30 JULY – 3 AUGUST Los Angeles
SIGGRAPH 2017

PHASE-FUNCTIONED NEURAL NETWORKS FOR CHARACTER CONTROL

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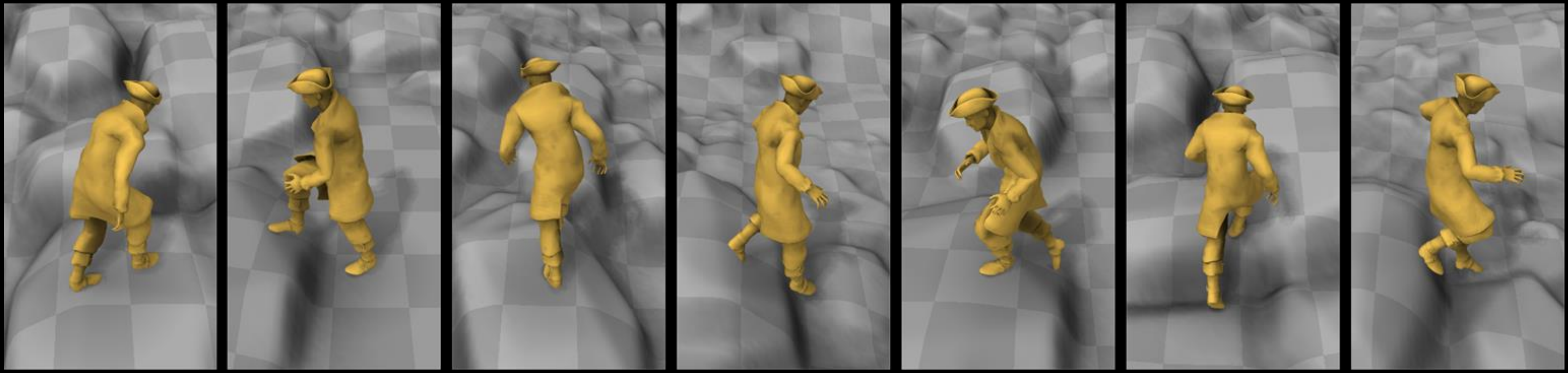
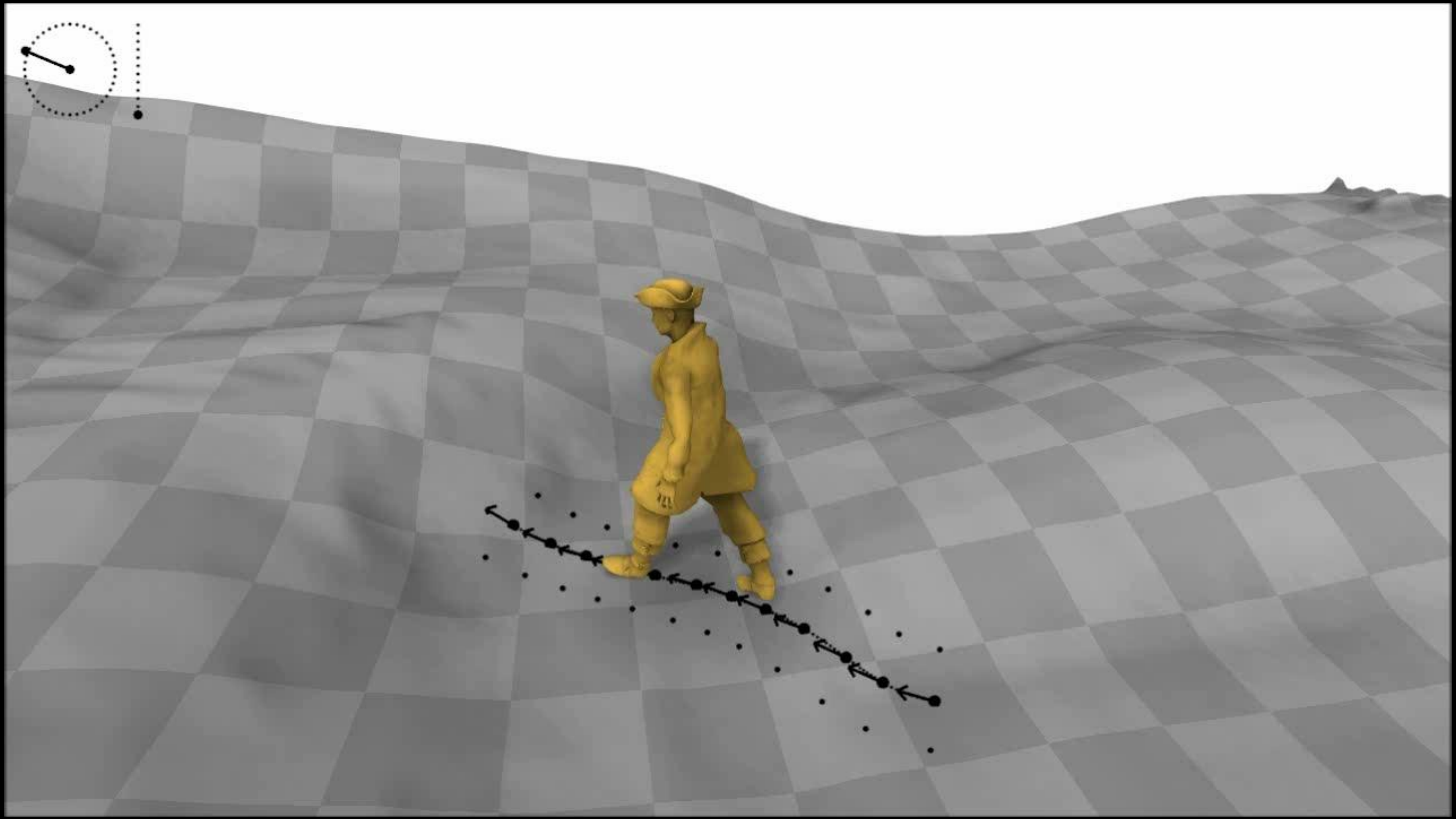
RESEARCH GOAL

Fast, compact, expressive character controller for games



FINAL RESULT



OVERVIEW

Background

Data Capture

Neural Network

Results

Conclusion

PREVIOUS WORK – MOTION X

Motion Graphs - Motion Fields - Motion Matching

[Kovar et al. 2002]
[Lee et al. 2002]
[Arikan et al. 2002]

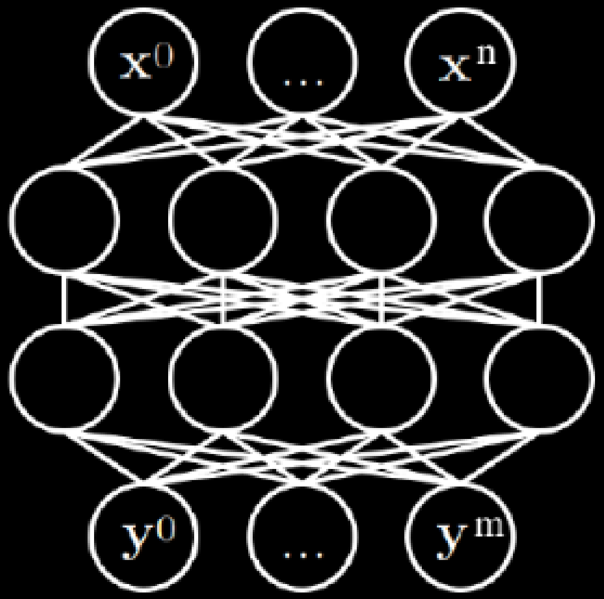
[Lee et al. 2010]

[Büttner 2015]
[Clavet 2016]

- **Scalability:**
  - Require full motion database to be stored in memory.
  - Require manual processing of data by artists (often).
  - Require tricky acceleration structures (e.g. kd-tree).

