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Introduction

The dynDGP

2D Motion adaptation

3D human motions

Retargeting

Motion adaptation by dynamical Distance Geometry

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[1] Antonio Mucherino and Douglas S. Gonçalves. "An Approach to Dynamical Distance Geometry". In: *Geometric Science of Information*. 2017.

The dynamical Distance Geometry Problem

Let $G = (V \times T, E, d)$ be a simple weighted undirected graph:

V	represents a set of objects
T	represents a (discrete) set of temporal instants
E	indicates whether distances between u_q and v_t are known
d	mapping $d : \{u_q, v_t\} \in E \longrightarrow (\delta(u_q, v_t), \pi(u_q, v_t)) \in \mathbb{R}_+ \times \mathbb{R}_+$

where

- δ is the distance value
- π is the priority

Definition

The dynamical **DGP** in dimension K.
Determine the realization

$$x : V \times T \longrightarrow \mathbb{R}^K$$

of G in $\mathbb{R}^K$ such that a penalty function σ is minimized.

A penalty function with priorities

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$$\sigma(x) = \frac{1}{2} \sum_{\{u,v\} \in E} \left(\pi(u,v) \cdot (\|x_u - x_v\| - \delta(u,v))^2 \right)$$

- $\pi(u,v) > 0$ is the priority level of the distance $\delta(u,v)$
- σ is differentiable when $\|x_u - x_v\| > 0$ if $\pi(u,v)\delta(u,v) > 0$

Motions: 2D

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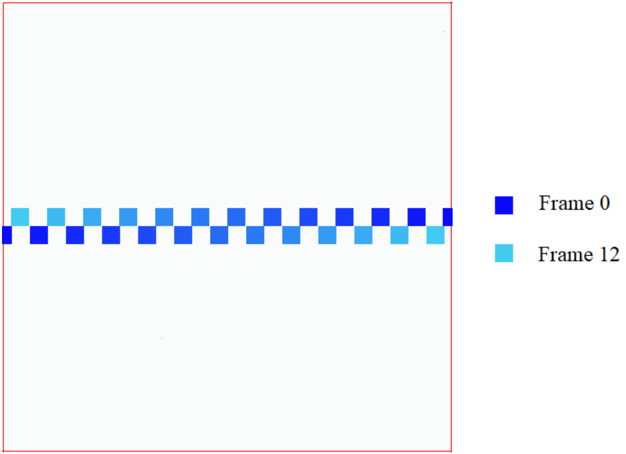
Simple shapes, moving frame by frame



Two squares crossing from opposite directions in a box.

2D Motions and the dynDGP

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We can create a dynDGP instance using such a 2D animation:

- the motion of every v is preserved by using the original distances
$$\delta(v_q, v_t) \quad \forall q \,:\, t-3 \leq q < t,$$
- collisions are avoided by including the constraint:
$$\delta(u_t, v_t) > \Delta \quad \forall t \in T, \forall u, v \in V \,:\, u \neq v,$$
where Δ is strictly positive.

The priority to the distances is assigned so that all newly introduced distances have maximal priority, and the distances between closer frames are more important.

Two crossing people avoiding collisions

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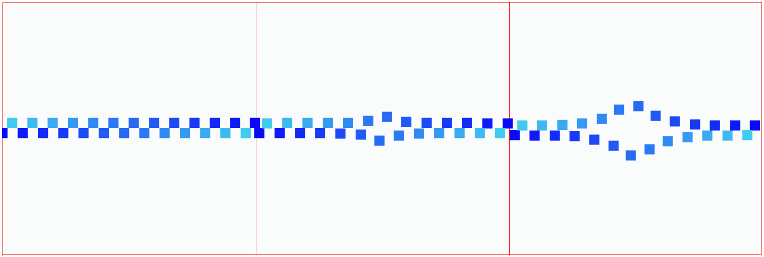
The dynDGP instance is solved using a non-monotone gradient descent method, which works well for finding local optima for non-convex methods[2]

