Several interaction control algorithms have been proposed for physical human-robot interaction (pHRI) with the aim of assisting human movements. Some example are “path control” [4], “virtual model control” [7], “clime” [9] or gravity compensation [5], [3]. This class of algorithms is often built upon a force/torque controller that is supposed to be ideally fast. However when the algorithm is implemented the force variable cannot be commanded instantaneously and its transients depend both on robot and human dynamics. In particular, using a traditional controller we can have slow force/torque responses when the human displays a low mechanical impedance and force/torque overshoots when the human has a high impedance configuration. These effects are undesirable because they can generate disturbances that interfere with the rehabilitation strategy and even potentially lead to instability and injuries.

Currently a wide used method to guarantee stable human robot interaction is based on PB control. Despite complexity of passivity formalism, passivity-based (PB) control is quite straightforward to implement [8], [6] and the whole stability can be guaranteed by assuming that humans behave in a passive way. Unfortunately in PB control it is not possible to give any servo specification, because the controller needs to be stable against any kind of external passive environment. No matter what kind of environment and no matter its scale, i.e. its level of inertia, stiffness or damping. It follows that this approach is very conservative and by completely neglect environmental dynamics it is not possible to speculate on control performance. It must be said that this limit is not due to passivity itself but to the absence of a human model. As a matter of fact authors proposing passive controllers for rehabilitation or pHRI usually do not comment about control tuning (that involves specifications). The implicit idea is of tuning the system by trial and error, considering an average human joint. It follows that an automatic tuning process with the human in the loop, both from the point of view of safety and of practical feasibility.

1) In our experience [2] it is quite difficult to carry out a tuning process with the human in the loop, both from the point of view of safety and of practical feasibility.

2) The tuning session can be time consuming. In fact if the passivity conditions are not satisfied in the first trial, it is necessary to reiterate the tuning until passivity is finally archived.

3) Pathologies can specifically affect limbs. With currently available PB controllers the tuning procedure should be carried out separately for each human and for each human joint. It follows that an automatic tuning process can be of paramount importance.

4) Humans typically change their dynamics in response to the environment and depending on the specific tasks.

To solve these issues we propose a model-based controller that automatically varies force control gains in response to changing conditions, to match the desired force/torque transient [1]. Since the whole human modeling is too complex, it is reasonable to think that a simplified model can tell us at least something about the human. In particular we approximate human joints and endpoints with second order linear models. Combining such generic models with adaptivity we meet two objectives: first using a generic model we can account for a generic human joint, and second using adaptivity we can update model parameters as the situation changes, e.g. when a grasped mass is added or when co-contraction is modified. We propose an approach inspired by model reference adaptive control (MRAC) where control specifications can be determined by the reference model, letting the tuning process be automatic and online adapting to changing conditions.

REFERENCES