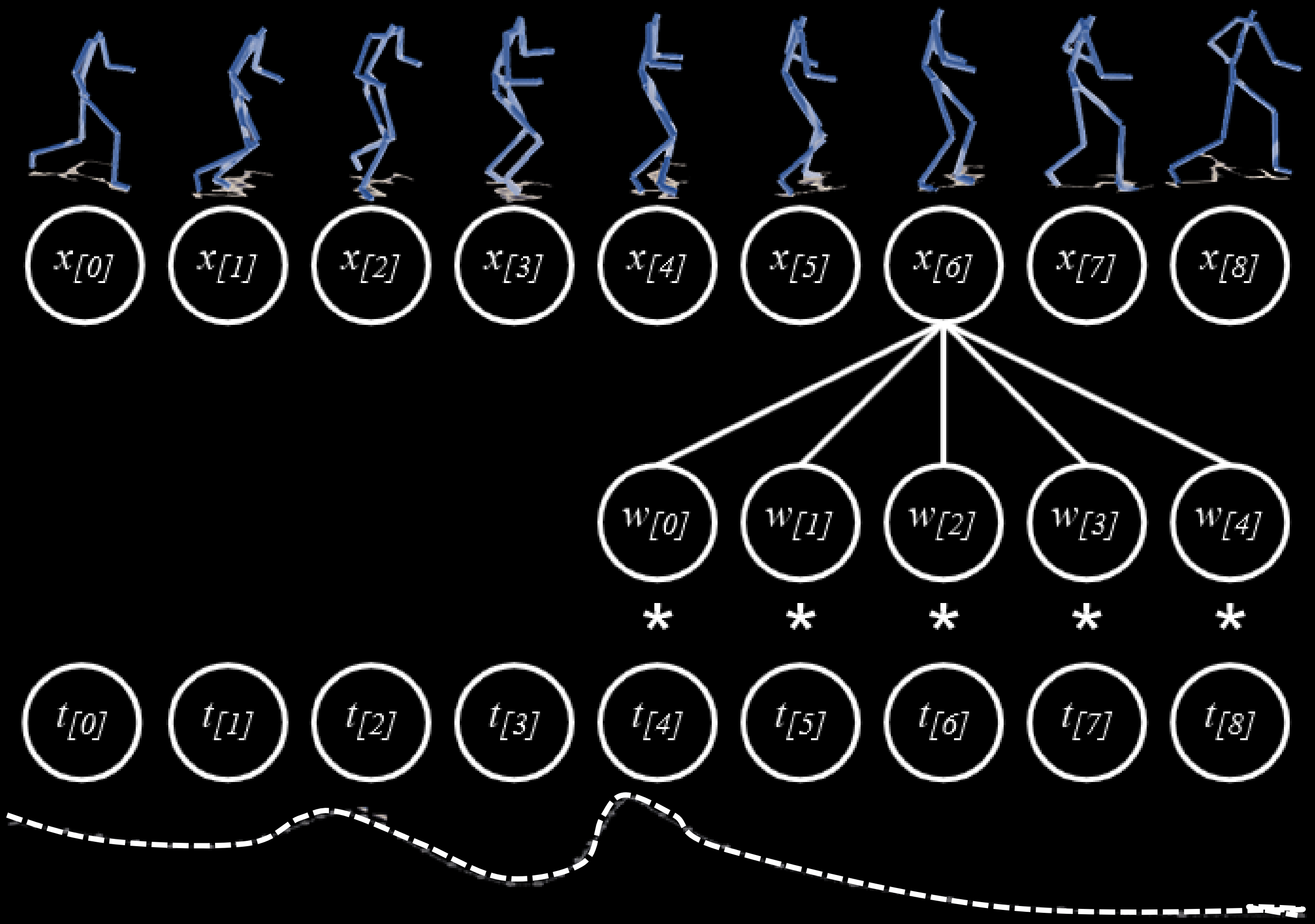
CAN NEURAL NETWORKS HELP?

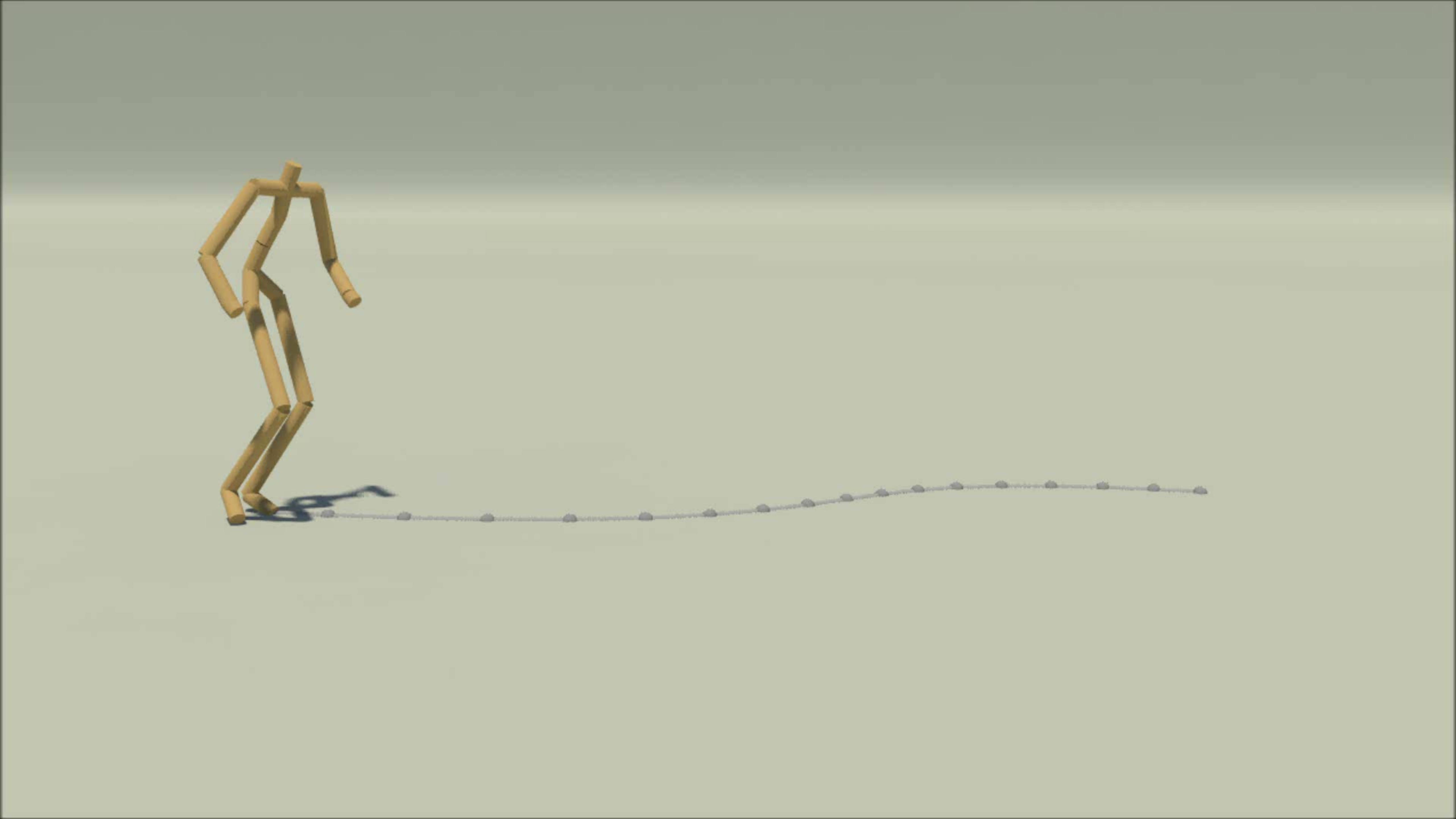
- **High Scalability**:
  - Virtually unlimited data capacity.
  - Fast runtime / low memory usage.
- **But how can they be used for motion generation?**



