Use of Simpleware Software for LS-DYNA® Analyses

Brian Walker *
Philippe Young **
Rajab Said **
* *Arup*
** *Simpleware Ltd*

Abstract

Simpleware have developed a suite of programs that are used to convert imaging data obtained from CT, microCT, MRI or Ultrasound scanning equipment into finite element meshes for use in LS-DYNA.
Simpleware provides what is effectively a 3D photocopier: three dimensional replicas can be generated automatically based on scans. In parallel, computer simulations can be used to assess the suitability or performance of objects in operation. Simpleware's technology has opened up FEA and RP manufacturing to a variety of applications and research fields including:

- *Industrial reverse engineering*
- *Research in materials and composites*
- *Non-destructive evaluation (NDE)*
- *Biomechanical Research*
- *Implant design and manufacturing*
- *Surgery simulation and planning*
- *Forensics*
- *Biomimicry*
- *Archeology*

ScanIP is used to import 3D imaging data from MRI, CT, Micro CT and Ultrasound scans. It provides a series of image processing and segmentation tools which allow the user to define areas of interest in the image based on grey scale values. The smoothing algorithms used by ScanIP are volume, topology and geometry preserving. This ensures the accuracy of both the generated surface reconstructions and mesh models is based on image accuracy alone. The segmented areas can then be exported as a 3D stereo lithography file or exported into +ScanFE for meshing. The stereo lithography files can either be used directly for producing rapid prototype parts or imported into CAD software.

+ScanCAD allows you to import a CAD model, position it interactively within the 3D imaging data and then generate a Scan IP mask. Scan CAD can be used to obtain patient specific models by positioning CAD models of different implants within a pre-operative scan. Post-operative performance can be simulated using the combined models and multiple scenarios can be tested easily.

The paper describes the software and illustrates its use in different fields of application.

Use of Simpleware Imaging Software for LS-DYNA® Analyses

10th International LS-DYNA Conference

Detroit, MI, USA

June 8th – 10th 2008

Brian Walker – Arup

Philippe Young – Simpleware Ltd

simpleware

June 2008

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Introduction

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Simpleware Ltd provides what is effectively a 3D photocopier: three dimensional replicas can be generated automatically based on scans. In parallel, computer simulations can be used to assess the suitability or performance of objects in operation. Simpleware's technology has opened up FEA and RP manufacturing to a variety of applications and research fields including:

- Industrial reverse engineering
- Research in materials and composites
- Non-destructive evaluation (NDE)
- Biomechanical Research
- Implant design and manufacturing
- Surgery simulation and planning
- Forensics
- Biomimicry

Simpleware software can be used in conjunction with the "Oasys LS-DYNA Environment" to make an efficient toolkit for the creation and running of models in LS-DYNA.

