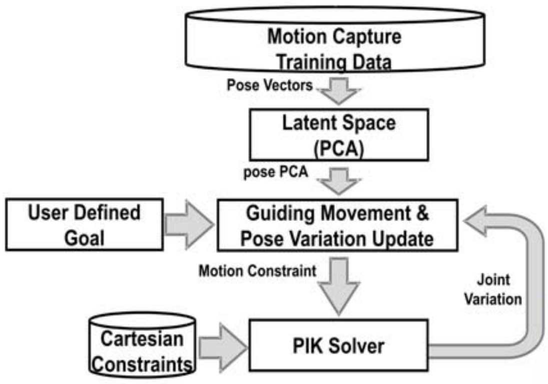
Controlling Gesture with Time Dependent Motion Synergy Constraints

Daniel Raunhardt[1], Ronan Boulic[1]

[1] Ecole Polytechnique Fédérale de Lausanne (EPFL), Virtual Reality Laboratory, {daniel.raunhardt, ronan.boulic}@epfl.ch

Human figures are difficult to animate such that they move in a coordinated and human-like fashion. Posture interpolation is easy for producing expressive gesture but it lacks guarantees when precise interactions with the environment is required. For this reason we explored the potential of Prioritized Inverse Kinematics (PIK) for gesture control when combined with a motion database. In this paper we introduce the concept of *motion primitive constraint* that takes advantage of the spatio-temporal coherence of captured motions to bias the PIK solution towards more natural looking pose variations. In summary our approach takes advantage of the expressiveness of original movements without sacrificing precise gesture control.



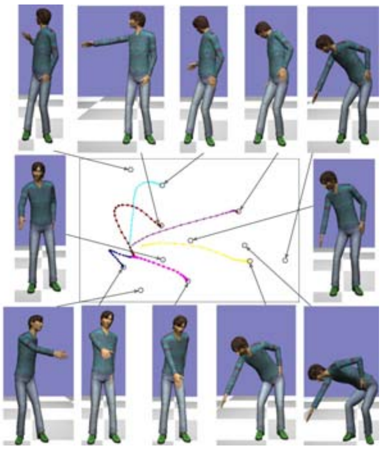


Fig. 1. *Left: System architecture: the captured motions are used to build a low-dimensional, latent space using Principal Component Analysis (PCA). This pose PCA space is used to guide the Prioritized IK convergence by predicting its immediate future at low cost. Right: pose PCA space learned from different motion capture reach sequences. Points indicate training poses included in the training set. Points that are connected belong to the same motion sequence. We present here only the first two Principal Coefficients.*

In our approach we represent each motion capture pose as a vector. We apply Principal Component Analysis (PCA) on all pose vectors to define a low dimensional representation of the original data called *pose PCA* (similar to [2]). The user specifies for which body parts (e.g. right hand) he wants to retain the spatio-temporal coherence of the captured movements. One key requirement is to be able to specify new goals that are far from the ones of the training set. Given a user-defined goal the first stage of our approach is to construct a *guiding movement* from the pose PCA space. The role of the motion primitive constraint is to encapsulate the instantaneous *coordinated pose variation* of such a guiding movement. The generic formulation of the motion primitive constraint allows us combine it with any other constraint (e.g. position, orientation, balance).

However there is no guarantee that the guiding movement we build achieves the user-defined goal as it may be outside the space of goals that can be produced with the pose PCA space (in the case of our example database the right hand goal could be outside the convex hull of the database goals). To overcome such a problem the motion primitive constraint is associated with a standard position constraint. As long as the right hand is far from the goal, we only use the motion primitive constraint. While approaching the goal, the influence of the position constraint is increased such that the right hand precisely reaches the goal while retaining as much as possible of the spatio-temporal coherence of the guiding movement.

We tested our approach on a sparse database with 400 captured poses from 16 reach gestures with the right hand (Fig 1 right). We use the six first principal components of our pose PCA space that represent 95% of the original data.

We tested three difficult reach goals for the right hand: once the goal is in the back, on the right side and on the left side. For every goal, there is no exact correspondence in the database (distance between desired goal and nearest goal in the database: 0.3-0.5m). We compared three approaches, PIK in the pose PCA, standard PIK [1] and PIK with our motion primitive constraint. In all cases, we had the fastest convergence to the stable final solution with the motion primitive constraint. Due to our sparse database, PIK in the latent space fails to find an exact solution while normal PIK requires many iterations compared to the motion primitive constraint. In addition the motion primitive constraint helps to avoid joints limits. This is a clear advantage as violated joint limits require a re-evaluation of the IK convergence loop [1]. We compute the pose PCA offline. The computation of the guiding movement in the pose PCA is between 7 ms and 11ms on a Pentium Dual Core 3.2Ghz with 2GB RAM. Given these performance measurements, it is possible to interactively change the goal of the right hand.

One limitation is the dependency to the motion database as only the style from the exploited database can be exploited. On the other hand one key advantage is that even a very sparse database is sufficient to generate a large space of derived - and precise - gestures. The precision is achieved by adding automatically an additional position constraint whenever necessary. We plan to extend our approach to higher dimensional motion synergies such as the generalized step (forward/backward, up/down, sideward, turn) and a generalized reach.

References

1 R. Boulic, M. Peinado, and B. Le Callennec. Challenges in exploiting prioritized inverse kinematics for motion capture and postural control. In 6th International Gesture Workshop, GW 2005, Lecture Notes in Artificial Intelligence Vol.3881, 2005

2 S. R. Carvalho., R. Boulic, D. Thalmann: Interactive low-dimensional human motion synthesis by combining motion models and pik. Comput. Animat. Virtual Worlds 18, 4-5 (2007), 493–503.