Determining the motion in a skeletal join from the articular surface geometry

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Bones in the skeletons of vertebrate animals meet at a joint. Relative motion between bones in a joint is dictated by the geometry of the contact between bones on the articular surface. The aim of this project is to determine the relation between the two.

The project builds upon a recent paper on the mechanics and evolution of the human foot. The central physical quantity in the paper is the stiffness of the human foot, especially at the instance of push-off with the ball of the foot, when the heel is lifted off the ground. We present evidence that just a drooping currency note is stiffened by giving it a little curvature across the width, it is the arch across the width of the foot that also stiffens it. While this simple picture is useful, it leaves many questions unanswered. For example, how should one define the curvature of the arches in the feet from skeletal geometry that directly influences the mechanics? Understanding the relation between the geometry of the articular surfaces in joints and the resulting motion is a crucial step needed to answer such questions.

The project will involve continuing the development of a computer program for digitally reconstructing skeletons from constituent bones. Three-dimensional models for individual bones in the foot are available from CT scans of the foot, courtesy of the Yale Biomechanics and Controls Laboratory directed by Prof. Madhusudhan Venkadesan. The computer program will systematically determine how they pack together in the foot and how the packing deforms under load. A preliminary version of the program is available.

The project will also branch out to other joints, such as the knee joint, not only because of its practical significance, but also because of the simplicity of such joints, and for which high-resolution imaging data and mechanical load-versus-displacement data are also available from the Yale Biomechanics and Controls Laboratory directed by Prof. Madhusudhan Venkadesan.

The work is of interest to surgeons in designing foot re-construction surgery.