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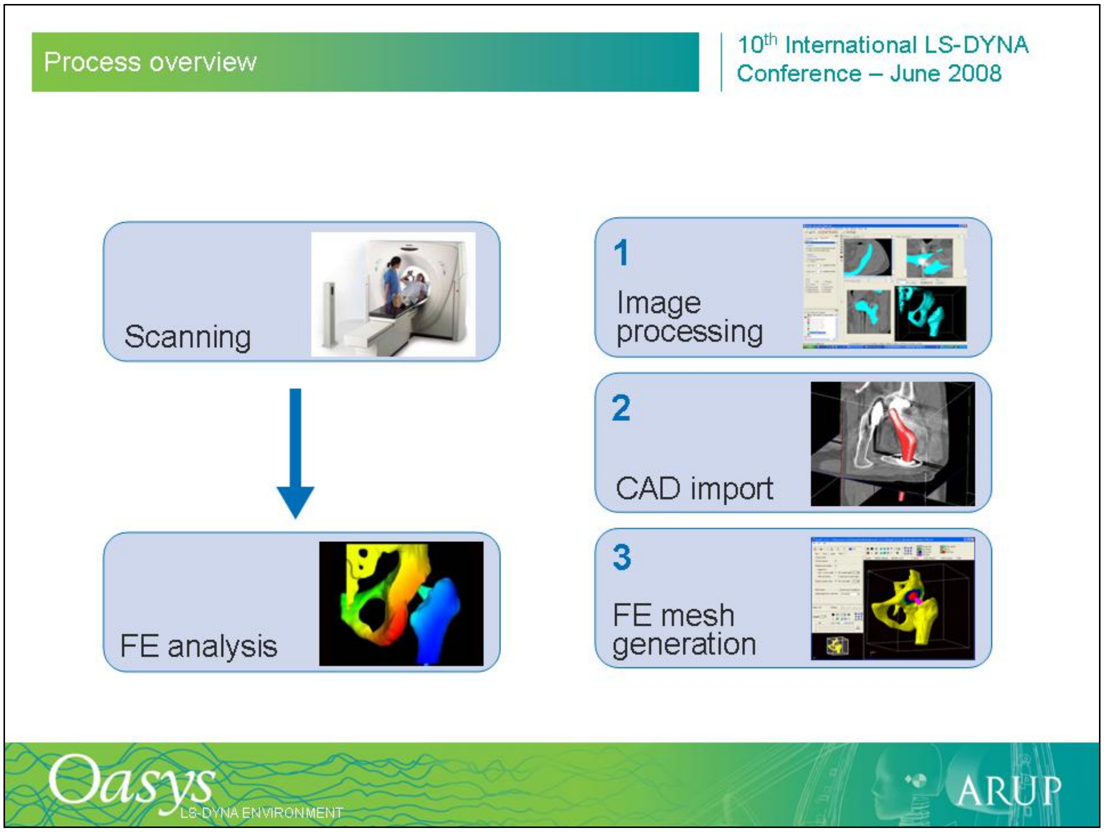
Process overview
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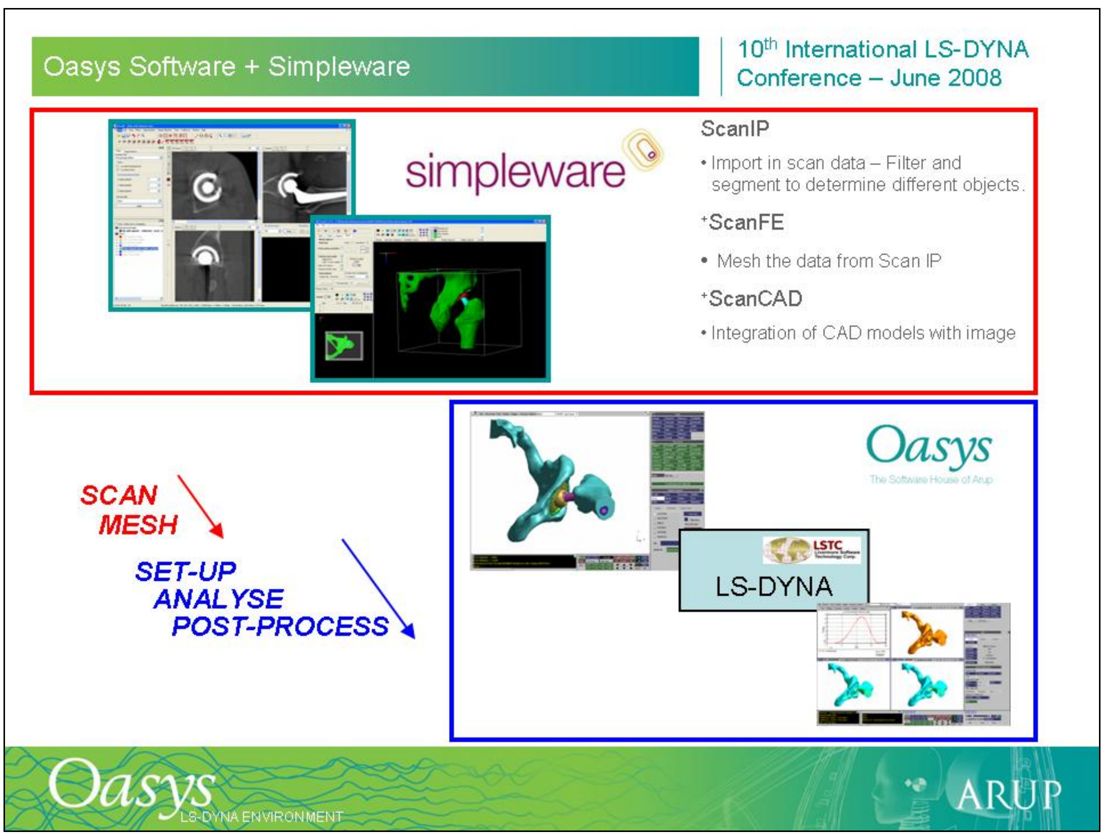
Scanning
FE analysis
1
Image processing
2
CAD import
3
FE mesh generation
Oasys
LS-DYNA ENVIRONMENT
ARUP


