IMPLANT INTEGRATION INTO MEDICAL SCAN DATA AND FINITE ELEMENT SIMULATION

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INTRODUCTION
Biomedical problems tend to involve domains which are geometrically complex over a range of scales. Much effort has gone into developing tools for generating computational meshes automatically from medical scan data (such as MRI and CT), allowing the easy creation of patient-specifc models. One obvious enhancement to this capability is to be able to interactively modify the geometry; this would for example allow the prior determination of the effect of certain surgical procedures. This paper will report on the application of new techniques allowing the insertion of CAD models into the original scan data. The paper will focus on the effect of certain surgical procedures, and a number of examples that cover different applications within the Computational Biomechanics field will be presented.

METHODS
The objective of this work is to combine CAD and image data to allow the introduction of additional geometrical elements into the patient-specifc computational model derived from the medical scan data. This could be achieved in two ways:

a) 'CAD-based' image-to-mesh tools could be applied here by combining the STL surface generated by the tool with STL surfaces representing the additional elements using some kind of solid modelling software, before passing the resulting composite object to the mesh generator to produce the final mesh. This may work well with simple structures, but can result in a considerable loss of features of the patient-specific scan data in more complex cases, as shown in this paper.

b) 'Voxel-based' image-to-mesh conversion techniques have been developed by the authors, in which the original medical scan itself can be altered by introducing CAD models of additional geometric elements, which are then voxelised to form an additional mask within the scan. This approach has led to the creation of commercial software, called +ScanCAD distributed by Simpleware Ltd. The result is a computational mesh for the whole problem including patient-specific objects and additional man-made objects.
The proposed techniques provide a unique approach to merging CAD and image data whilst preserving the features and fidelity of the scanned image.

CASE STUDIES
The functionality provided opens the door to modelling a wide range of problems in medicine and dentistry as well as in consumer product design. Examples presented in this paper include the virtual positioning of CAD models of different implants (e.g. hip implant, spine fixation, dental implants) within a pre-operative scan. An example of such a virtual assembly can be found in Figure 1.

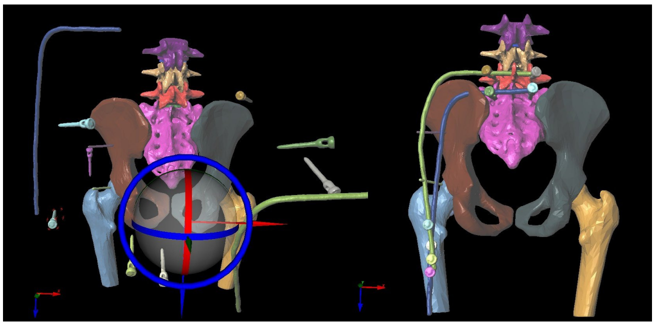

Figure 1: Virtual assembly of an internal fixation system in +ScanCAD.

Post-operative performance can then be simulated using the combined models, and multiple scenarios (e.g. sensitivity of stress field to implant alignment, use of different reaming tools, etc.) can be tested straightforwardly. Figure 2, for example, shows the response of a hip system under static loading conditions.

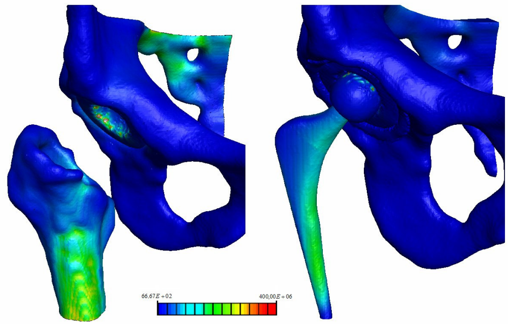

Figure 2: Hip implant under static loading conditions.

CONCLUSIONS
The presented case studies demonstrate the potential of the approach for the generation of patient-specific FE models based on 3D clinical scans. In spite of their complexity and sophistication, full FE simulations could be carried out on commonly available PCs, opening up a wide range of previously difficult or intractable problems to numerical analysis, including patient-specific implant design..