Render the Possibilities

SIGGRAPH2016

THE **43RD** INTERNATIONAL
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& Computer Graphics Interactive Techniques

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A Deep Learning Framework for Character Motion Synthesis and Editing

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Outline

Motivation

Synthesis

Editing

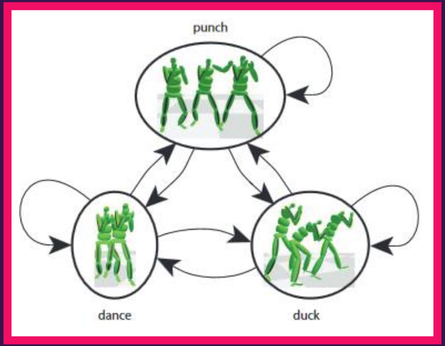
Discussion

Goal

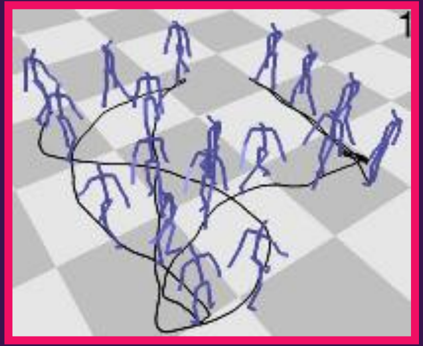
Data driven synthesis of motion from high level controls with no manual preprocessing

Previous Work

- Lots of manual processing (Graphs, Trees)
  - Segmentation
  - Alignment
  - Classification



[Heck et al. 2007]

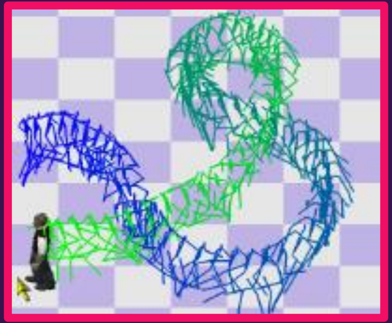


[Kovar et al. 2002]

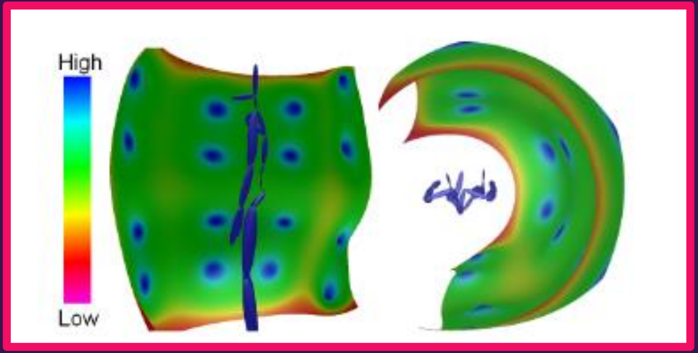
Previous Work

- Scalability Issues (RBF, GP, GPLVM, kNN)
  - Must store whole database in memory
  - Grows $O(n^2)$ with number of data points
  - Requires expensive acceleration structures

[Lee et al. 2010]

