How can nature help us find mechanical solutions ?

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This keynote aims to summarize our research work done in bioinspired design in the last years. The subject about material structure, mechanical joints and actuators design will be detailed during this talk.

Based on Nature knowledge, a bio-inspired workpiece structural optimization approach will be presented in this talk. This approach is derived from bones structure. The aim of this method is to reduce workpieces weight maintaining for a given mechanical resistance. Like in bones, the porosity of the workpiece to optimize is controlled by a bio-inspired method which is function of the local stress field. Shape, size, and orientation of the porosities are derived from bone structure; two main strategies are used: one inspired of avian species and other inspired of terrestrial mammals. Subsequently, to validate this method, an experimental test was carried out for comparing a topological optimization and the proposed bio-inspired designs. Experimental test results demonstrated the usefulness of the proposed method. This bio-inspired structural optimization approach opens new prospects in design of openwork workpiece.

Recent knowledge about biological joint morphogenesis opens new perspectives in mechanics to automate joint contact surface design. The work evaluates the feasibility of a generative design method inspired by the joint morphogenesis process to develop contact surfaces. A finite element model of joint morphogenesis reported in literature was implemented. This morphogenesis process was adapted and implemented for mechanical applications. The results show that the bioinspired joint shaping process adds matter in the zones next to the contact zone decreasing the contact pressure (up to 57%). The results demonstrate the feasibility of implementing biological growing rules in generative design.

Designing resilient actuators is an industrial challenge partly because an index of resilience does not exist yet. In this work, several definitions of resilience are analyzed based on which an index quantifying resilience for actuators is proposed. This index allows comparing resilience of a wide range of manufactured and biological actuators. The two manufactured actuators chosen as iconic models, a hydraulic cylinder, and a bio-inspired McKibben muscle, are shown not to be resilient by design. Differently, two biological actuators likely to be resilient were analyzed. The pulvinus resilience index shows that it is partly resilient depending on damage location. The most promising is the skeletal muscle which has been shown to be highly resilient. Finally, the bio-inspired roots of resilience are discussed: resilience may originate from multi-scale structural design.