Collision Analysis and Safety Evaluation using a Collision Model for Blunt Robot-Human Impacts

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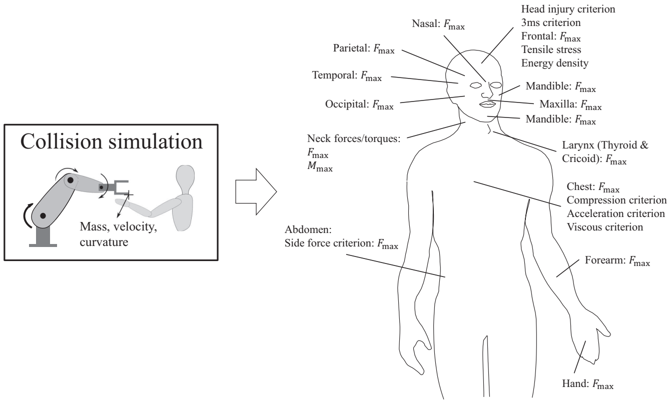

Fig. 1. Mapping robot parameters to human injury severity for blunt impacts using a collision simulation.

I. Introduction

It is primary to ensure human safety during applications of physical human-robot interaction in either industrial or domestic environments. To gain insight into injury mechanisms during robot-human collisions, blunt impact experiments with automobile crash-test dummies were conducted for various contact scenarios [1], [2]. Well established biomechanical severity indices were experimentally evaluated for several human body parts in order to quantify the influence of robot parameters on human injury probability. In addition to blunt impacts, drop test experiments were carried out in [3], using pig abdominal tissue, which has similar properties to human tissue. The specimen were impacted with different contact primitives (e.g. spheres or wedges) at varying impact velocities and masses. The general outcome of the experiments was the mapping from robot mass, velocity, and curvature to human injury of a specific body part.

II. Approach

In this work, we complement the injury database developed in [3] with collision data of blunt robot-human impacts. As real impact experiments require large efforts and it is not possible to modify robot parameters or contact scenarios arbitrarily, we developed a collision simulation consisting of a multibody human model and a simplified robot model. Virtual collisions against certain human body parts provide physical quantities such as forces, torques, and deflections that can then be used to evaluate injury severity indices, see Fig. 1. For verification, the simulation results are compared to experimental data obtained from biomechanical literature and the previsouly mentioned robotic impact experiments [4], [1], [2]. By simulating a wide range of robot impact masses and velocities, any robot, ranging from lightweight designs to heavy duty indutrial robots can be evaluated.

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III. Results

As illustrated in Fig. 1, several severity indices were evaluated for each body part. In Fig. 2 the maximum contact force for collisions against the frontal bone, depending on the impacting robot mass and velocity, is depicted. In addition to

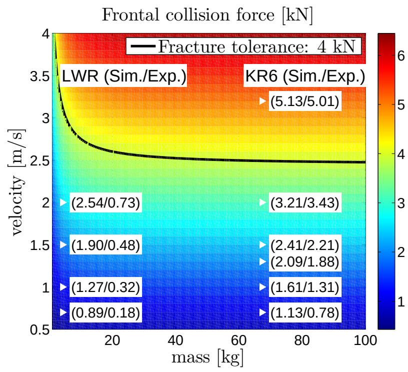

Fig. 2. Mass-velocity dependency of frontal bone contact force. The human fracture tolerance is indicated, experimental data is compared to simulation results.

simulation and experimental results (e.g. collisions of DLR LWR-III and KUKA KR6 against a Hybrid III dummy), the average fracture tolerance found in literature is depicted. This dynamic threshold subdivides the figure into a critical and subcritical region by means of critical contact force. Overall, the simulation provides a feasibile, mostly conservative, estimation of human collision behavior.

References

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