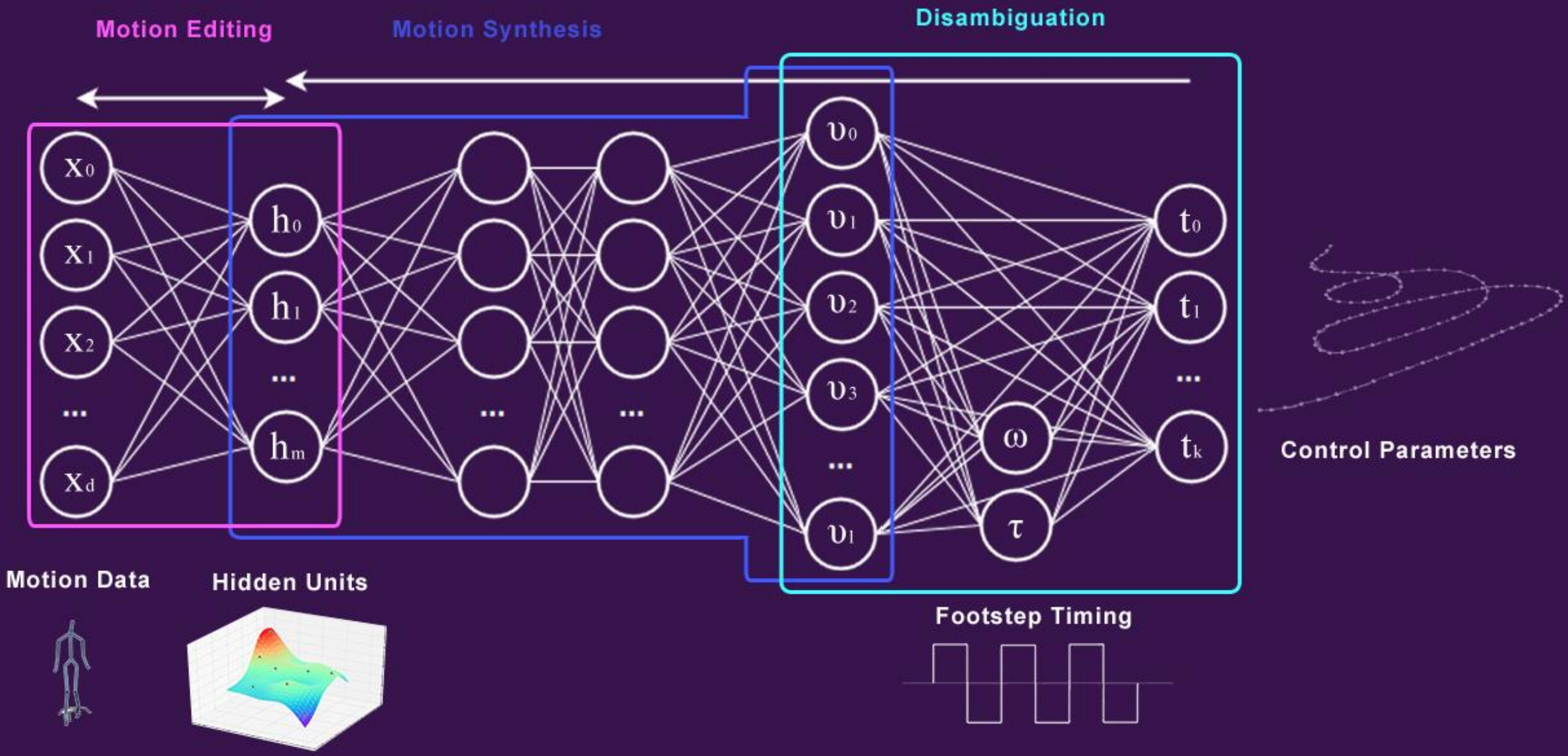


[Park et al. 2002]



[Mukai and Kuriyama 2005]

Overview


Motion Editing
Motion Synthesis
Disambiguation
x0
x1
x2
...
xd
h0
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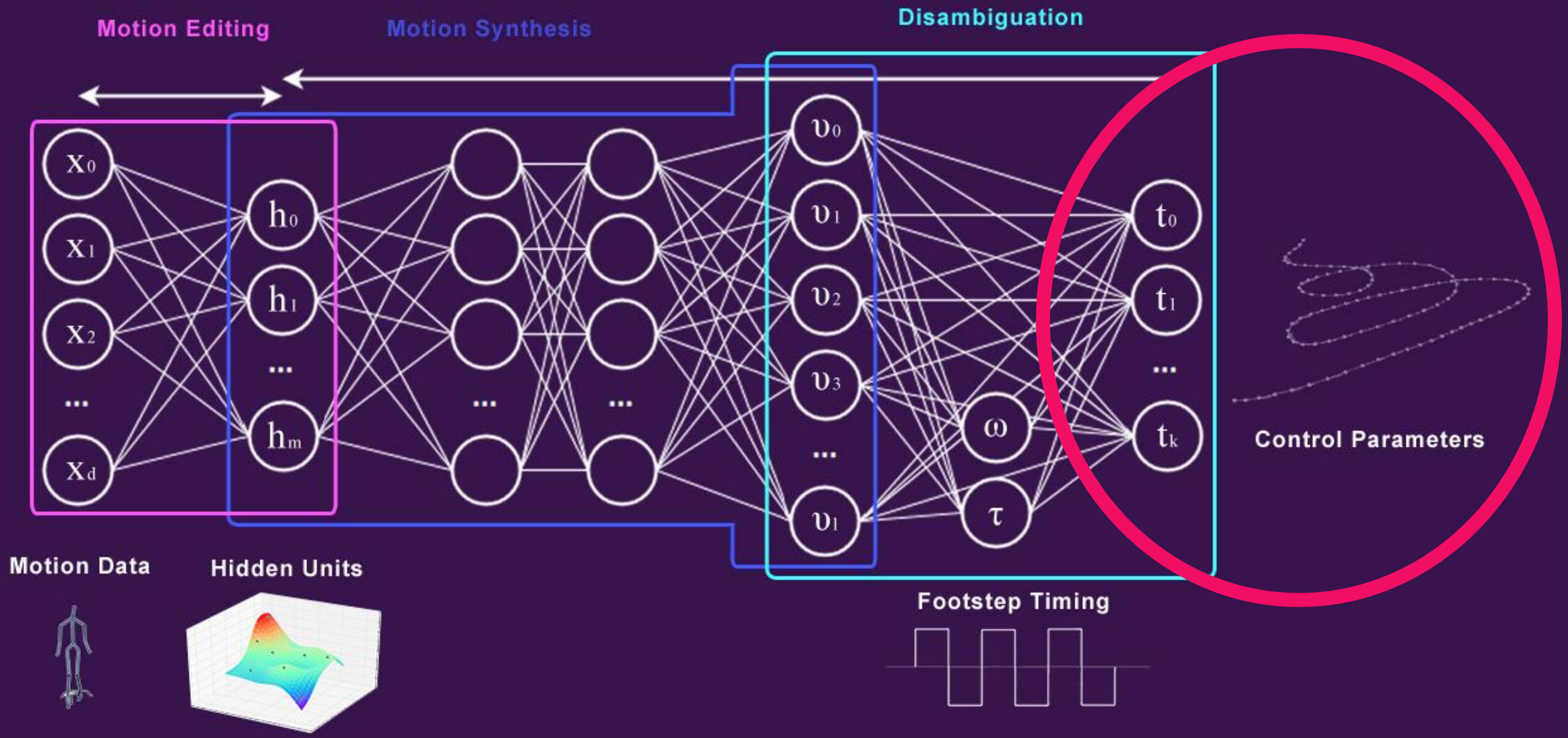
t0
t1
...
tk
Control Parameters
Motion Data
Hidden Units
Footstep Timing

