Self-organization of entangled curly hair: numerical and experimental approach

Internships with Chile 2024

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Practical details: Internship proposal with Chile, starting on January 2024

Context Over the last 30 years the graphics community has actively worked on the simulation of dense fibrous assemblies such as human hair or animal fur. Whether it is for the realistic animation of characters by the entertainment industry, for its applications in cosmetology, or for the design of mechanical structures, simulating accurately such kinds of systems remains challenging and computationally costly. Furthermore, a rich underlying phenomenology arises from the interaction between fibers, driven by the interplay between geometry, frictional contact, and elasticity. Due to the large number of degrees of freedom and the strong coupling between the length-scales at which fibers interact, innovative approaches are crucial.

Recent developments for the simulation of frictional fibers [2, 4, 5, 3] have made possible the efficient simulation of tens of thousands interacting fibers producing visually appealing images. However, these simulators remain limited to fibers with small natural curvature, making them unable to retrieve the rich phenomenology observed for highly curly fibers. Additionally, in many cases, the underlying model for the simulation is not systematically tested for its validity.

To bring a breakthrough on the realistic simulation of frictional fibers, we believe that a combined effort between numerics, physics and mechanics is required. On one side numerics has developed a large amount of knowledge to efficiently solve burdensome problems, while physics and mechanics have a long-standing culture to model and study complex systems. Progressively, these communities are joining their work to, on one side produce more capable physics-based simulators [2, 1], and in the other find model configurations to study the physical validity of simulations [6].

Figure 1: Spontaneous self-organization of entangled curly hair.

Objective The objective of this internship is to join our current numerical and experimental work whose goal is to develop an efficient numerical model capable of deal with highly curly interacting fibers. Two main challenges are noticeable: the high computational cost of solving elastic equations coupled with non-smooth phenomena, as is frictional contact; and finding reliable model scenarios and metrics to which one can contrast numerical solutions and experimental measurements. In these sense, we believe that the self-organization and clustering, observed in long highly curly human hair, presents a rich scenario that combines elasticity/geometry with frictional contact, where one can make experimental estimations at different scales. This work will take advantage of numerical Kirchhoff models for rods, contact detection, and frictional contact solvers developed by the ELAN team, and additionally, we expect for this study to have an important experimental component to conceive novel setups and collect data to compare with simulations.

Skills required Candidates should have a good understanding in numeric analysis (modeling, discretization of ODEs and PDES for mechanical systems, finite elements, optimization) and algorithms. We expect for the candidate to have a minimum of understanding in C/C++ and Python/Matlab. In addition, we are looking for candidates interested in application of numerics for physics and mechanics, capable to work alongside in real physical experiments.

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