Unsupervised deep learning encoders/decoders for laparoscopic 3D depth estimation and surface reconstruction

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Abstract

Accurate and real-time methodologies for a non-invasive three dimensional repre- sentation and reconstruction of internal patient surfaces is one of the main research fields in computer-assisted surgery and endoscopy. Mono and stereo endoscopic im- ages of soft tissues and observable organs are converted into three-dimensional rep- resentation by the estimation of depth maps. In this Thesis, I developed and tested self-supervised stacked and Siamese encoder/decoder neural networks suited to work during a minimally invasive surgery, while respecting the constraint of real-time and in mono and/or stereo configurations. Computed depth-maps from monocular and stereo endoscopic images are tested with three different test sets known in literature and with a new challenging test set generated through simulated environments. I introduced also a fuzzy adaptive algorithm to fine tune depth estimations perturbed by specular reflection and other artifacts. The models I present outperform mono and stereo depth estima- tion obtained by state-of-the-art models on similar researches. Extensive robustness and sensitivity analyses on more than 30 000 frames are performed. This Research Thesis leads to important results and improvements in monocular and stereo real-time depth estimations of soft tissues by showing, also, their efficacy and applicability in real surgical workd-flows.