1. **Title**: Improvement of a biomechanical human body model, for impact applications: derivation of numerical injury criteria and tolerance limit.

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4. **Description of the subject**:

   Numerical simulations are interesting ways to investigate physical phenomenon and also to avoid costly experimental devices. In a mechanical framework, it allows predicting the behaviour of a mechanical structure under severe loadings, and access to data which can be difficult to observe during experiments. As an example, numerical simulations like finite element methods are widely used for the understanding of high speed dynamics phenomenon such as impact mechanics. More precisely, in the framework of biomechanics, this numerical method has allowed developing powerful models, able to predict the occurrence of a trauma when the human body is subjected to severe loadings, and also to develop and design protection devices. An example of this concept is illustrated in figure 1 showing a finite element model of the thorax in interaction with a seat belt.
The development of such biomechanical models is not an easy task, and the PhD student will have to investigate and achieve several topics linked to mechanical engineering, injury biomechanics, and also numerical theories:

- Mechanical parameters of the involved materials (such as biological tissues) to derive constitutive laws has to be conducted in a biofidelic manner to obtain significant and realistic results with the biomechanical model. Visco-elastic, hyperelastic, hydrodynamic laws, or combinations of all, have to be implemented correctly in the model, and validation have to be conducted against experimental data of the literature.

- The highly non-linear phenomenon involved in these cases are also generated by interfaces and contacts between an object and the human body, or organs of the human body against another. The choice of the contact interface and the way to model these contacts is also a challenge to simulate correctly the human body in a context of dynamic loading and a use of explicit code.

- Penetrating impact in the human body often generate important damage of the organs. At a mechanical level, it will be of interest to model correctly the “plasticity”, as well as the “rupture” of these specific materials. In that context, limitations of classical finite element analysis can occur, leading to a choice of alternative methods to simulate correctly perforation of a structure in the body (meshless method or transformation of solid element to particules during the calculation, for example).

- The laboratory has an accident database provided by an hospital concerning free falls. All these accidents, are well documented, and clinical aspects of injuries are available. A correlation between the injuries and mechanical parameters in the biomechanical model has to be found, by replicating these accidents with the biofidelic model, with an aim of developing statistically-based injury criteria and tolerance limit, at a numerical level.

- Finally, once injury criteria and tolerance limit have been found, protecting device will be developed and design (such as seat-belts, air-bags) and will be numerically tested, in order to assess their protection ability.
Finally, this PhD thesis is defined by the development of a model representative of the human body and simulations of various material (biological tissues, mechanical structures in interaction with the human body, protecting devices) will have to be conducted in a specific framework of impact biomechanics, with a final objective of improvement of this human body injury predicting numerical tool.

5. **references**:


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