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Estimation of External Forces Using Local Displacement of Elastic Body

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Abstract

Endoscopic and robotic surgery has enabled minimally invasive procedures and allowed surgeons to perform delicate operation. However, because careful tool operation is required during surgery and current robotic surgery system cannot transfer forces, surgeons operate organs while estimating contact forces from only visual information. If intraoperative measurement and physical estimation of the deformed organs are possible during surgery, the state of organs will be recognized physically and quantitatively, which will make the recent surgery more safe and reliable. Although contact forces on the forceps has been investigated, the physical state of organs is not studied well.

This study proposes a new method for estimating external forces based on local displacement observation of elastic bodies. We assume that the external forces are sparse in manipulating organs that partially connected to other tissues. Local displacement of organs can be measured or estimated from multiple endoscopic cameras or from ultrasound systems. By applying L1-norm minimization to finite element method, the proposed method computes external forces applied to the mesh model from local displacements of the partially observed vertices. Some simulation studies are conducted to confirm the effectiveness of the method. The experiments showed that the external forces are successfully estimated by partial observation of the deformed shape.

Keywords: Force estimation, L1-norm minimization, Intraoperative support.

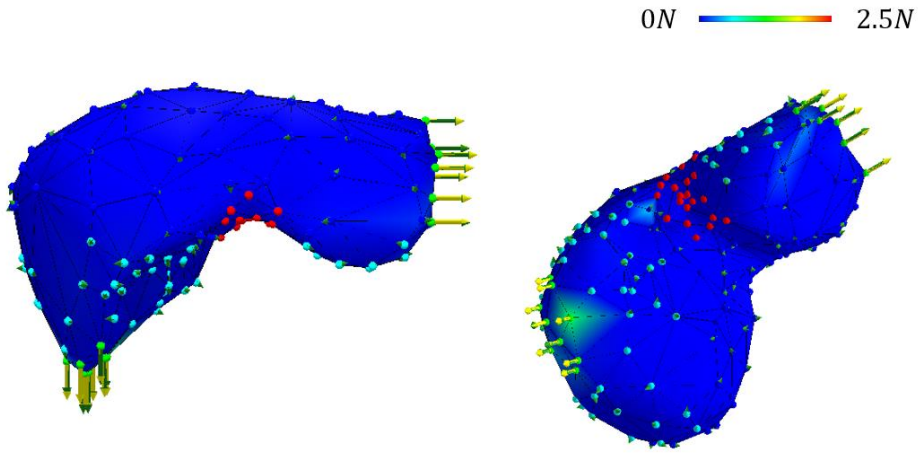

Figure 1. Force estimation result and error between the estimated force and the target force. Yellow arrows are the estimation target. The estimated results (green arrows) are computed from displacement of the observed vertices (light blue).