in a way comparable to conventional x-ray imaging. A time counter can be used to measure the imaging time to compare the calculated x-ray dose and the amount of contrast fluid used for the simulated interventions with and without haptic feedback. An additional visualization of the contact force can be turned on and off.

Control unit of training demonstrator for radiological angiography

Literature