CONVOLUTIONAL NEURAL NETWORKS

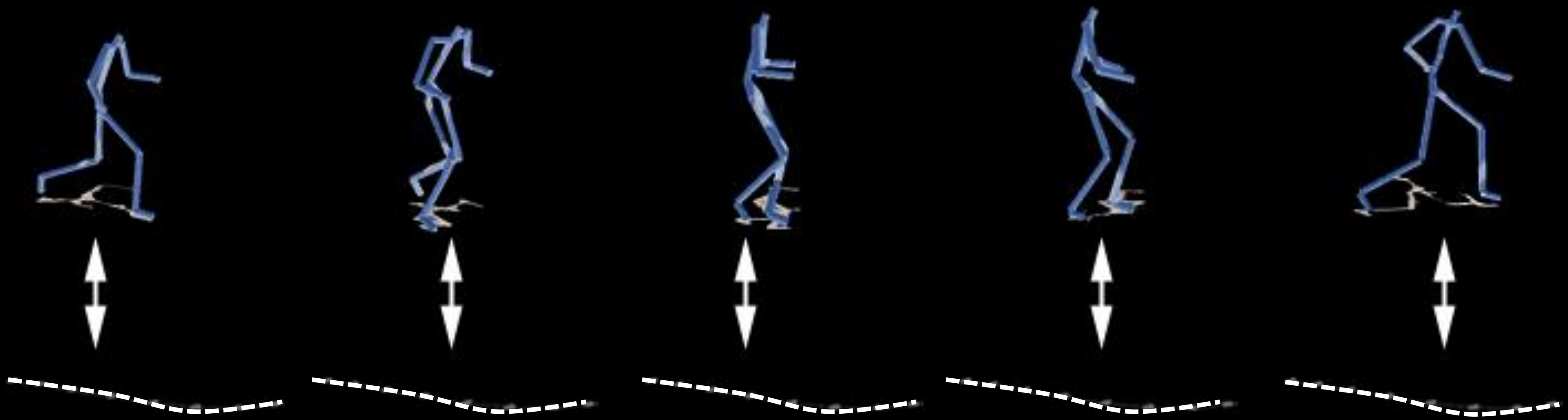
Learn a mapping from a user control signal to a motion





WHAT HAPPENED?

- **Ambiguity**: same input maps to multiple different motions.

