# Efficient Motion Retrieval in Large Motion Databases
# Supplementary Material – Queries and Additional Illustrations

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## Queries

This section details the queries we used to generate the results described in the paper, and shown in the accompanying video.

**Atomic queries for effort metrics.** We define a set of atomic queries for each of the 4 effort metrics which can be used in conjunction with other queries for motion retrieval. An atomic query, $\mathtt{q}_+(K_{\mathrm{s}}^{\text{time}}(u_{\mathrm{k}}))$ indicates that the returned motion should have positive time effort (sudden motion) for body segment $s$. Similarly, $\mathtt{q}_-(K_{\mathrm{s}}^{\text{time}}(u_{\mathrm{k}}))$ indicates that the returned motion should have negative time effort (sustained motion) for body segment $s$.

**Locomotion.** A walking motion of one or more cycles is defined as alternating single support phases.

$$\mathtt{q}_1(K^{\text{support}}(u)) \leftarrow ((\mathtt{LF}^+ \cdot \mathtt{RF}^+) \vee (\mathtt{RF}^+ \cdot \mathtt{LF}^+))^+$$

Running motions are queried by introducing a flight phase between alternating single support phases.

$$\begin{aligned}\mathtt{q}_2(K^{\text{support}}(u)) \quad \leftarrow \quad & ((\mathtt{LF}^+ \cdot \mathtt{NS}^+ \cdot \mathtt{RF}^+) \vee \\ & (\mathtt{RF}^+ \cdot \mathtt{NS}^+ \cdot \mathtt{LF}^+))^+\end{aligned}$$

Jumping motions are specified by introducing a flight phase between double support phases.

$$\mathtt{q}_3(K^{\text{support}}(u)) \leftarrow (\mathtt{BF}^+ \cdot \mathtt{NS}^+ \cdot \mathtt{BF}^+)$$

A hopping motion is specified by using the same single support before and after the flight phase.

$$\mathtt{q}_4(K^{\text{support}}(u)) \leftarrow (\mathtt{LF}^+ \cdot \mathtt{NS}^+ \cdot \mathtt{LF}^+)$$

Displacement of the center of mass during the flight phase can be used to query forward jumps. For example, the composite query $\mathtt{Q}_1 = \mathtt{q}_3 \wedge \mathtt{q}_5 \wedge \mathtt{q}_6$ retrieves high forward jumps.

$$\begin{aligned}\mathtt{q}_5(K^{\text{com-disp-x}}(u)) &\leftarrow (0 \cdot 5 \cdot 0) \\ \mathtt{q}_6(K^{\text{com-disp-y}}(u)) &\leftarrow (0 \cdot 3 \cdot 0)\end{aligned}$$

A straight line walking or running motion has direct space effort for the hips, as specified below. A roundabout motion can be similarly queried by specifying indirect space effort.

$$\mathtt{Q}_2 = (\mathtt{q}_1 \vee \mathtt{q}_2) \wedge \mathtt{q}_+(K_{\text{hip}}^{\text{space}}(u))$$

A stiff walking motion with repeated peaks in acceleration has sudden time effort.

$$\mathtt{Q}_3 = \mathtt{q}_1 \wedge \mathtt{q}_+(K_{\text{hip}}^{\text{time}}(u))$$

**Climbing Motions.** Climbing motions can be queried by specifying a monotonically increasing center of mass displacement along the Y axis. Introducing a displacement along the X axis produces motions such as climbing a flight of stairs.

$$\begin{aligned}\mathtt{q}_7(K^{\text{com-disp-x}}(u)) &\leftarrow (0 \cdot 2 \cdot 4) \\ \mathtt{q}_8(K^{\text{com-disp-y}}(u)) &\leftarrow (0 \cdot 1 \cdot 2)\end{aligned}$$

**Gestures.** Gestures in the left or right hand are queried by specifying a displacement in the hand over the duration of the motion.

$$\begin{aligned}\mathtt{q}_9(K_{\text{l-hand}}^{\text{disp}}(u)) &\leftarrow (0 \cdot 1) \\ \mathtt{q}_{10}(K_{\text{r-hand}}^{\text{disp}}(u)) &\leftarrow (0 \cdot 1) \\ \mathtt{q}_{11}(K_{\text{l-hand}}^{\text{orient-z}}(u)) &\leftarrow (- \cdot 0) \\ \mathtt{q}_{12}(K_{\text{r-hand}}^{\text{orient-z}}(u)) &\leftarrow (- \cdot 0)\end{aligned}$$