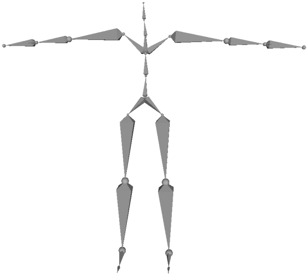


original $\Delta = 0.1$ $\Delta = 0.2$

[2] Antonio Mucherino. “Manipulating Two-Dimensional Animations by Dynamical Distance Geometry”. In: *Recent Advances in Computational Optimization*. 2020.

Human motions: skeletal structures

- We will focus on human motions
- The skeletal anatomy of the character is represented by a graph $G = (V, E)$, where V are the *joints* of the skeleton, and E are the *bones* connecting these joints



- These graphs G are trees
- The function below, combined with the graph G provides the posture 0 of the human motion

$$\chi : v \in V \longrightarrow \chi(v) \in \mathbb{R}^3$$

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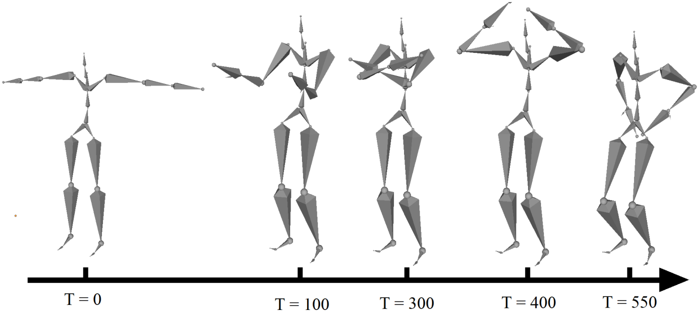
- Assign 3 Euler angles θ (pitch), ϕ (roll) and η (yaw) to each bone
- Posture 0: all these angles are equal to 0
- This triplet of angles combined with the length of the bone (v, p) describes the orientation and the displacement of v w.r.t to p.
- This way, we can describe a human motion as follows:
  $\rho : (v, t) \in V \times T \longrightarrow (\theta_v^t, \phi_v^t, \eta_v^t) \in \mathbb{R}^3$



Retargeting

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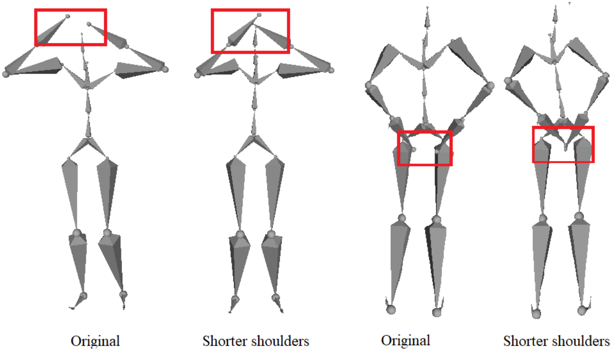
- Can we impose the same movement to a different skeleton?
- Classical approaches are based on bone angle transfer



They cannot avoid undesired collisions and sometimes fail to retain desired contacts.

Retargeting: a new approach (1)

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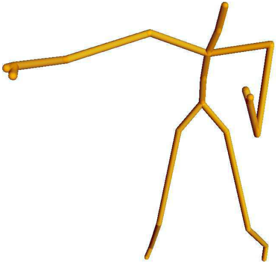
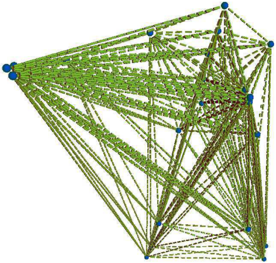
We can represent human motions by distances[3]





They can represent either *bones*, or rather *relative movements*.

[3] Antonio Mucherino et al. "A Distance-Based Approach for Human Posture Simulations". In: *FedCSIS 2017*. IEEE, Sept. 2017.