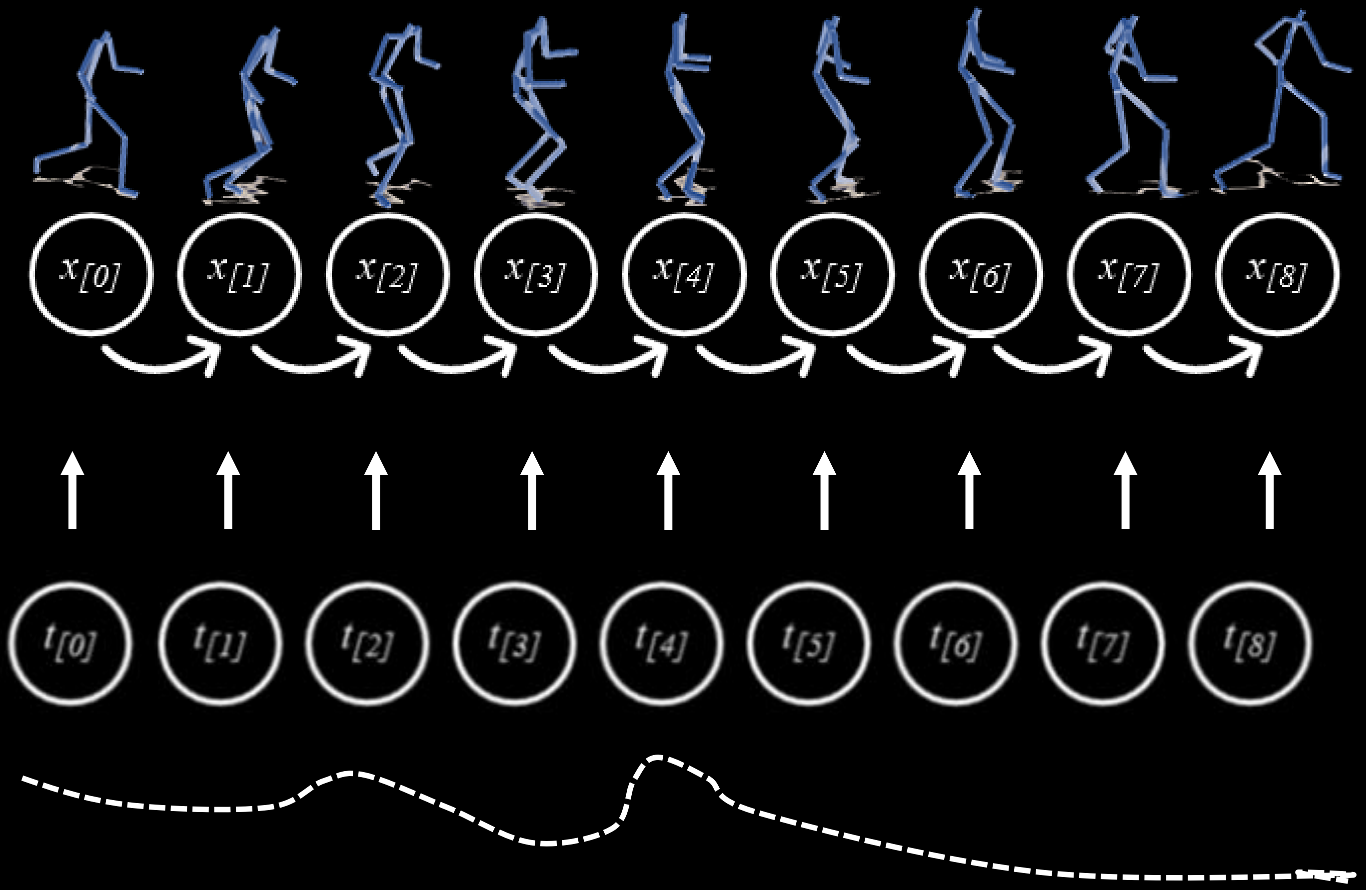


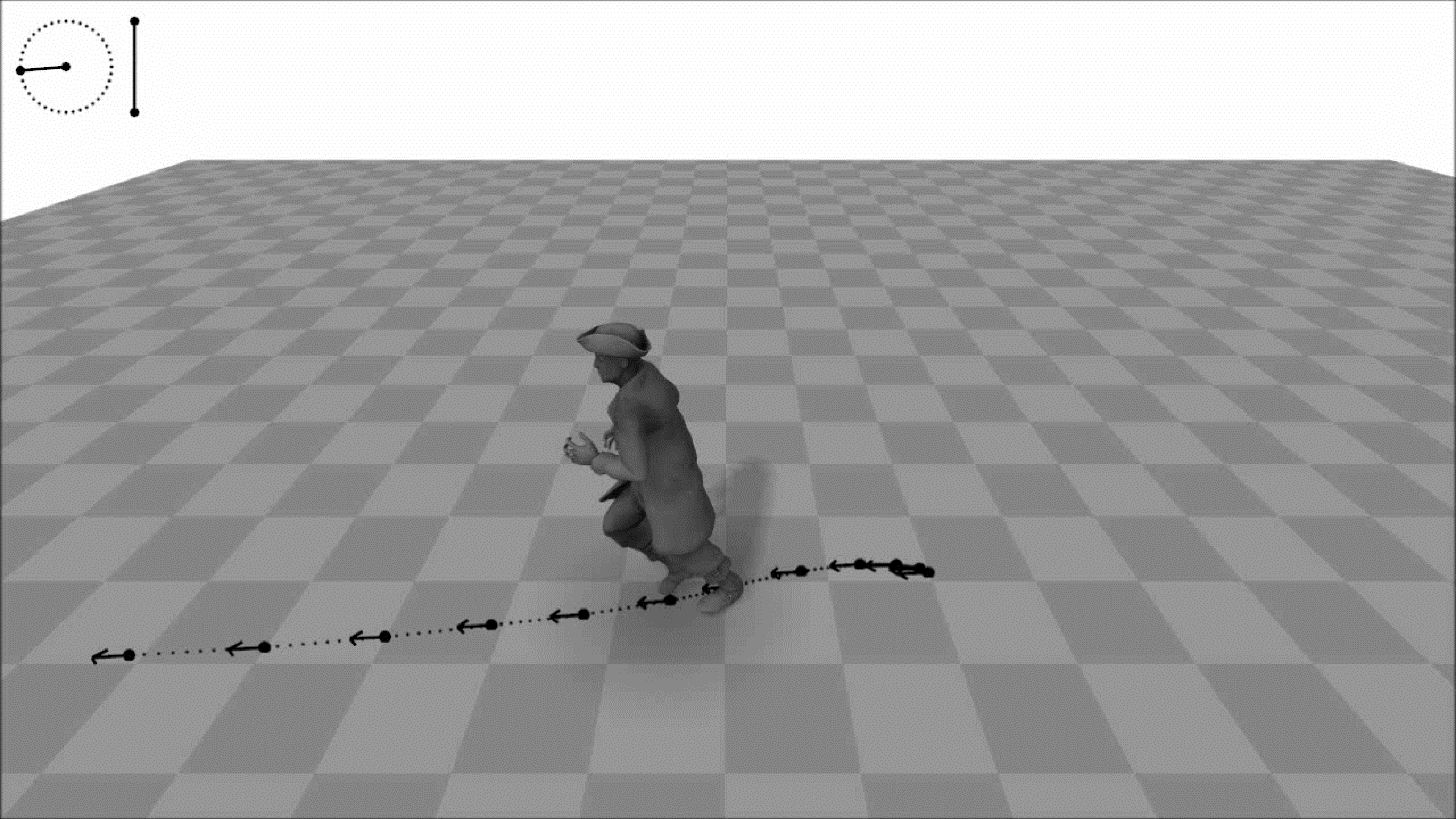
CONVOLUTIONAL NEURAL NETWORKS

- **Practicality:**
  - Require a trick to remove the ambiguity in the input [Holden et al. 2016].
  - Whole input trajectory must be given beforehand.
  - Multi-layer CNNs are still too slow for games.

RECURRENT NEURAL NETWORKS

Learn a mapping from the previous frame(s) to next.





RECURRENT NEURAL NETWORKS

- **Quality:**
  - State of the art produces ~10 seconds before “dying out”
    [Fragkiadaki et al. 2015]
  - Difficult to avoid “floating”.
  - Still has issues of ambiguity.

SUMMARY

- **Scalability**:
  - How can we scale to large amounts of data?

- **Ambiguity**:
  - How do we solve the ambiguity problem?

- **Quality**:
  - How can we make the generated motion look good?

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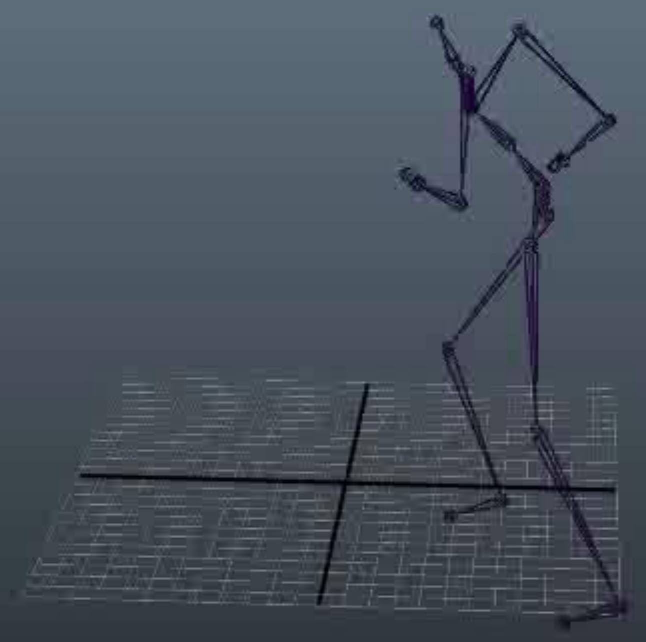
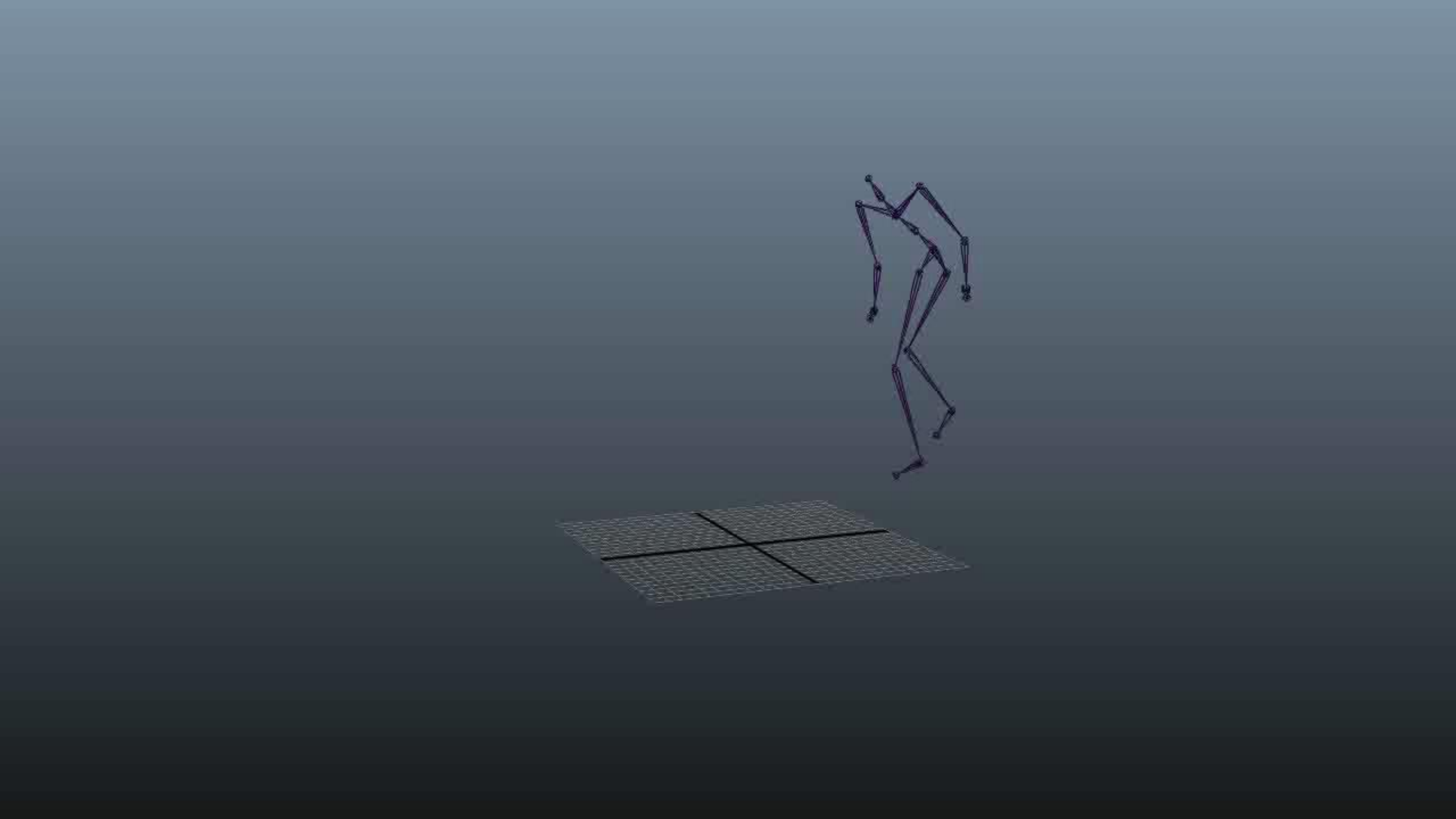
DATA CAPTURE