Overview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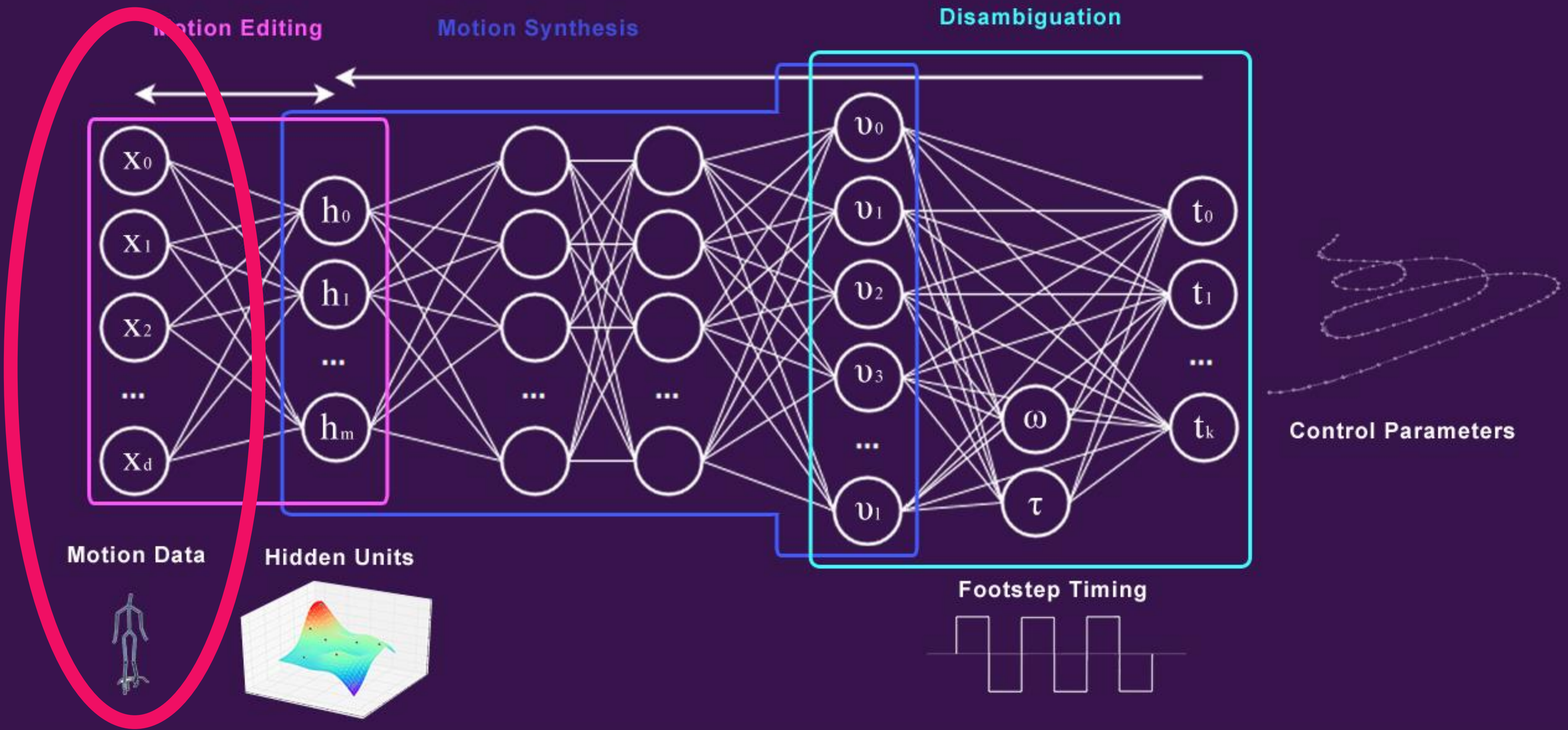
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Motion Synthesis
Disambiguation
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...
t_k
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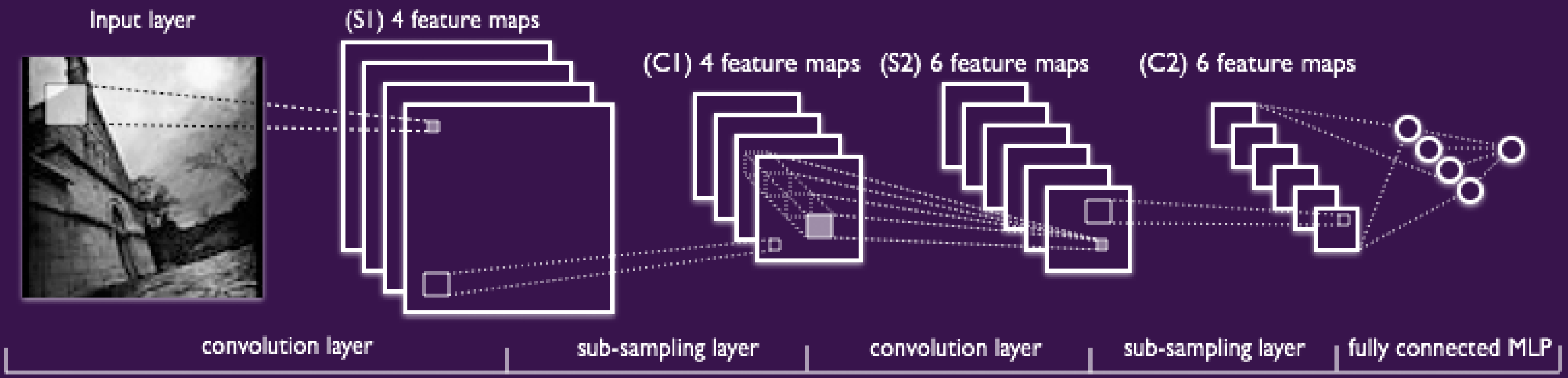
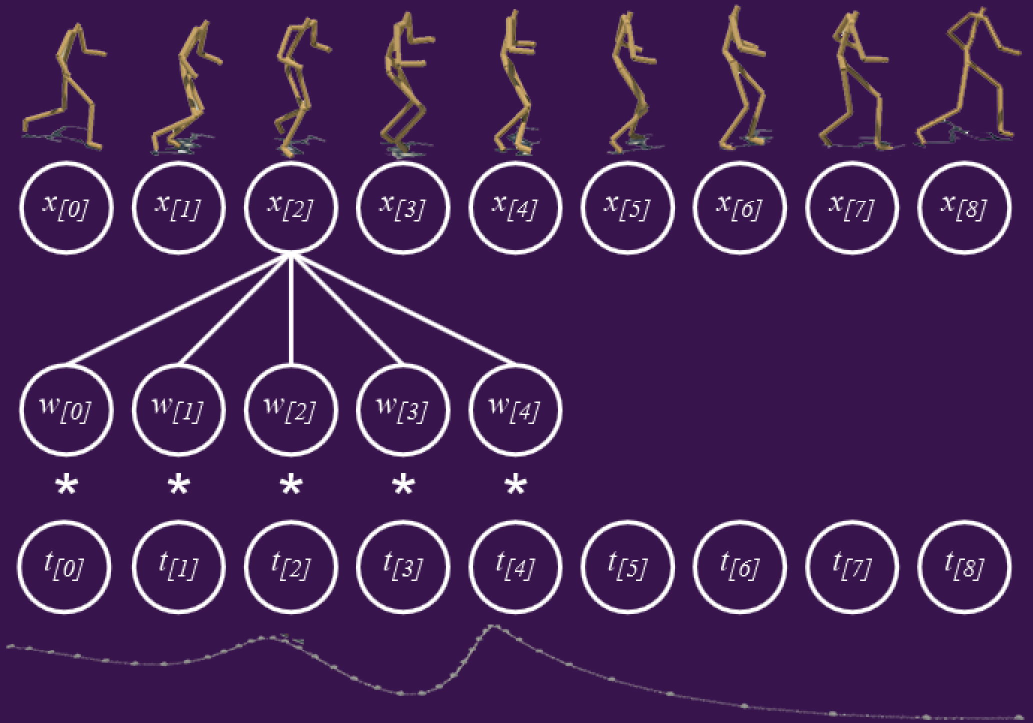
Convolutional Neural Networks

