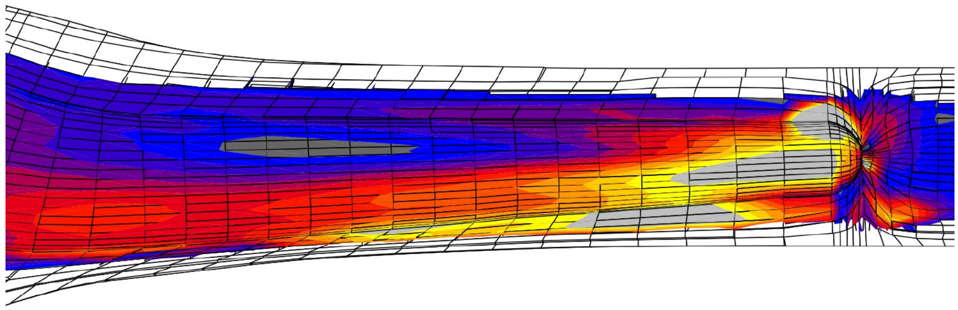
Success Story

Trinity College Dublin



An "Order of Magnitude" Improvement in Orthopaedic Research

"The Altix will enable us to jump an order of magnitude in the complexity of our computational work."

– Dr. John Britton, Research Fellow, Trinity Centre for Bioengineering

The Trinity Centre for Bioengineering at Trinity College, University of Dublin was established in 2002. Its research – which has its roots in the university's Mechanical Engineering department - focuses on developments in orthopaedic and other medical devices; biological algorithms for simulations such as bone remodelling (the process by which bones are continually renewed); and tissue engineering – how to grow biological replacements for various parts of the body.

The Centre is known in particular for its strength in orthopaedics, and now employs more than a dozen principal investigators and 30 researchers - who, in addition to experimental projects, are focusing more and more on computational work.

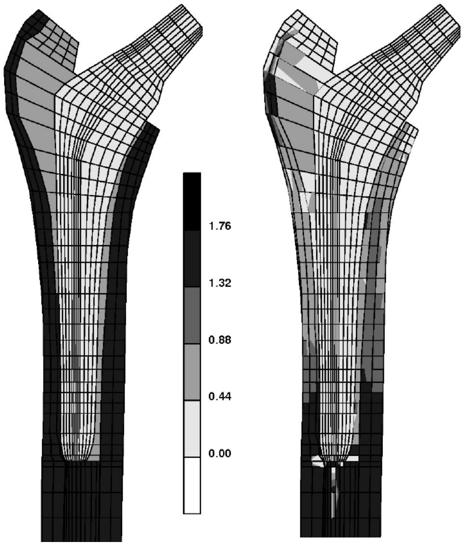
"Initially we used desktop PCs for this, but found we were constrained by the amount of computing power we could bring to bear on it. We therefore set up a small PC cluster, which although it was low cost, wasn't a particularly elegant solution," explains Dr. John Britton, Research Fellow from the Centre for Bioengineering. "We recently secured some significant funding and decided to use part of this to purchase a dedicated high performance computing (HPC) system. We wanted a single image solution for ease of use; evaluated a number of tenders; and SGI emerged as the preferred supplier."

"What swung the order SGI's way was their depth of support, and proven expertise in bioengineering and bio-mechanics – including the applications we use," says Dr. Alex Lennon, Research Fellow, also from the Centre. "As part of the tender process we provided a finite element analysis benchmark test for which SGI's result was by far the fastest of all the systems we evaluated."

The Centre subsequently purchased an SGI® Altix® 350 server with 32 processors, 128GB RAM and 2.4TB disk.

Before
Bone
Remodeling

After
Bone
Remodeling



Both images show the cross-section of an uncemented femoral component implanted in a femur. The "Before Bone Remodelling" image shows dense cortical bone (dark gray) for the entire outer layer of the femur. The "After Bone Remodelling" image shows bone resorption (lighter grays) and bone deposition (darker grays) after an extended period of implantation. (The grayscale represents bone density).

"The Altix will enable us to jump an order of magnitude in the complexity of our computational work," continues John Britton. "One example is in Patient Specific Prosthesis Analysis, an advanced computational project for which we've spent over a decade developing core bio-mechanical algorithms that can simulate how a medical implant performs inside the body. We're looking in particular at hip replacement, and have managed to combine our algorithms to run simulations based on an individual patient's unique pathology and anatomy, simulate several years of use of the implant, and predict whether or not it will perform satisfactorily, given the patient's lifestyle.

"Comparing the Altix with the PC cluster, the cluster's limited memory meant the mesh density was much lower, and we had an upper limit of around 10,000 elements in a finite element model. Some of our advanced algorithms, such as those simulating bone remodelling and damage accumulation, have very non-linear behaviour, and it was taking a couple of days to run each simulation. But with the Altix we can run these in a couple of hours, entirely in memory, and run several simulations concurrently across multiple CPUs. We've also increased some of our model sizes by a factor of five, and see these growing even larger to give a more realistic geometry which is much closer to the patient's actual anatomy.

"We're working with several orthopaedic surgeons in Ireland to get the technique adopted as part of their standard pre-operative planning procedure. They'll be able to take the patient's medical image, send it to us so we can convert it into a finite element model, simulate the implant the surgeon wishes to use, and estimate its probability of survival – optimising the outcome, and benefiting patients, surgeons and healthcare organisations by lowering the total cost of each procedure.

