Computer vision

Recent advances in computer vision have revolutionized many aspects of society but have yet to find significant penetrance in neurosurgery.

Computer vision is an interdisciplinary scientific field that deals with how computers can be made to gain high-level understanding from digital images or videos. From the perspective of engineering, it seeks to automate tasks that the human visual system can do.

Computer vision tasks include methods for acquiring, processing, analyzing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information, e.g., in the forms of decisions.

Understanding in this context means the transformation of visual images (the input of the retina) into descriptions of the world that can interface with other thought processes and elicit appropriate action. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory.

As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. As a technological discipline, computer vision seeks to apply its theories and models for the construction of computer vision systems.

One proposed use for this technology is to aid in the identification of implanted spinal hardware. In revision operations, knowing the manufacturer and model of previously implanted fusion systems upfront can facilitate a faster and safer procedure, but this information is frequently unavailable or incomplete. The authors present one approach for the automated, high-accuracy classification of anterior cervical hardware fusion systems using computer vision.

Patient records were searched for those who underwent anterior-posterior (AP) cervical radiography following anterior cervical discectomy and fusion (ACDF) at the authors' institution over a 10-year period (2008-2018). These images were then cropped and windowed to include just the cervical plating system. Images were then labeled with the appropriate manufacturer and system according to the operative record. A computer vision classifier was then constructed using the bag-of-visual-words technique and KAZE feature detection. Accuracy and validity were tested using an 80%/20% training/testing pseudorandom split over 100 iterations.

A total of 321 total images were isolated containing 9 different ACDF systems from 5 different companies. The correct system was identified as the top choice in 91.5% ± 3.8% of the cases and one of the top 2 or 3 choices in 97.1% ± 2.0% and 98.4 ± 13% of the cases, respectively. Performance persisted despite the inclusion of variable sizes of hardware (i.e., 1-level, 2-level, and 3-level plates). Stratification by the size of hardware did not improve performance.

A computer vision algorithm was trained to classify at least 9 different types of anterior cervical fusion systems using relatively sparse data sets and was demonstrated to perform with high accuracy. This represents one of many potential clinical applications of machine learning and computer vision in neurosurgical practice [1).

Surface matching (and more generally the matching of structures) is an important subject of computer vision, which has given rise to an important amount of research papers.

In the past, the accuracy of surface matching has been shown to be disappointing.

Mongen and Willems aimed to determine whether this had improved over the years by assessing application accuracy of current navigation systems, using either surface matching or point-pair matching.

Eleven patients, scheduled for intracranial surgery, were included in this study after a power analysis had shown this small number to be sufficient. Prior to surgery, one additional fiducial marker was placed on the scalp, the "target marker," where the entry point of surgery was to be expected. Using one of three different navigation systems, two patient-to-image registration procedures were performed: one based on surface matching and one based on point-pair matching. Each registration procedure was followed by the digitization of the target marker's location, allowing calculation of the target registration error. If the system offered surface matching improvement, this was always used; and for the two systems that routinely offer an estimate of neuronavigation accuracy, this was also recorded.

The error in localizing the target marker using point-pair matching or surface matching was respectively 2.49 mm and 5.35 mm, on average ($p < 0.001$). In those four cases where an attempt was made to improve the surface matching, the error increased to 6.35 mm, on average. For the seven cases where the system estimated accuracy, this estimate did not correlate with target registration error ($R2 = 0.04$, $p = 0.67$).

The accuracy of navigation systems has not improved over the last decade, with surface matching consistently yielding errors that are twice as large as when point-pair matching with adhesive markers is used. These errors are not reliably reflected by the systems own prediction, when offered. These results are important to make an informed choice between image-to-patient registration strategies, depending on the type of surgery at hand [2].

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Huang KT, Silva MA, See AP, Wu KC, Gallerani T, Zaidi HA, Lu Y, Chi JH, Groff MW, Arnaout OM. A computer vision approach to identifying the manufacturer and model of anterior cervical spinal hardware. J Neurosurg Spine. 2019 Sep 6:1-7. doi: 10.3171/2019.6.SPINE19463. [Epub ahead of print] PubMed PMID: 31491759.
2)
Mongen MA, Willems PWA. Current accuracy of surface matching compared to adhesive markers in patient-to-image registration. Acta Neurochir (Wien). 2019 Mar 16. doi: 10.1007/s00701-019-03867-8. [Epub ahead of print] PubMed PMID: 30879130.