Oasys Software + Simpleware
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simpleware
ScanIP
• Import in scan data – Filter and segment to determine different objects.
+ScanFE
• Mesh the data from Scan IP
+ScanCAD
• Integration of CAD models with image
SCAN
MESH
SET-UP
ANALYSE
POST-PROCESS
Oasys
The Software House of Arup
LSTC
LS-DYNA
Oasys
LS-DYNA ENVIRONMENT
ARUP

Simpleware Software

Three Packages

- ScanIP

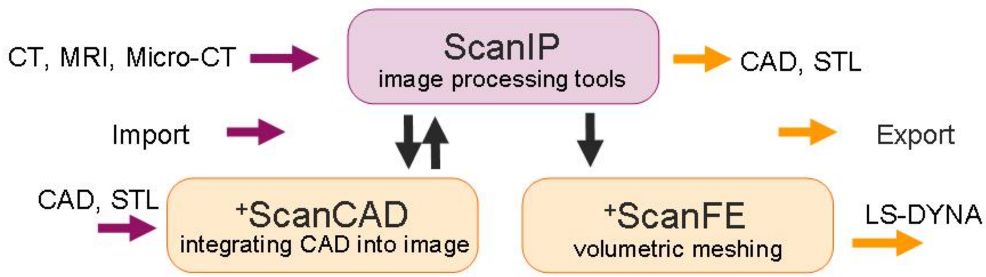
  Image Processing and CAD Model Generation

- +ScanFE

  Volume/Surface Mesh Generation for FE/CFD

- +ScanCAD

  Integration of CAD Models within Image Data



ScanIP

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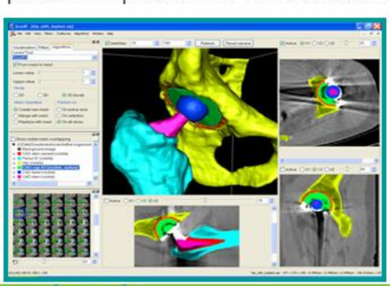
3D imaging data from MRI, CT, Micro CT and Ultrasound scans

- Image processing and segmentation tools (which allow the user to define areas of interest in the image based on grey scale values)
- Smoothing algorithms are volume, topology and geometry preserving. This ensures the accuracy of both the generated surface reconstructions and mesh models is based on image accuracy alone.
- The segmented areas can then be exported as a 3D stereo lithography file or exported into +ScanFE for meshing.
- The stereo lithography files can either be used directly for producing rapid prototype parts or imported into CAD software.



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ScanIP – Input Data

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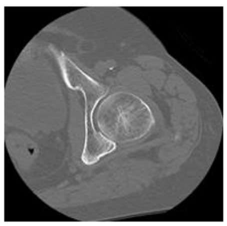
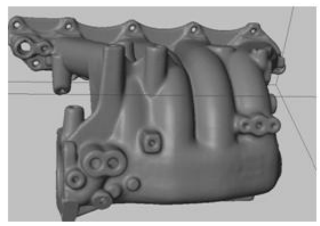
Raw
- One file containing pixel values
- Additional info needed (pixel type, number of pixels in each direction, spacing)

Stack of images
- One image file (BMPs, JPEGs, PNGs)
- Additional info needed (spacing)

DICOM
- Designed to handle all images used in medical world
- Data on CD: DICOMDIR file + dicom image files
- Usually, on a CD, only a selection of files can be used to form a 3D volume.





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ScanIP – CT vs MRI

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What is measured
- CT: amount of absorbed X-rays
- MRI: "movement" of Hydrogen protons excited by the magnets

Effect on the patient/subject
- CT: To be avoided when possible for live patients
- MRI: no known impact on a person's health

Image clarity - CT
- Presence of artefacts when high density objects are present (obfuscation, no distortion)
- When parts can be distinguished visually, threshold based algorithms are often very efficient.
- Not efficient at segmenting soft tissue.

Image clarity - MRI
- Presence of artefacts when magnetic objects are present (distortion)
- More parts can be distinguished visually, but threshold based algorithms are often difficult to use.
- Very efficient at picking up soft tissues

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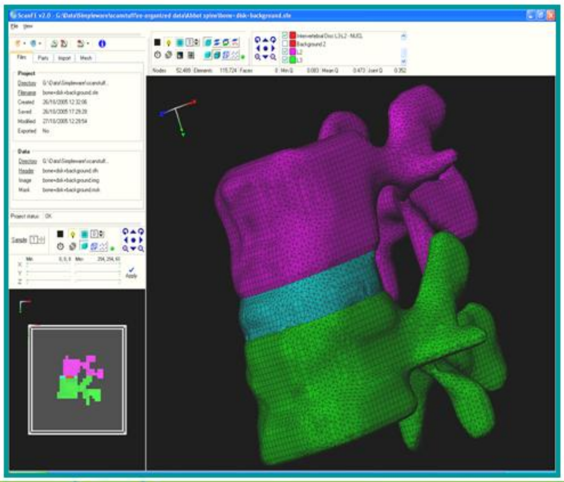
+ScanFE

