MASTER THESIS PROJECT:
MATHEMATICAL FOLDING OF AIRBAGS

Within Autoliv, crash safety systems such as safety belts and airbags are developed for the car industry. In the development of new airbags, both mechanical testing and mathematical modelling are carried out, where the last alternative is used to an increasing extent as a quick and effective tool to evaluate new concepts. Mathematical modelling of an airbag inflation is a complex problem. The airbag is folded and compressed into a housing. The folding process itself is complicated, especially regarding passenger side airbags, which initially have a 3-dimensional shape. These types of airbags are first folded to a flat shape containing several creases. A subsequent folding according to a certain scheme makes it possible to finally compress the folded airbag into its housing. The folded airbag is thereafter inflated using a gas generator, where the airbag unfolds to a position where it can protect the occupant. Today, complete tools to fold 3-dimensional mathematical models of airbags are not available.

In a licentiate work (Cromvik, 2007), a mathematical formulation of an old japanese paper folding technique (origami folding) has been used to predict the crease pattern which is needed to create a 2-dimensional (flat) state from a 3-dimensional geometry (airbag). For the flattening process itself, mathematical optimization has been used. In the continuing work, the folding routines are to be developed to handle more general geometries (tasks 1 and 2 below) and also to be implemented in a graphical user interface (task 3):

1. Approximation of the airbag geometry
To create the crease pattern using the existing origami method, it is necessary to approximate the airbag by a polyhedron (picture below). The polyhedron approximation can be based either on the individual 2-dimensional parts of the airbag or directly on the 3-dimensional airbag. An optimization routine is to be developed which approximates a given 2- or 3-dimensional geometrical object by a piecewise linear shape (polyhedron), considering various quality measures (edge length, area, volume, shape etc.).

2. Alternative folding algorithm
An alternative algorithm for the actual folding phase (flattening phase) from a 3-dimensional to a 2-dimensional shape of an airbag is to be developed. In this alternative algorithm, the airbag is first cut along every crease which has been generated by the existing origami method. Every part is then folded individually and finally, when all surfaces are parallel in the plane state, the parts are sewed together again. This method is to be developed to a user-friendly tool and adopted to the existing folding modules.

3. Graphical user interface (GUI)
A graphical user interface is to be developed to work as a framework for the various folding modules. The program shall be able to import various CAD formats (for example IGES) and visualize the results of different parts of the folding process. The results shall be possible export to various formats, for example the LS-Dyna format.

The work is suitable for 20 points master thesis work projects with 2-3 students specializing in applied mathematics, numerical optimization and C++ programming. The tasks can also be carried out individually.

Contact persons:
Krystoffer Mroz, Autoliv Research , Phone: +46 322 62 63 46, krystoffer.mroz@autoliv.com
Bengt Pipkorn, Autoliv Research, Phone.: +46 322 62 63 41, bengt.pipkorn@autoliv.com
Prof Stig Larsson, Mathematical Sciences, Chalmers, 031-7723543, stig@chalmers.se
Prof Kenneth Eriksson, University West, Trollhättan, 0520 - 22 34 64, kenneth.eriksson@hv.se
Christoffer Cromvik, Mathematical Sciences, Chalmers, 031-7723515, christoffer.cromvik@chalmers.se