
Prof Karol Miller

Projects suggested by students in mathematical modelling and computer simulation of mechanical, biomechanical and electromechanical systems (especially in biomechanics and robotics) are welcome.

Projects in collaboration with Harvard Medical School

1. Automated generation of patient-specific computational models from radiological images
2. NEW: “Medical Image Analysis – comparative analysis of neuroimage registration methods”.

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3. NEW: Modelling fracture of materials using cellular automata.

Some very complex phenomena, that at the first sight look random, such as turbulent fluid flow or crack propagation in breaking materials, are very difficult to model using a traditional approach based on mathematical equations. This project will investigate the applicability of the alternative to mathematical equations: direct observation of the evolution of cellular automata. Mathematica software package will be used. Strong mathematical and programming skills are essential to be successful in this project.

4. NEW: Mechanical properties of brain-skull interface

These properties are unknown, and at the same time critically important for modelling head injury and neurosurgery. Smart experiment is needed.

Biomechanics (see also [www.mech.uwa.edu.au/ISML](http://www.mech.uwa.edu.au/ISML)):

5. Biomechanics: modelling and computer simulation of brain tumour growth

Modelling the growth of brain tumours is a very challenging problem of continuum mechanics. It requires knowledge of patophysiology as well as solid mechanics. This is a perfect project for a student with strong mathematical background and willingness to learn about cancers.

6. Biomechanics: Surgical simulation

The goal of this research is to model and simulate deformable objects for applications requiring real-time interaction. We are particularly interested in medical applications including simulation-based training, skills assessment and planning, as well as other non-medical domains where real-time interactivity is needed.

7. Biomechanics: Computer simulation of brain extension and torsion in vitro

Recent developments in robotics technology, in particular the emergence of automatic surgical tools and robots as well as advances in virtual reality techniques, call for closer examination of the
mechanical properties of brain tissue. To improve the capabilities of surgical operation planning and surgeon training systems based on the virtual reality techniques, the prediction of the brain deformation based on the model is needed. The project will involve building Finite Element Model (using ANSYS and ABAQUS) of cylindrical brain samples and simulating the loads applied during in vitro experiments conducted in 1999 in Japan, see [http://www.mech.uwa.edu.au/~kmiller/Biomechanics.html](http://www.mech.uwa.edu.au/~kmiller/Biomechanics.html)

The model will be geometrically simple but will incorporate non-linear mechanical properties of brain tissue.

8. **Biomechanics: computer simulation of hydrocephalus – comparison of single-phase and bi-phasic models**

Hydrocephalus has been modeled using two very different mathematical frameworks. In this project these frameworks will be quantitatively compared and conclusions drawn as to which method is preferable.

9. **Biomechanics: Computer simulation of contact mechanisms in synovial joints**

It is known that contact processes occurring in synovial joints are associated with arthritic conditions. The understanding of these processes occurring in synovial joints appears to be a vital link in understanding and controlling osteoarthritis. In this project a computer model of contact between articulating surfaces of synovial joint in sliding motion will be developed. Comprehensive, fully non-linear, mathematical model of the contact mechanism will provide new insights into operation of asymptomatic as well as pathological joints.

10. **Biomechanics: Robotic total knee replacement - the investigation into the optimal contact surface between a bone and an implant**

Presently surgeons prepare a flat surface between a tibia and the implant in the total knee replacement procedure. However, the introduction of robots to operating rooms allows preparation (cutting) quickly and precisely fairly complicated contact surfaces. The objective of this project is to find an optimal shape from the point of view of the stress distribution in the bone. Creating simple, linear finite element models will be required.

11. **Biomechanics: Modelling of intervertebral disc pathologies by Finite Element Method**

A lot of people suffer from back pain. One of the causes of the low back pain are pathological processes occurring in the intervertebral discs, generally called discopathy. The objective of this project is to construct a finite element model of the disc and its endplates so that the possible mechanical reasons for the disc failure can be investigated.

12. **Biomechanics (numerical methods):** Investigation of stepping algorithms for large systems of ordinary differential equations.

This is a numerical methods project. Love of mathematics is required.
13. Biomechanics: Investigation of influence of material properties on computations in displacement-zero traction problems

This is a finite element simulation project using ANSYS.

Robotics:

14. Singularity analysis of parallel robots

15. Robotics for construction, in collaboration with W/Prof. Arcady Dyskin

16. Dynamic control of parallel manipulators

17. Recalibration of parallel manipulators