- Single-step conversion to multi-part volumetric mesh
- Assignment of complex material properties based on signal strength
- Direct export to LS-DYNA®, (no re-meshing necessary)
- FE model is exact replica of the STL



+ScanFE Features

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- Robust, automated and accurate surface and volume reconstruction (STL and FE)
- Multiple structures meshed simultaneously
- Adaptive meshing
- Generation of models for multi-physics simulations
- Volume and topology preserving smoothing: morphological accuracy contingent only on image quality
- RP models are exact geometric replica of FE mesh
- Generation of material properties based on signal strength
- No intermediary steps necessary (which would reduce quality and take more time)

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+ScanCAD

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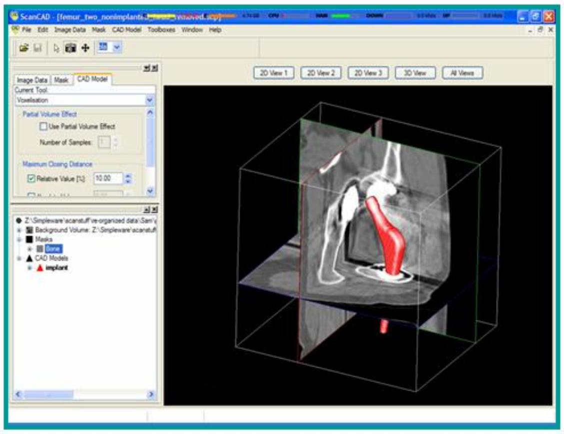
+ScanCAD allows you to import a CAD model, position it interactively within the 3D imaging data and then generate a Scan IP mask. Scan CAD can be used to obtain patient specific models by positioning CAD models of different implants within a pre-operative scan. Post-operative performance can be simulated using the combined models and multiple scenarios can be tested easily.



- Import of CAD data into 3D image
- Interactive positioning, e.g. for pre-operative planning
- Export as multi-part CAD/STL or volumetric mesh (FE/CFD)

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Mesh Generation

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(1) Segment structures of interest
(2) Reconstruct smooth representation

CAD Approach:

Export geometric surface model to CAD - mesh with advancing front…

Voxel Approach:

Mesh directly from 3D segmented data (VOMAC/Grid based)

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Mesh Generation

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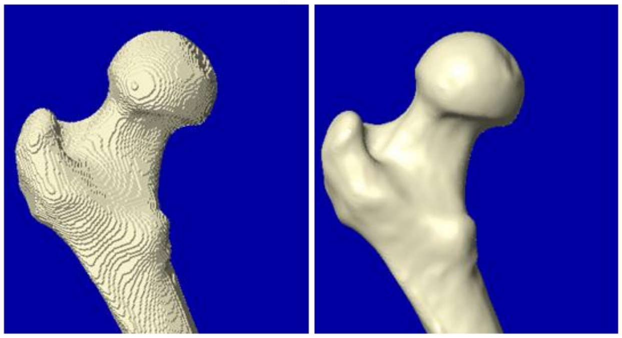
Reconstruct smooth representation



Smoothing accuracy

You can have models (CAD surface or FE volume meshes) in which the geometric accuracy is only dependent on image accuracy if you ensure you use:

- Topology Preserving anti/aliasing and smoothing
- Volume Preserving anti/aliasing and smoothing
- Sub-voxel accuracy-possible by exploiting partial volumes

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Mesh Generation

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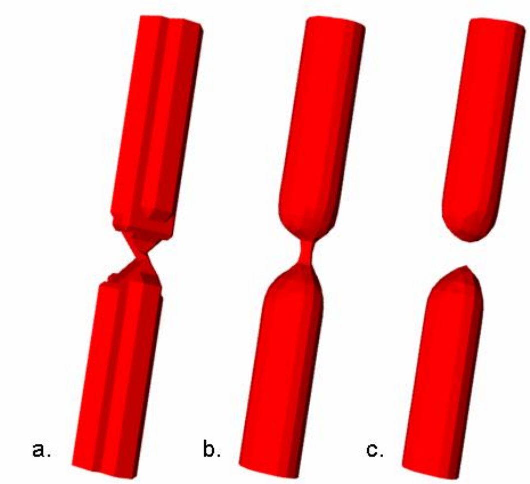
Topology preservation