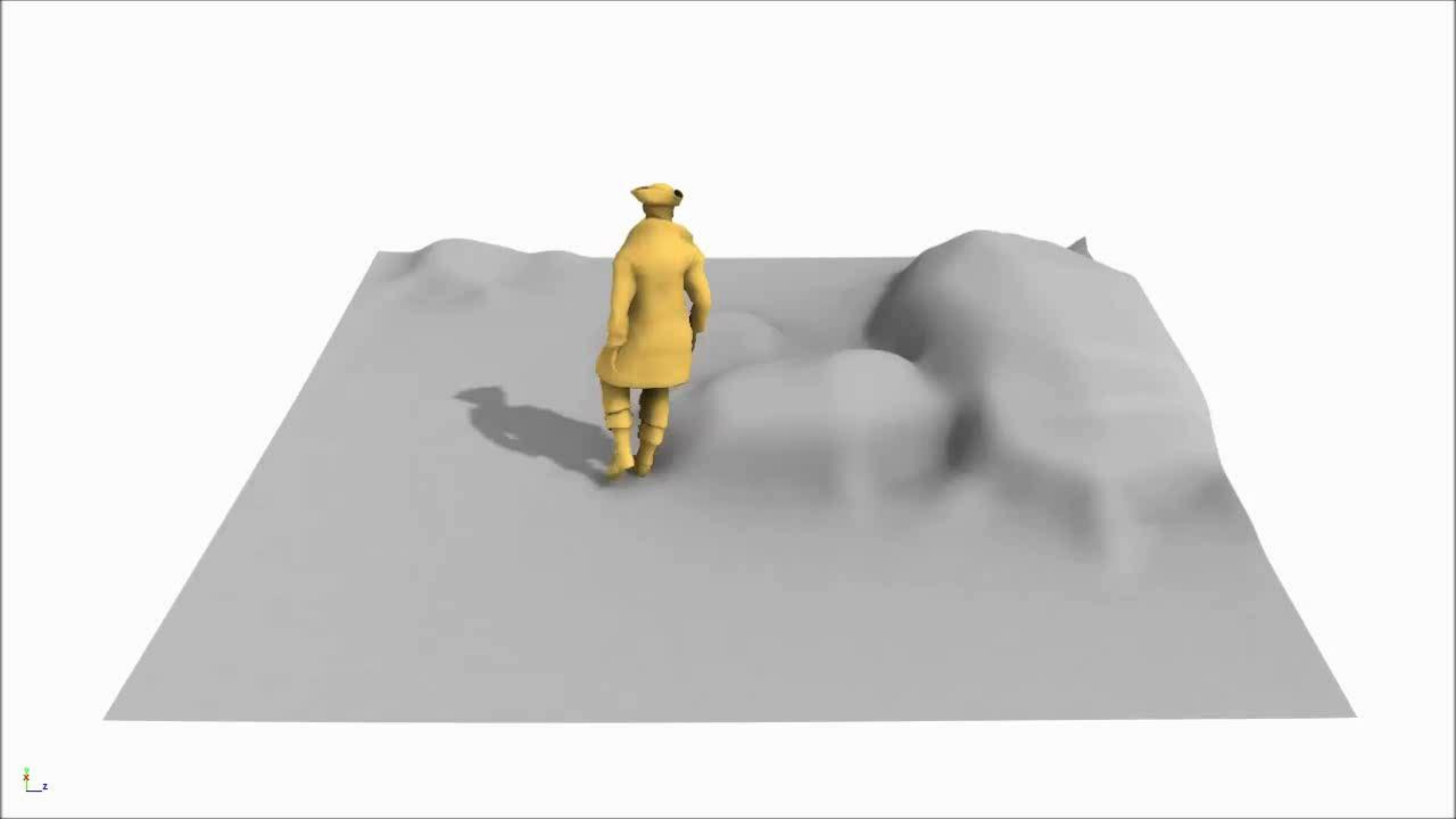
- **Unstructured data capture:**
  - Around 2 hours of raw locomotion mocap data (~1.5 GB).
  - Each capture is around 10 minutes long.
  - Each contains a mixture of gaits, facing directions, etc.
  - We placed chairs, tables in capture volume to climb over.





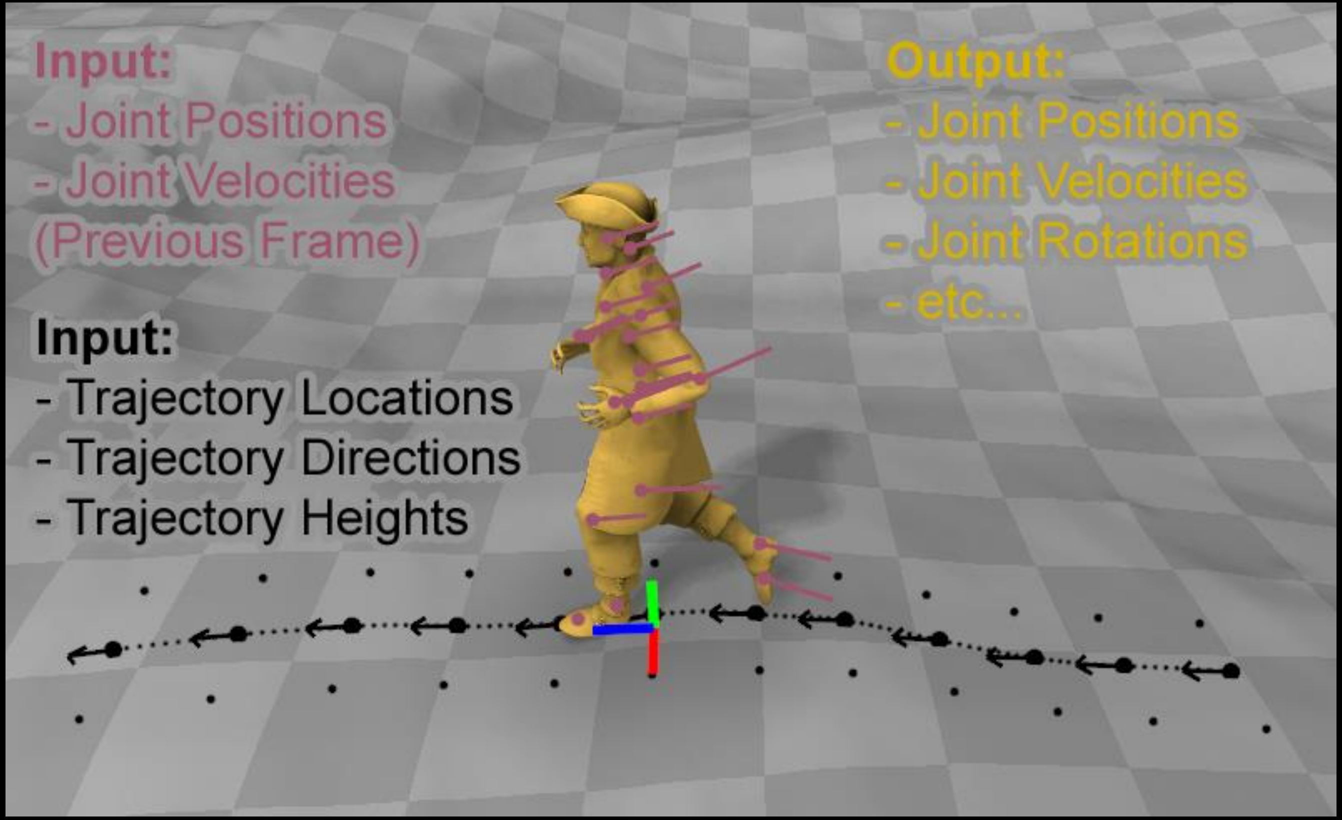
TERRAIN FITTING

- We want to have terrain geometry to learn from alongside motion.
- But capturing motion and geometry together is difficult.
- Make a database of heightmaps and fit patches from it to each locomotion cycle.