Retargeting: a new approach (2)

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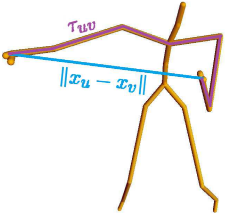
Idea: once the bone lengths are modified, distances representing movements need to be adapted to the new morphology.



- distances can be *normalized/denormalized* by using shortest-paths over the involved kinetic chains[4]
- This way, we obtain a "target" distance matrix D for the new morphology,

[4] Antonin Bernardin et al. "Normalized Euclidean Distance Matrices for Human Motion Retargeting". In: MIG. Barcelona, Spain, 2017.

The Distance Geometry Problem: variation

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Let $G = (V, E, d)$ be a simple weighted undirected graph:

- V represents the set of joints
- E the the distances from the target distance matrix D
- d mapping $d : \{u, v\} \in E \longrightarrow (\delta(u, v), \pi(u, v)) \in \mathbb{R}_+ \times \mathbb{R}_+$

where

- δ is the distance value
- π is the priority

Definition

A variation of the **DGP** in dimension K.
Given an initial realization $x_0 : V \rightarrow R^K$, determine the realization

$$x : V \times T \longrightarrow \mathbb{R}^K$$

of G in $\mathbb{R}^K$ such that the penalty function σ is minimized.

Retargeting: a distance-based approach (3)

At every frame i we go through this process[5]:

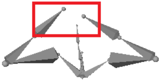
1. we obtain a "target" distance matrix for the new morphology at frame i.
2. we initialize the list of Euler angles at the results of frame $i - 1$.
3. we use gradient descent to optimize the angles such that the distances between the joints are as close to the obtained target distance matrix as possible.

Essentially, at every frame we optimize a static DGP instance, rather than solving a single dynDGP instance

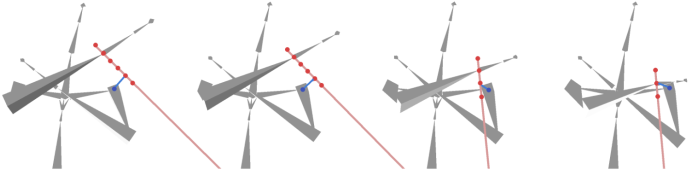
[5] Simon B. Hengeveld and Antonio Mucherino. “A Revisited Distance-based Approach to Human Skeleton Motion Retargeting”. Work in progress. 2021.

Choosing priorities π

Joints are important when they are close to each other
$\Rightarrow$ Look n frames ahead and check if $\delta(u, v)$ is below some threshold



$\Rightarrow$ Check the *interaction distance*[6]



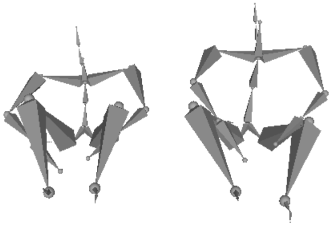
[6] Antonio Mucherino. "Introducing the Interaction Distance in the context of Distance Geometry for Human Motions". In: *Chebyshevskii sbornik* 20 (Nov. 2019).

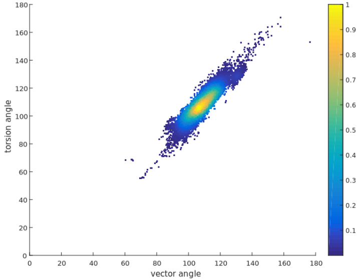
Retargeting: solutions

- We developed a Java class that takes as input two .bvh files (original and adapted morphology) and outputs the retargeted motion as another .bvh file
- Tests were done on motions from the motion capture database from the Carnegie Mellon University: `http://mocap.cs.cmu.edu/`
- Video clip with resulting animations

Challenges and future work

- A difficult motion: sitting with hands under legs
- Using extra constraints based on analysis of Motion capture database





Thanks!

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