a. Original image, unsmoothed

b. Topology preserving smoothing

c. Non-topology preserving smoothing

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Mesh Generation

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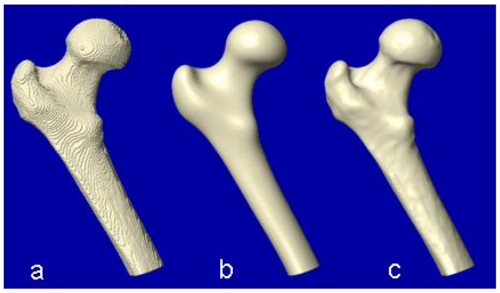
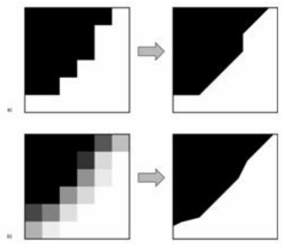
Volume preservation



a. Original image, unsmoothed (203,238 mm^3).
b. Traditional smoothed (180,605 mm^3, Δvolume = -11.14%)
c. Simpleware developed proprietary (202,534 mm^3, Δvolume = -0.35%)

Partial volume



a. Binary interpolation
b. Greyscale based interpolation

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Mesh Generation

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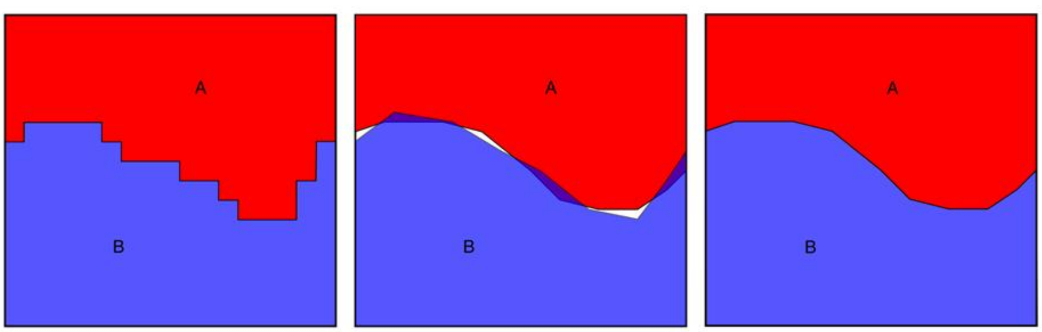
Multi-part smoothing

Require robust automated mesh generation for topologies of arbitrary complexity (such as foams) and with any number of Volumes of Interests

- Conforming interfaces
- Three + part junction problem
- High quality **Surface** and **Volume** meshes

Conforming Interfaces



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Case Studies

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Four Cases Studies

1. Human Eye
2. Head and Neck model
3. Auxetic Foam
4. Engine Block

Eye Model

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Human Eye

- Patient specific computer models of the human eye based on *in vivo* MRI acquisitions were constructed.
- Bio-fidelic three dimensional numerical meshes of the orbital area including the eye and surrounding soft and hard tissues generated.
- Impact with projectile modelled using LS-DYNA

Data acquisition

Segmentation

FE and STL model generation

Impact simulation in LS-DYNA

Eye Model

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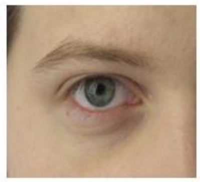
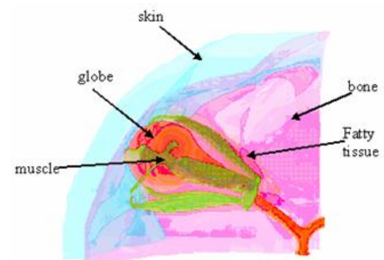
A 29 year Caucasian female

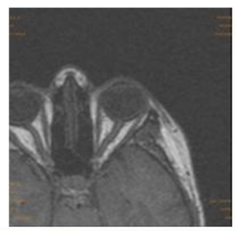


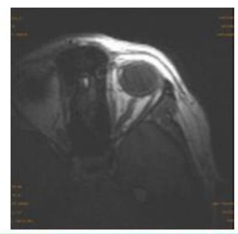


Models constructed based on two high resolution MRI scans of the right orbital area (using head coil and surface coil).

Transparent top view of model showing each mask including bone, skin, globe, fatty tissue and muscles

In-plane and out-of-plane resolution of 1mm. The data consisted of 50 slices, each at a pixel resolution of 128x128.