- Great success in classification and segmentation for images, video, sound
- We can use CNN on motion data too



Convolution

Filters convolve over temporal dimension



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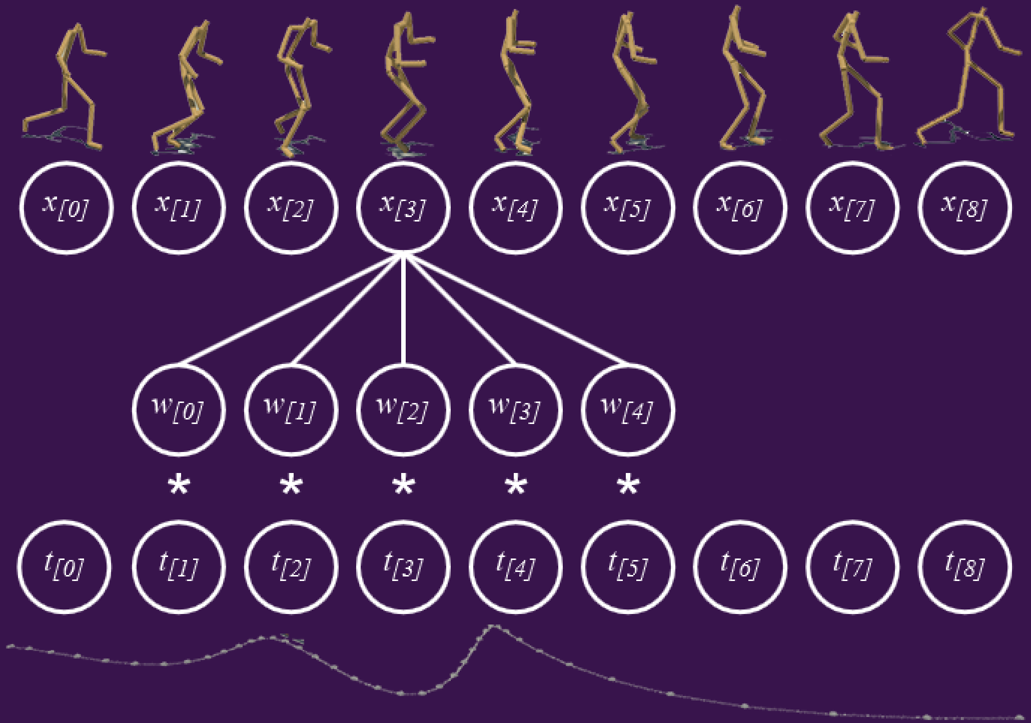

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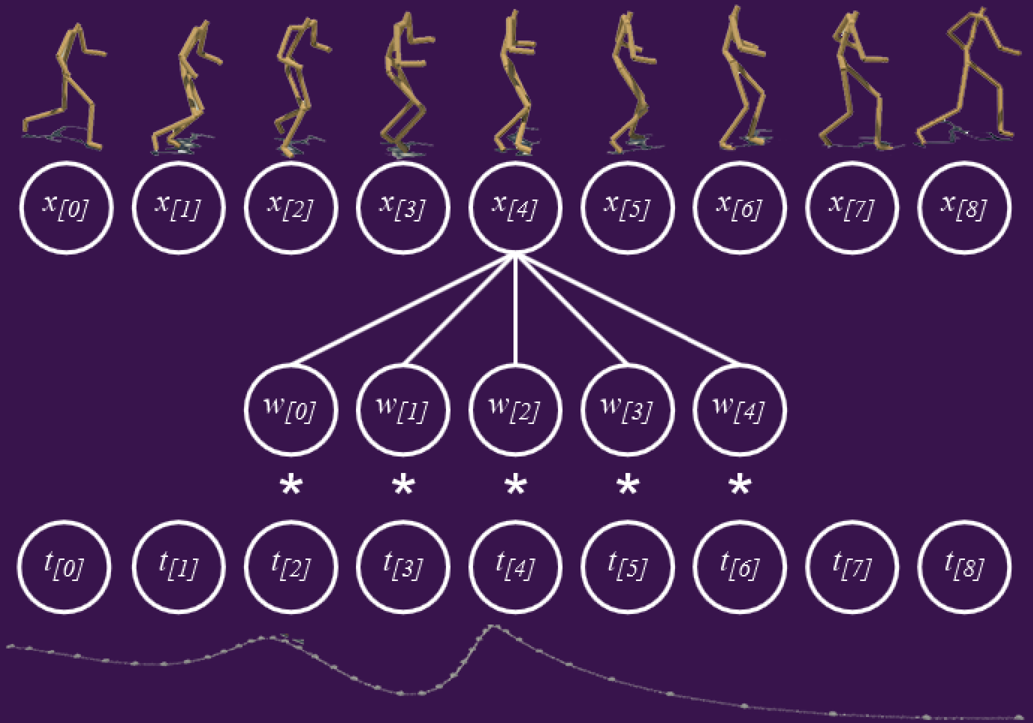