PARAMETERISATION

- Has a large effect on the final quality.
- Window of the trajectory local to the character.
- We add **gait**, **terrain height**, and other variables.



OVERVIEW

PHASE-FUNCTIONED NEURAL NETWORK

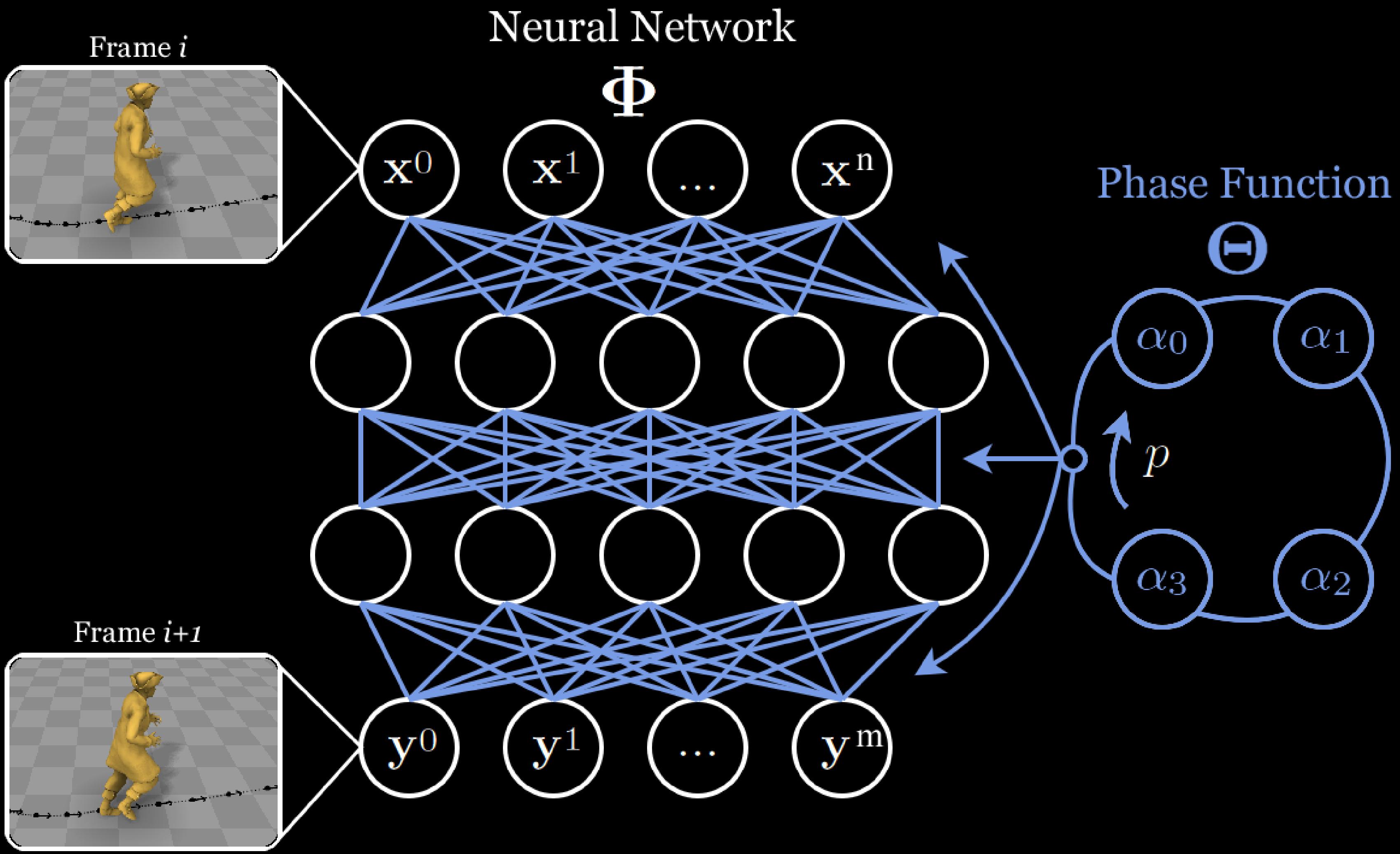
A Neural Network where the weights are generated as a function of the phase.

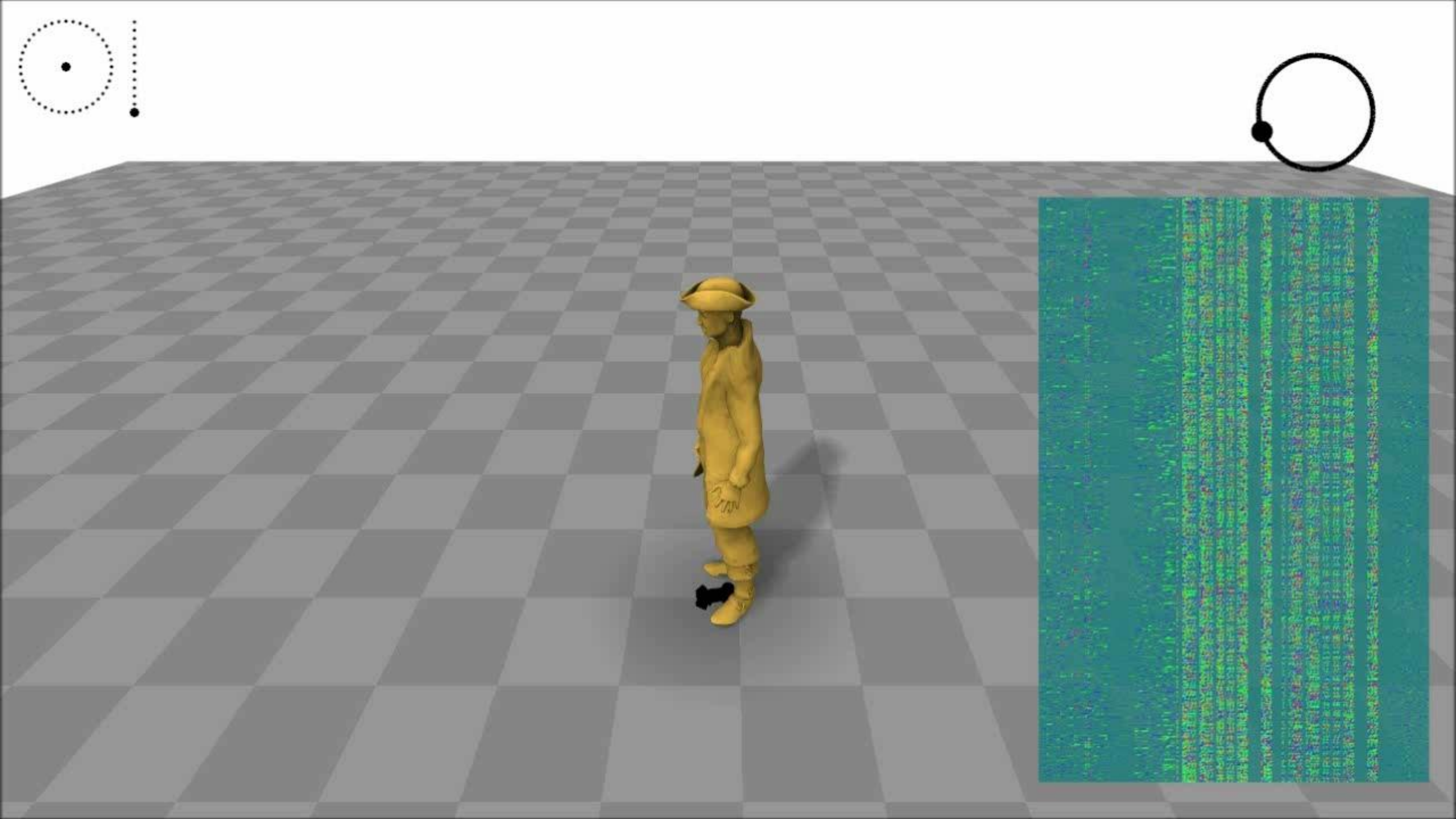
THE PHASE

The “phase” is the scalar variable in the range 0 to 2π representing the point in time of the current pose in the locomotion cycle.