Eye Model

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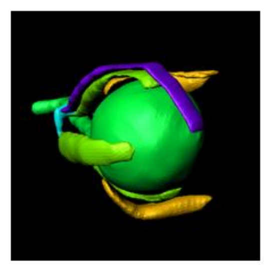
Segmentation within ScanIP

6 different segmented structures

- Globe and optic nerve
- Bony orbit
- Eyelids
- Fat
- Facial soft tissues
- Extra-ocular muscles

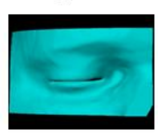


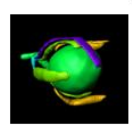
Meshed in ScanFE

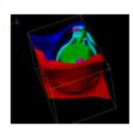
Volume mesh: mixed hex/tet elements or pure tet.

Structures/parts modelled either as volumetric meshes or as surface meshes as required (e.g. the bony orbit modelled as a rigid structure defined by surface shells).

Model Completed in Oasys PRIMER







Eye Model

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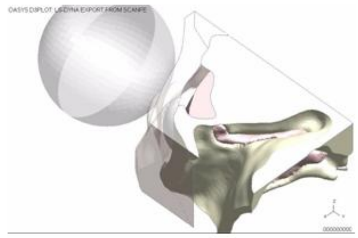
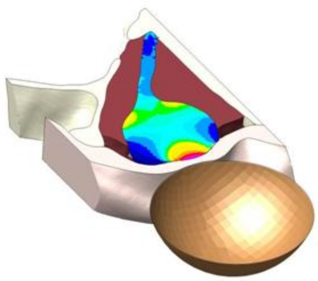
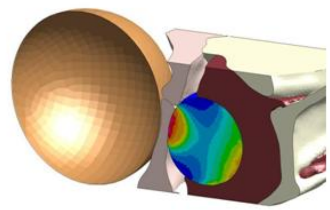
- Impact with golf ball (42 mm diameter, 45g mass)
- Impact Velocity 4.47 m/s
- Single surface contact
- Material Models
  - Skin: Mooney-Rivlin material model
  - Bone: Rigid
  - Globe and fat: Elastic
  - Ball: Rigid







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Auxetic Foam

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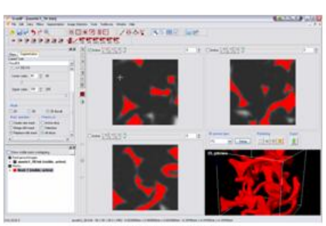
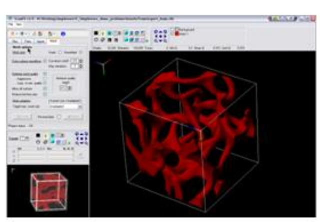
Auxetic Foam

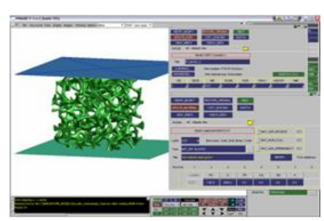
- Foams have a negative Poisson's ratio – Expands in all directions when stretched.
- Areas of application
  - Prosthetic materials
  - Surgical Implants
  - Suture/muscle/ligament anchors
  - Filters
- High Resolution scan of foam courtesy of Prof. Gerry Seidley, University of Washington.
- Mesh Generated using ScanIP and +ScanFE
- Analysed in LS-Dyna – Explicit code allows a high volumetric compression to be analysed.



Segmentation



Mesh



Set Up

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Auxetic Foam

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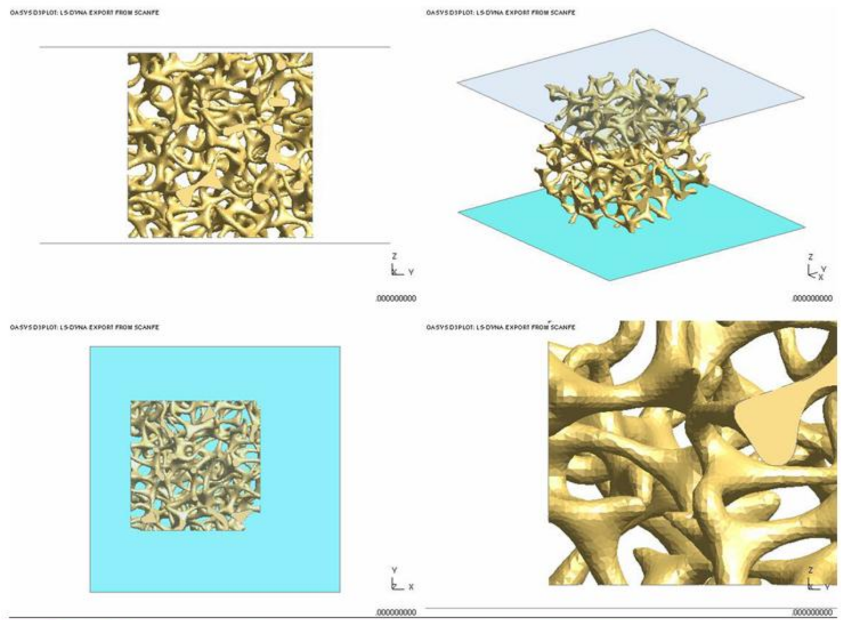