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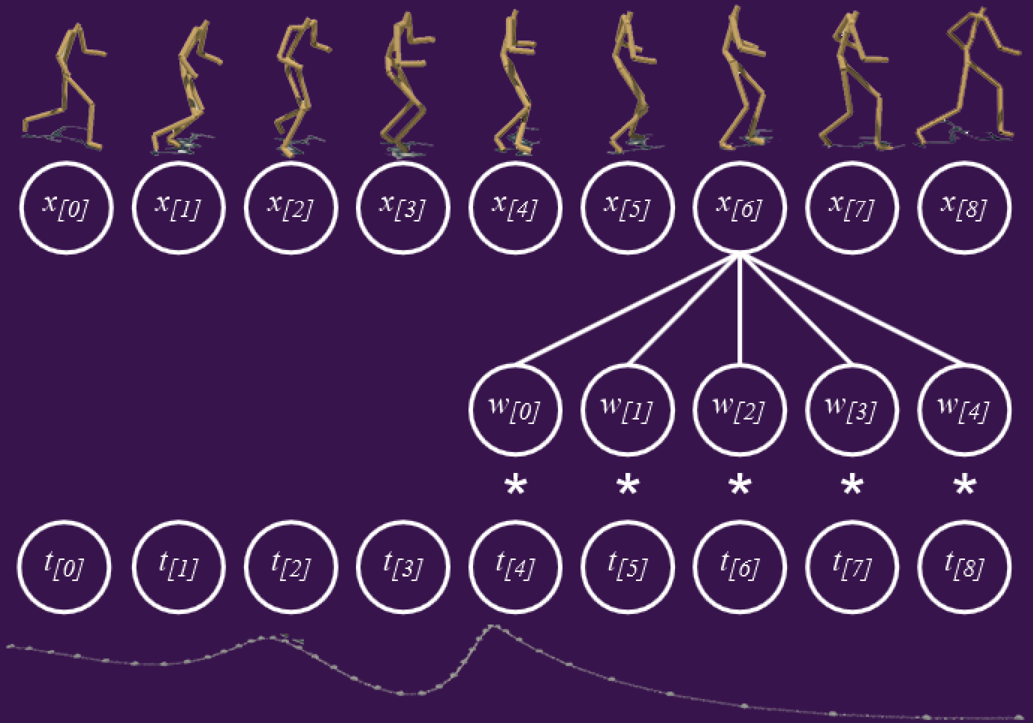

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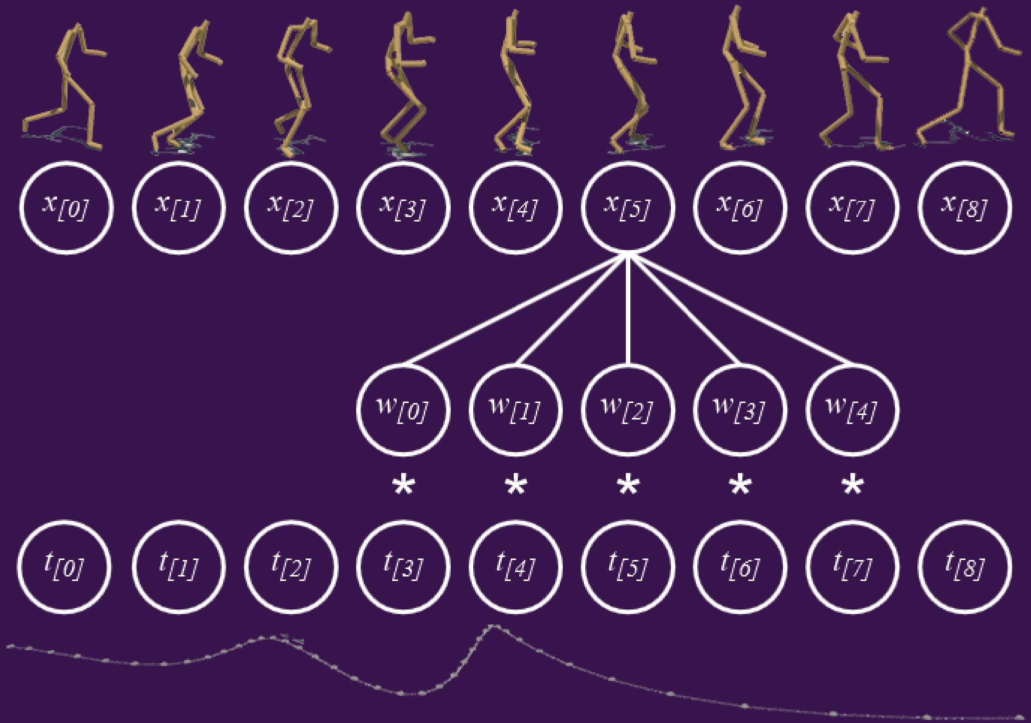