"Another area we're looking at is bone remodelling. We've developed algorithms to model this, both at the level of an entire

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Research Fellow,
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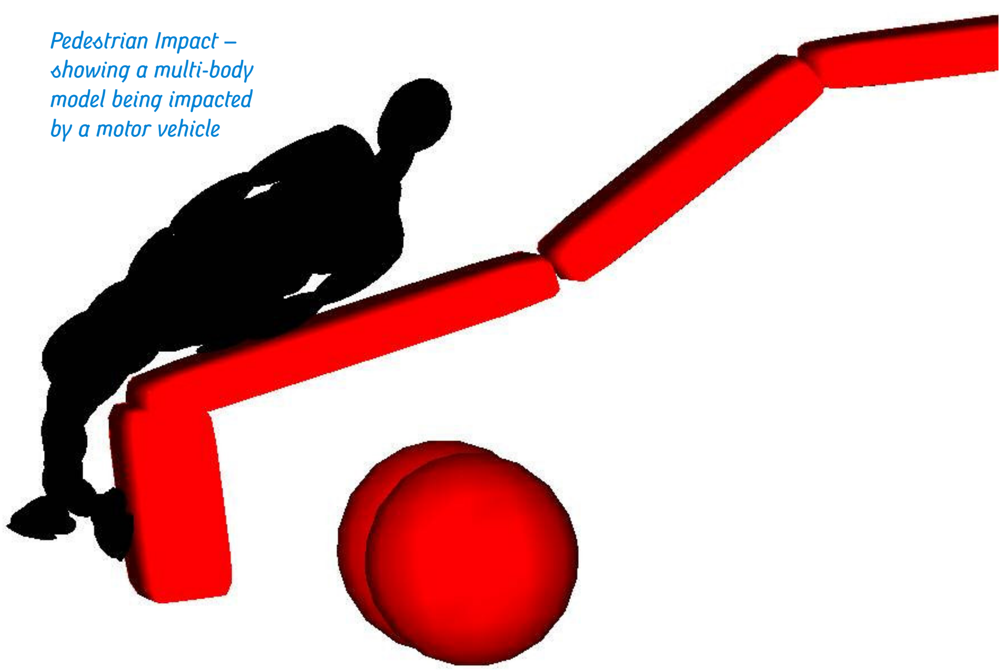
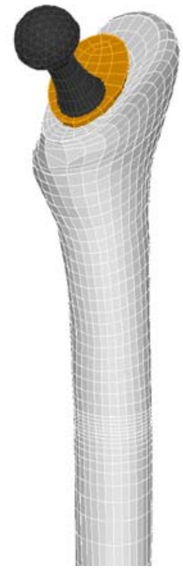
Pedestrian Impact – showing a multi-body model being impacted by a motor vehicle



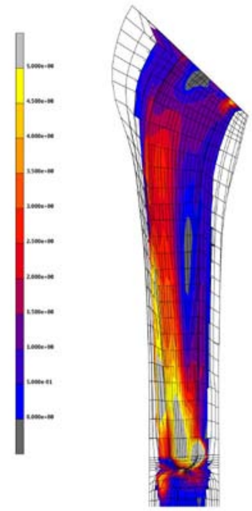
Patient Specific Images:

Patient Specific x-ray – medical image of immediate post-operative implanted hip

Patient Specific Positioning – replicating the placement of the hip implant in a 3D solid model representing the patient's anatomy (dark gray = implant, gold/brown = cement mantle, light gray = femur)



Patient Specific Mesh – showing the completed finite element mesh



Patient Specific Cement Stress – maximum prinicpal stress levels in MPa in the cement mantle after a single loading cycle

bone profile, such as how a femur is renewing itself in response to altered loading; and at micro level, with the behaviour of the individual struts that make up spongy bone. A finite element model of a 1cm3 volume of spongy bone at high resolution requires several million elements, hence the requirement for HPC to model it.

"This is part of an EU-funded project looking at treatments for osteoporosis. The Centre have has several experiments investigating how bone changes in response to osteoporosis, and we're simulating the results of these to produce a model of its effects on humans. We're also looking at the effects of different drug treatments on bone properties to see if they make the bones stronger, and their level of effect on the bone."

One of the Centre's ongoing projects is modelling pedestrian impact by motor vehicles. The researchers have used multi-body computer models of bones impacted by cars to investigate the inuries caused. The Euro NCAP safety tests now include a measure of pedestrian safety but this needs substantially more research, especially into risk posed by the increasing proportion of high-fronted vehicles, such as SUV's. The Centre's team are therefore using their new computational power to develop tests that accurately model the impact of the vehicle on a human being - to assist with the design of more pedestrian-friendly cars and other motor vehicles.

"We're also one of the few teams looking at cardiovascular stents - the devices used to treat arterial blockages, and

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reopen an artery that has been closed off by plaque formation," concludes Alex Lennon. "We have people working on modelling arterial tissue, which often has an adverse reaction whereby the plaque will reform due to damage induced by the stent; and a project to optimise the stent design in relation to shape, plastic deformation etc. This involves a lot of mechanical simulation in terms of contact and non-linear material behaviours, and the sorts of 50-100,000 element models which, although they can be run on a PC, really need HPC if you're going to do a parametric study of any kind.

"Stent procedures are one of the fastest growing invasive procedures in the world, so this is obviously a big area for people doing simulations as well. With our existing models we've been limited to looking at the mechanical effects of opening a stent within an artery, but one of the big growth areas is the use of drugs to reduce the effects of stents – which adds a whole new order of magnitude of complexity to the simulation. We believe though that with our new HPC resource we could start modelling these effects as well."

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