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Head and Neck Model

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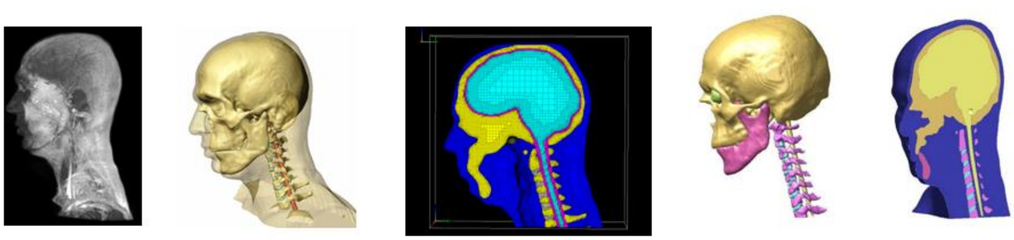
Head and neck model.

- Data created by Simpleware (ScanIP and ScanFE), and Oasys Primer.
- Research model to study different material models.
- Model contains 2,000,000 solid elements.
  - Brian
  - Skull
  - Cervical Vertebrae
  - Intervertebral Disks
  - Mandible
  - Eye
  - Impactor



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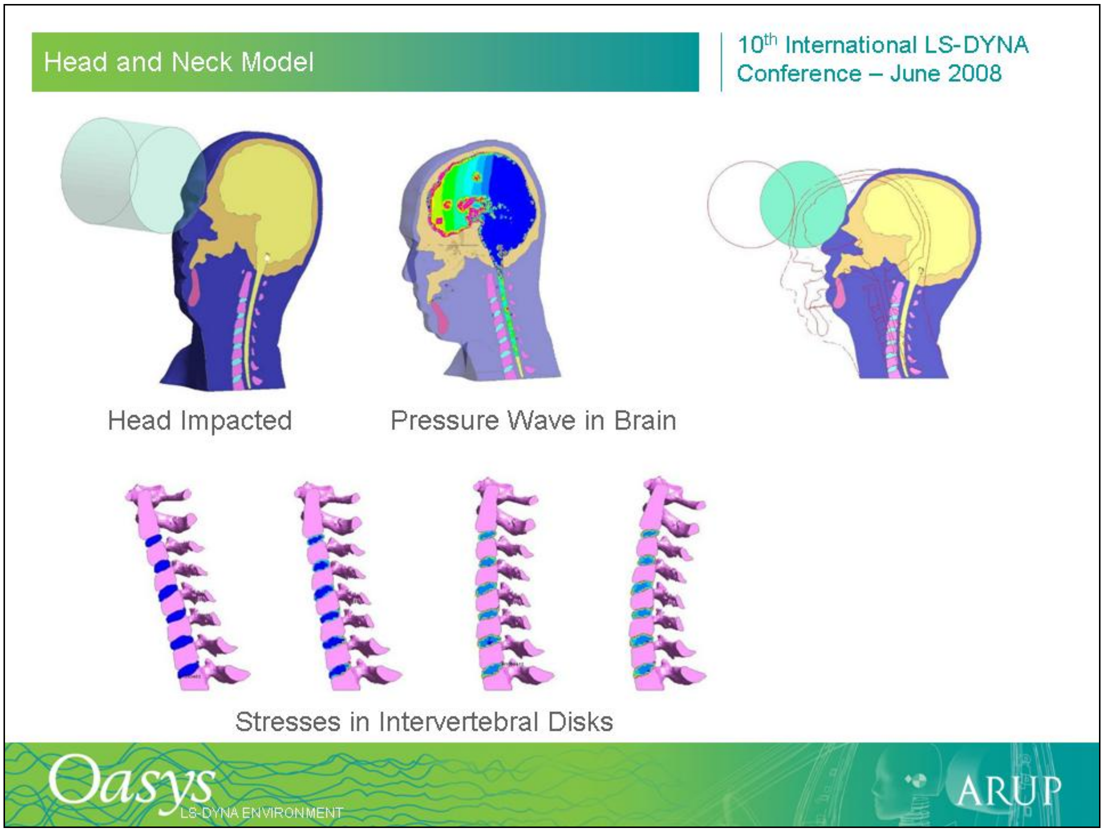
Head and Neck Model
10th International LS-DYNA
Conference – June 2008
Head Impacted
Pressure Wave in Brain
Stresses in Intervertebral Disks
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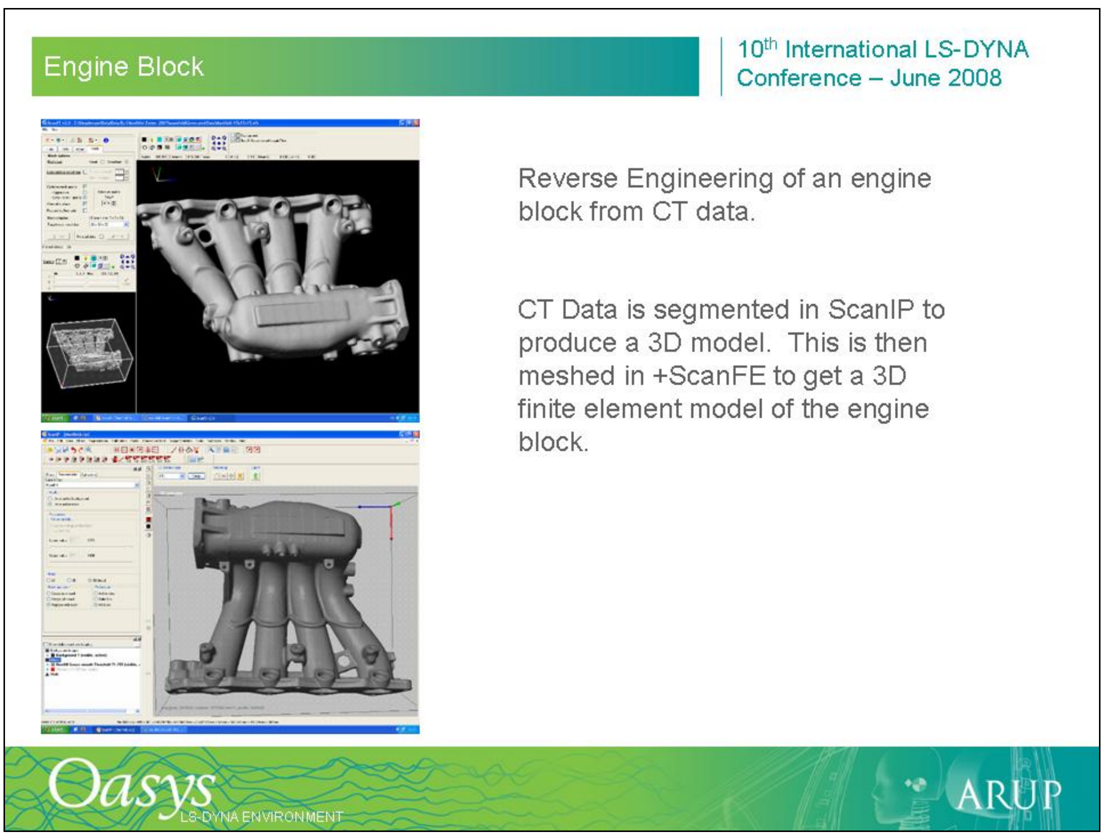
Engine Block
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Reverse Engineering of an engine block from CT data.
CT Data is segmented in ScanIP to produce a 3D model. This is then meshed in +ScanFE to get a 3D finite element model of the engine block.
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Conclusions

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Simpleware software offers:

- A fast and accurate method to obtain LS-DYNA finite element meshes from 3D scan data.
- A powerful new tools for carrying out physics based simulation based on models reverse engineering from 3D imaging data:
- An approach characterised by **Robustness** and **Accuracy**
- In combination with experimental tests can be used for characterisation of soft and hard tissue material properties

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Contacts

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Brian Walker
Arup
The Arup Campus
Blythe Valley Park
Solihull
West Midlands
B90 8AE
UK

T. +44 (0) 121 213 3317
M. +44 (0) 7775 706147
E. brian.walker@arup.com
W. www.arup.com/dyna

Philippe Young
Simpleware Ltd
Innovation Centre
Rennes Drive
Exeter
Devon
EX4 4RN
UK

T. +44 (0) 845 508 7240

E. p.young@simpleware.com
W. www.simpleware.com

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