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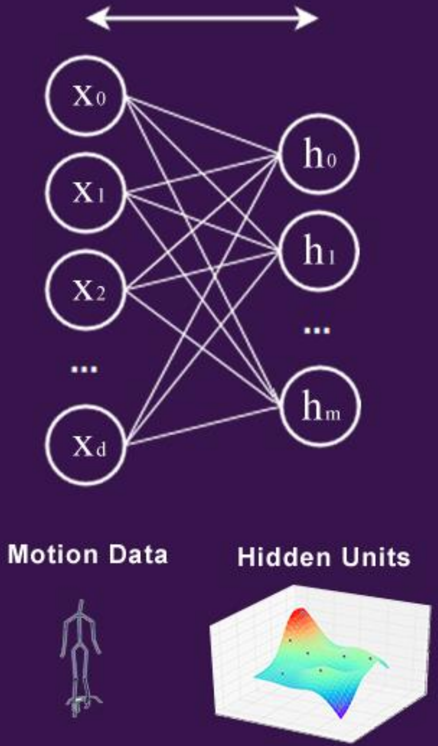
Motion Editing

Post processing may not ensure naturalness

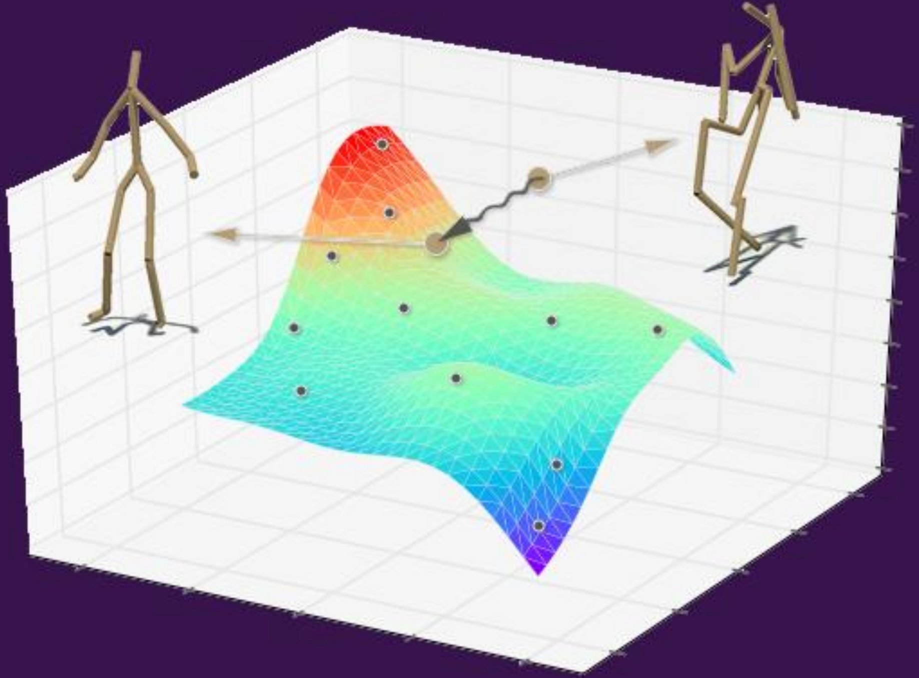
Motion Editing

- We edit using the motion manifold learned by a Convolutional Autoencoding Network [Holden et al. 2015]



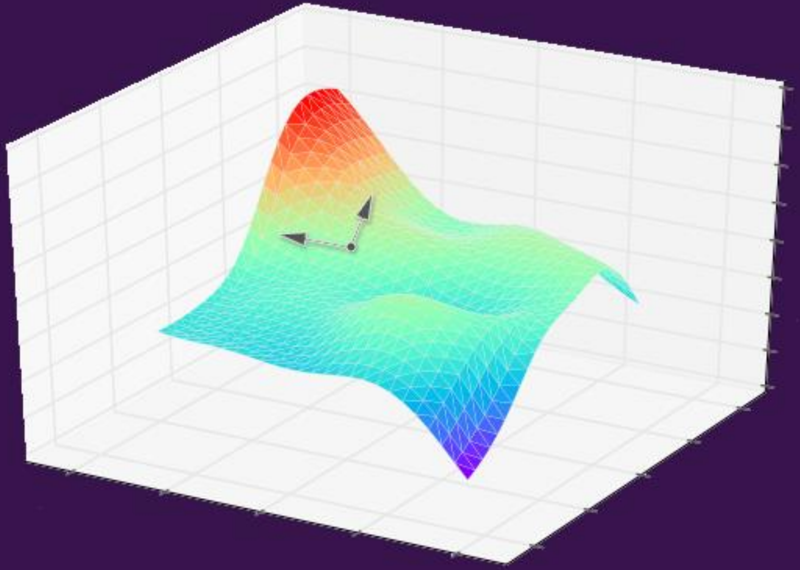
Autoencoder

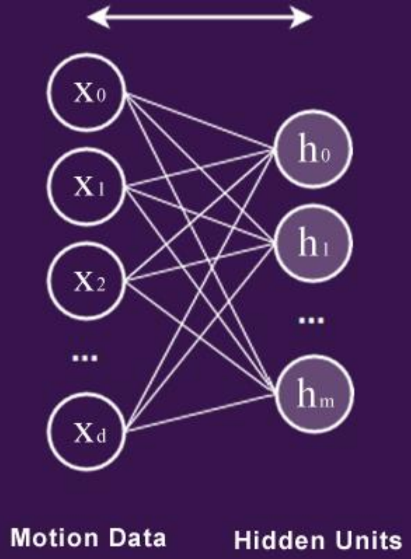
- Learns *projection operator* of motion manifold



