AN ORIGINAL INVERSE KINEMATICS ALGORITHM FOR KAYAKING

Vincent Fohanno[1], Mickaël Begon[2], Floren Colloud[1] and Patrick Lacouture[1]

Laboratoire de Mécanique des Solides, Université de Poitiers, Poitiers, France[1]
Département de Kinésiologie, Université de Montréal, Montréal, Canada[2]

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INTRODUCTION: For some sports, *e.g.* kayaking and rowing, ecological conditions represent a challenge for collecting three-dimensional kinematics. The lower-limbs are partially hidden by the boat and motion analysis systems used in laboratory are not suitable for outdoor and on-water measurements. An inverse kinematics (IK) approach has been proposed where a few tasks would be measured by inertial sensors or inclinometers (Begon & Sardain, 2007). However, due to the lack of actual kinematics, the authors could not assess its reliability. The purpose of this study is to assess the accuracy of this IK algorithm by comparison with a standard algorithm of global optimization.

METHODS: A kayaker equipped with 88 markers performed six trials of paddling on an ergometer. The kinematics were collected with a 10-cameras motion analysis system at 300 Hz (T40, Vicon, Oxford, UK). A 17-segment 42-degree of freedom (*dof*) chain model was defined and personalized for the kayaker. The IK algorithm was composed of two parts to determine the joint kinematics based on both upper-limb with paddle and lower-limb closed loop constraints. The lower-limbs had as much *dof* as tasks (n=7). The tasks were the ankles positions and the pelvis rotation in the horizontal plane. Using an iterative procedure, the inversion of the Jacobian matrix (**J**) gave the configuration which satisfied the task equation. For the upper-limbs, the control space was larger than the task space (22 *dof versus* 7 tasks). The tasks were the rotation of the scapular girdle in the horizontal plane, the paddle position and orientation. The algorithm involved a damped pseudo-inverse of **J** and an optimization term to keep the joint angles as far as possible of the joint limits by projecting its gradient into the null space of **J**. The Root mean square differences (*RMSd*) for each joint angle time history between the IK algorithm and a standard algorithm of global optimization were calculated and expressed in degrees.

RESULTS and DISCUSSION: The average *RMSd* were 6°, 10° and 8° for the trunk, upper-limb and lower-limb *dof* respectively. These results correspond to errors reported in locomotion (Reinschmidt *et al*, 1997). In paddling, kayakers fully extend elbows and knees. These configurations close to singularities were handled by a pseudo-inverse of **J** and the optimization term. Due to the large control space, a lexicographic method should improve the kinematic agreement (Marler, 2005). The next step will be to collect the tasks using inertial and position wireless sensors for a population of elite kayakers.

CONCLUSION: This IK method can be applied to many sports in order to estimate the athlete's kinematics using a few tasks measured by wireless sensors.

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