- **Given the phase:**
  - The pose of the character is far less ambiguous.
  - The space of poses is smaller and more convex.
  - The average pose is not the character “floating”.

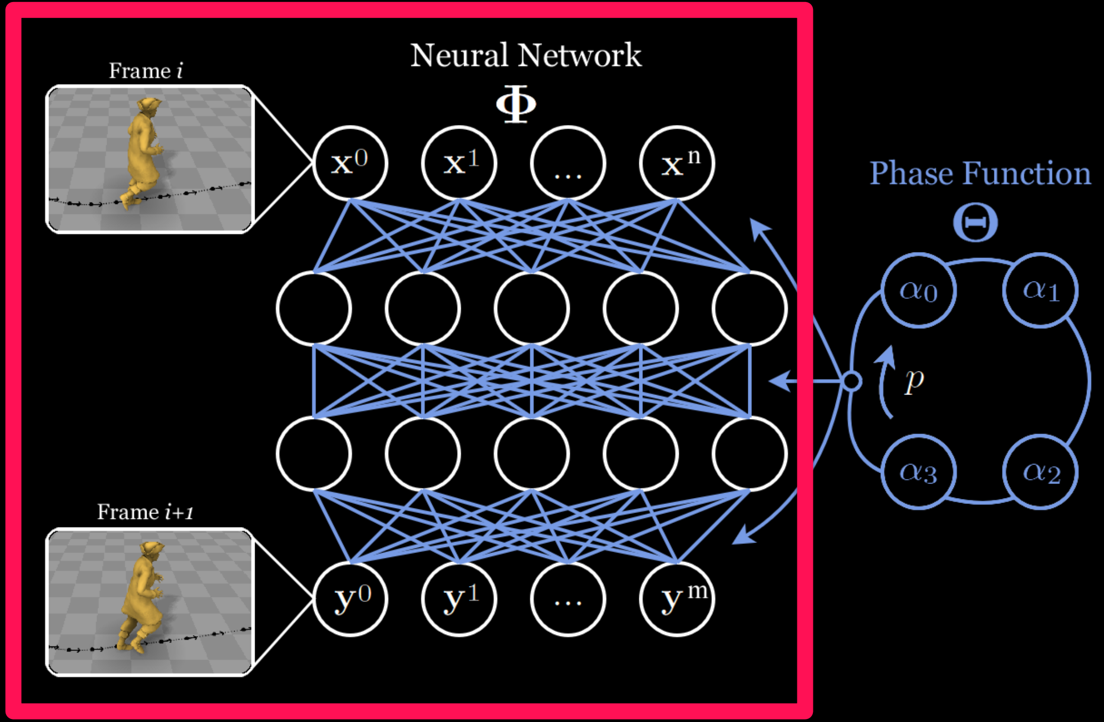
PHASE-FUNCTIONED NEURAL NETWORK





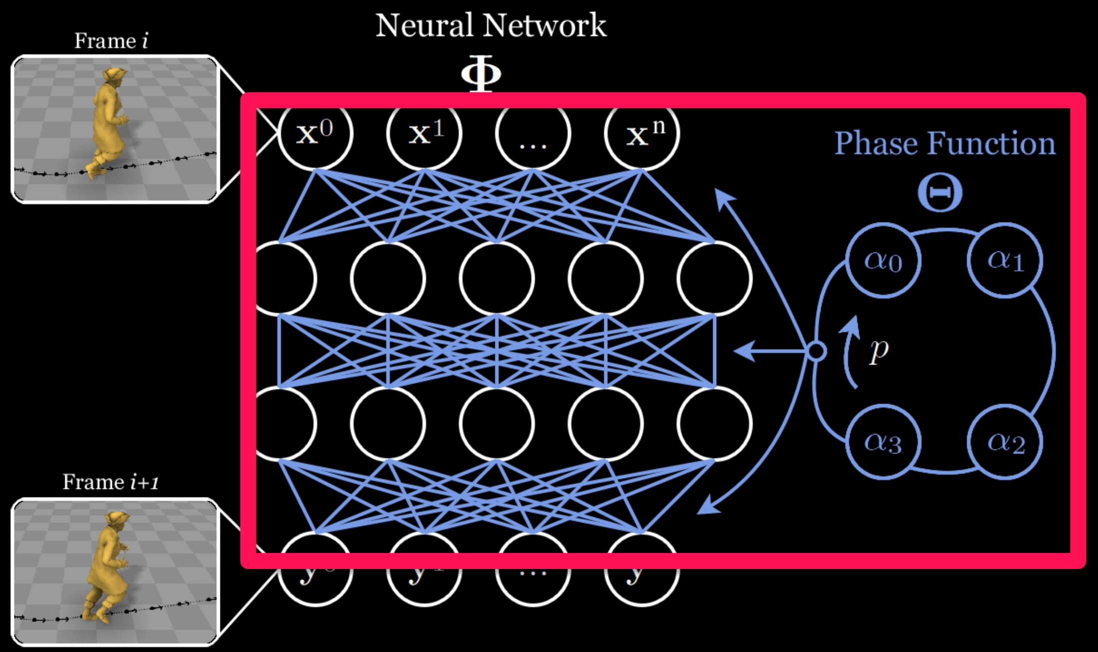
NEURAL NETWORK

- Feed-Forward Neural Network.
- 2 hidden layers.
- 512 hidden units per layer.
- ELU activation function.



PHASE FUNCTION

- Outputs neural network weights.
- Cyclic cubic spline function interpolating 4 *control points*.
- Each *control point* is effectively a set of neural network weights.