Manifold Surface

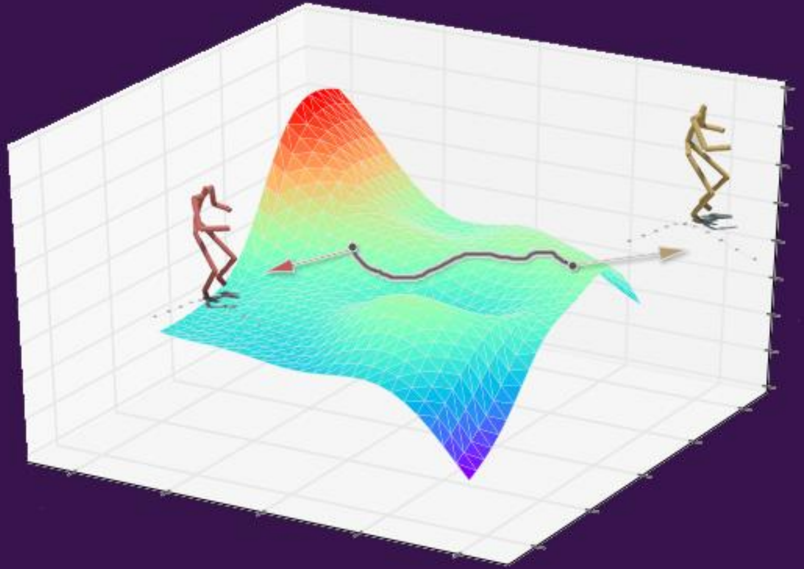
- *Hidden Unit* values parametrise manifold surface
- Adjusting them ensures motion remains natural

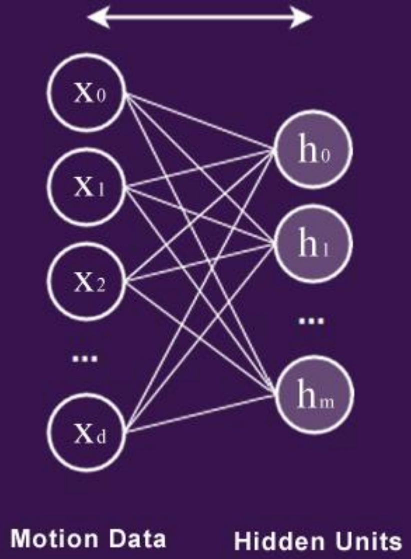




Constraint Satisfaction

- Motion editing is a *constraint satisfaction problem* over *Hidden Units*





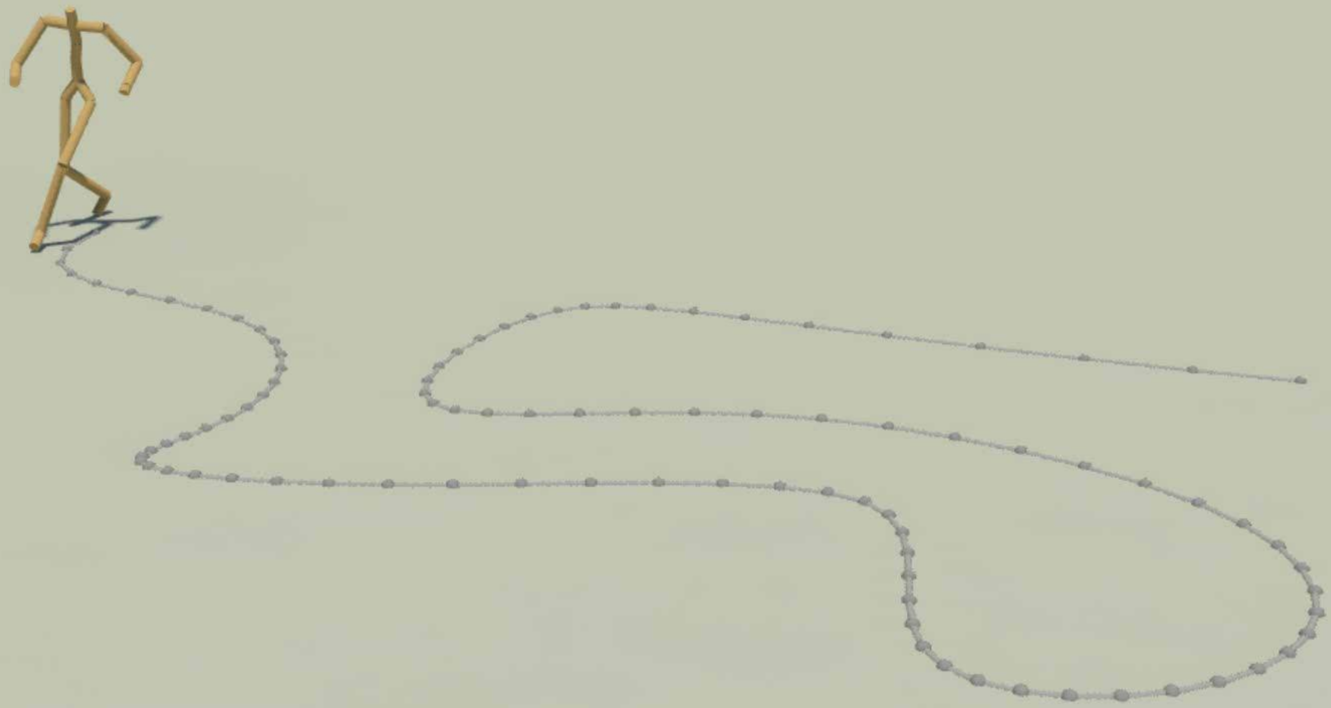
Constraint Satisfaction

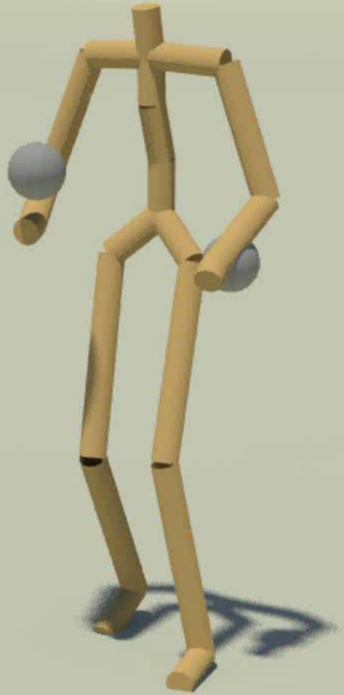
- Local foot velocity must equal global velocity