Gestures in both hands is specified using the composite query $\mathtt{Q}_4 = \mathtt{q}_9 \wedge \mathtt{q}_{10}$. Gestures in either hand are specified using the composite query $\mathtt{Q}_5 = \mathtt{q}_9 \vee \mathtt{q}_{10}$. Introducing a forward orientation constraint is achieved by indicating that the hand must be aligned with its shoulder along the forward vector at the end of the gesture: $\mathtt{Q}_6 = \mathtt{Q}_4 \wedge \mathtt{q}_{11} \wedge \mathtt{q}_{12}$. A strong forward punching motion in the right hand can be defined using the weight key:

$$\mathtt{Q}_7 = \mathtt{q}_{10} \wedge \mathtt{q}_{12} \wedge \mathtt{q}_+(K_{\text{r-hand}}^{\text{weight}}(u_{\mathrm{k}}))$$

A gesture in either arm that is direct in space effort, light in weight effort, and free in flow effort is queried as follows:

$$\begin{aligned}\mathtt{Q}_8 \quad \leftarrow \quad & (\mathtt{q}_9 \wedge \mathtt{q}_+(K_{\text{l-hand}}^{\text{space}}(u_{\mathrm{k}})) \wedge \\ & \mathtt{q}_-(K_{\text{l-hand}}^{\text{weight}}(u_{\mathrm{k}})) \wedge \mathtt{q}_-(K_{\text{l-hand}}^{\text{flow}}(u_{\mathrm{k}}))) \vee \\ & (\mathtt{q}_{10} \wedge \mathtt{q}_+(K_{\text{r-hand}}^{\text{space}}(u_{\mathrm{k}})) \wedge \\ & \mathtt{q}_-(K_{\text{r-hand}}^{\text{weight}}(u_{\mathrm{k}})) \wedge \mathtt{q}_-(K_{\text{r-hand}}^{\text{flow}}(u_{\mathrm{k}})))\end{aligned}$$

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**Jumping Jacks.** Jumping jack motions are queried using a composite query specified on the support key, arm and leg orientations, and bounding box of the entire body. We assume that the starting configuration of the character is with both feet on the ground and the arms distended over the head. The support key alternates between periods of double support and no support for 4 cycles during the completion of a jumping jack motion. During support, the arms are either pointing upwards or pointing downwards, perpendicular to the ground plane. When the hands are up in the air, the feet make an angle of approximately 30 degrees, and are in their neutral position when the arms are directed downwards. The extension and contraction of the bounding box of the body is also specified to query the jumping jack motion.

$$
\begin{aligned}
\mathrm{q}_{13}(K^{\text{support}}(u)) &\leftarrow (\mathtt{BF}^{+} \cdot \mathtt{NS}^{+} \cdot \mathtt{BF}^{+} \cdot \mathtt{NS}^{+} \cdot \mathtt{BF}^{+} \cdot \\
&\quad \mathtt{NS}^{+} \cdot \mathtt{BF}^{+} \cdot \mathtt{NS}^{+} \cdot \mathtt{BF}^{+}) \\
\mathrm{q}_{14}(K^{\text{orient-x}}_{\text{hand}}(u)) &\leftarrow (\mathtt{90}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{-90}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{90}^{+} \cdot \\
&\quad \mathtt{-}^{+} \cdot \mathtt{-90}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{90}^{+}) \\
\mathrm{q}_{15}(K^{\text{orient-x}}_{\text{feet}}(u)) &\leftarrow (\mathtt{30}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{0}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{30}^{+} \cdot \\
&\quad \mathtt{-}^{+} \cdot \mathtt{0}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{30}^{+}) \\
\mathrm{q}_{16}(K^{\text{shape-y}}(u)) &\leftarrow (\mathtt{2}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{1}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{2}^{+} \cdot \\
&\quad \mathtt{-}^{+} \cdot \mathtt{1}^{+} \cdot \mathtt{-}^{+} \cdot \mathtt{2}^{+}) \\
\mathrm{q}_{17}(K^{\text{shape-x}}(u)) &\leftarrow (\mathtt{1}^{+} \cdot \mathtt{2}^{+} \cdot \mathtt{1}^{+} \cdot \mathtt{2}^{+} \cdot \mathtt{1}^{+} \cdot \\
&\quad \mathtt{2}^{+} \cdot \mathtt{1}^{+} \cdot \mathtt{2}^{+} \cdot \mathtt{1}^{+})
\end{aligned}
$$

The composite query used to query the jumping jack motion is the AND combination of the above atomic queries. Note that atomic queries for both hands and both legs are specified.