TRAINING ALGORITHM

1. Input phase p in phase function to generate network weights $\boldsymbol{\alpha}$.

2. Using weights $\boldsymbol{\alpha}$, input $\boldsymbol{x}$ into neural network to generate output $\boldsymbol{y}$.

3. Measure error in output $\boldsymbol{y}$.

4. Back-propagate error through **both** neural network **and** phase function to update values of *control points*.

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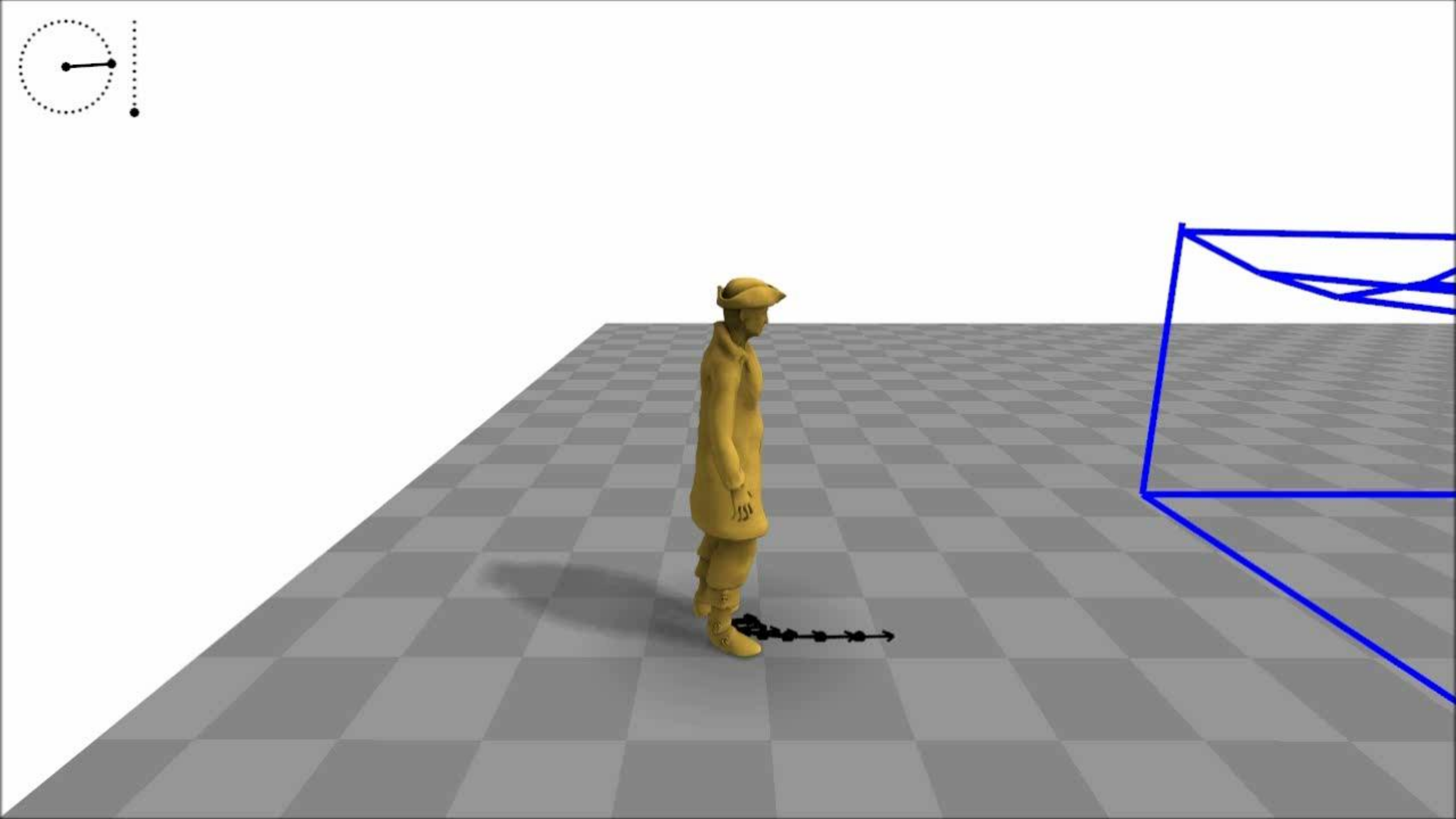

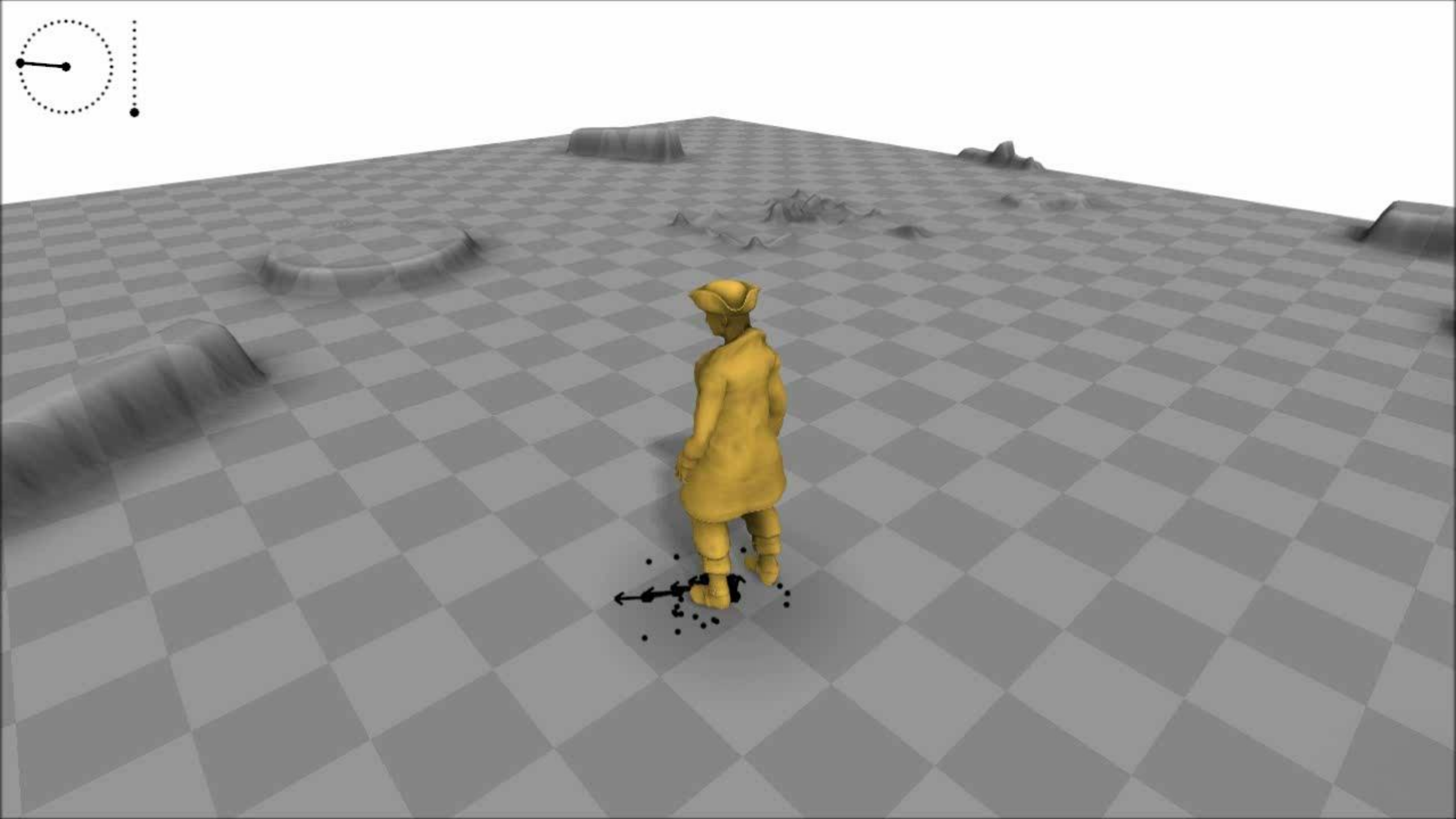

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PHASE-FUNCTION PRECOMPUTATION

Computation of phase function is a bit slow (for games).

- **Pre-compute phase function:**
  - Phase is scalar in range $0 \leq p \leq 2\pi$.
  - We can pre-compute phase function in this range.
  - Interpolate pre-computed values at runtime.
  - Provides a trade-off between memory and speed.

PERFORMANCE

Runtime	Memory
1.8 ms	10 mb
or	
0.8 ms	125 mb

NEGATIVES

- **Training Time:**
  - Longer than usual as each mini-batch item has different phase.
- **Artistic Control:**
  - Difficult for artists to direct / edit outcome of this kind of setup.
- **Unpredictability:**
  - Difficult to predict what the results will be like and why.

POSITIVES

- **Scalability**:
  - Neural Networks can easily scale to huge amounts of data.
- **Ambiguity**:
  - Factoring out the phase very effectively reduces ambiguity.
- **Quality**:
  - Good parametrisation and simple structure helps control quality.

QUESTIONS?