$$Pos(\mathrm{H}) = \sum_j \|\mathbf{v}_r^{\mathrm{H}} + \omega^{\mathrm{H}} \times \mathbf{p}_j^{\mathrm{H}} + \mathbf{v}_j^{\mathrm{H}} - \mathbf{v}'_j\|_2^2.$$

- Output trajectory must equal input trajectory

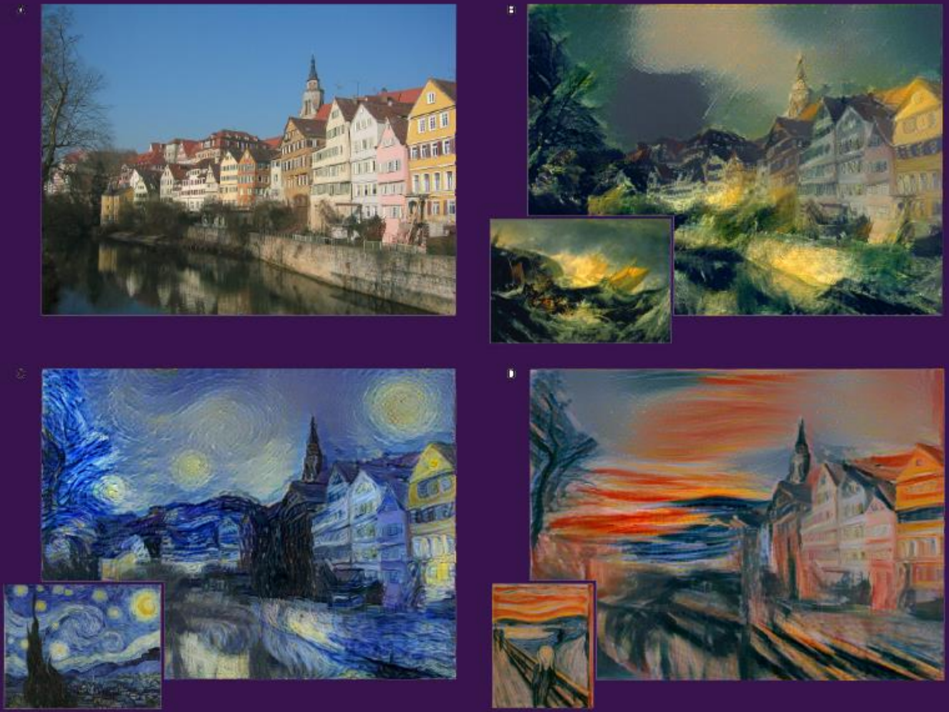
$$Traj(\mathrm{H}) \quad = \quad \|\omega^{\mathrm{H}} - \omega'\|_2^2 + \|\mathbf{v}_r^{\mathrm{H}} - \mathbf{v}'_r\|_2^2$$





A Neural Algorithm of Artistic Style

- Combine style of one image with content of another [Gatys et al. 2015]



Style Constraint

- Gram Matrix of *Hidden Units* encode style
- Actual Values of *Hidden Units* encode content

$$Style(\mathbf{H}) = s\|G(\Phi(\mathbf{S})) - G(\mathbf{H})\|_2^2 + c\|\Phi(\mathbf{C}) - \mathbf{H}\|_2^2$$

$$G(\mathbf{H}) = \frac{\sum_i^n \mathbf{H}_i \mathbf{H}_i^T}{n}$$

- **No correspondence between clips required!**

Style Constraint

- Gram Matrix of *Hidden Units* encode style
- Actual Values of *Hidden Units* encode content

$$Style(\mathbf{H}) = s\|G(\mathbf{\Phi}(\mathbf{S})) - G(\mathbf{H})\|_2^2 + \underbrace{c\|\mathbf{\Phi}(\mathbf{C}) - \mathbf{H}\|_2^2}_{\text{Content Term}}$$

$$G(\mathbf{H}) = \frac{\sum_i^n \mathbf{H}_i \mathbf{H}_i^T}{n}$$

- **No correspondence between clips required!**

Style Constraint

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$$Style(\mathbf{H}) = s\|G(\Phi(\mathbf{S})) - G(\mathbf{H})\|_2^2 + c\|\Phi(\mathbf{C}) - \mathbf{H}\|_2^2$$

Style Term

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$$G(\mathbf{H}) = \frac{\sum_i^n \mathbf{H}_i \mathbf{H}_i^T}{n}$$

Gram Matrix

- **No correspondence between clips required!**

Style Constraint

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- **No correspondence between clips required!**

Style

Content

Transfer

Outline

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Synthesis

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Training

- **Motion Manifold**
  - Several large databases (including whole CMU)
  - Training takes around 6 hours

- **Motion Synthesis**
  - Task specific data only (e.g. locomotion only)
  - Training takes around 1 hour

Contribution

- **High quality synthesis** with **no manual preprocessing**
- Motion synthesis and editing in **unified framework**
- **Procedural**, **parallel** technique

Future Work

- Need more general solution for ambiguity issue
- Wish to use more high level features with a deeper network
- What changes are required for interactive applications?