

Robot Composer & Pianist



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Introduction

Music: an inherently human and creative process

- > Composition: memory, abstract object structure in space (harmony) and time (melody) and emotion
- > Execution: mapping all of these onto the motor cortex and the motor cortex onto the motor neurons

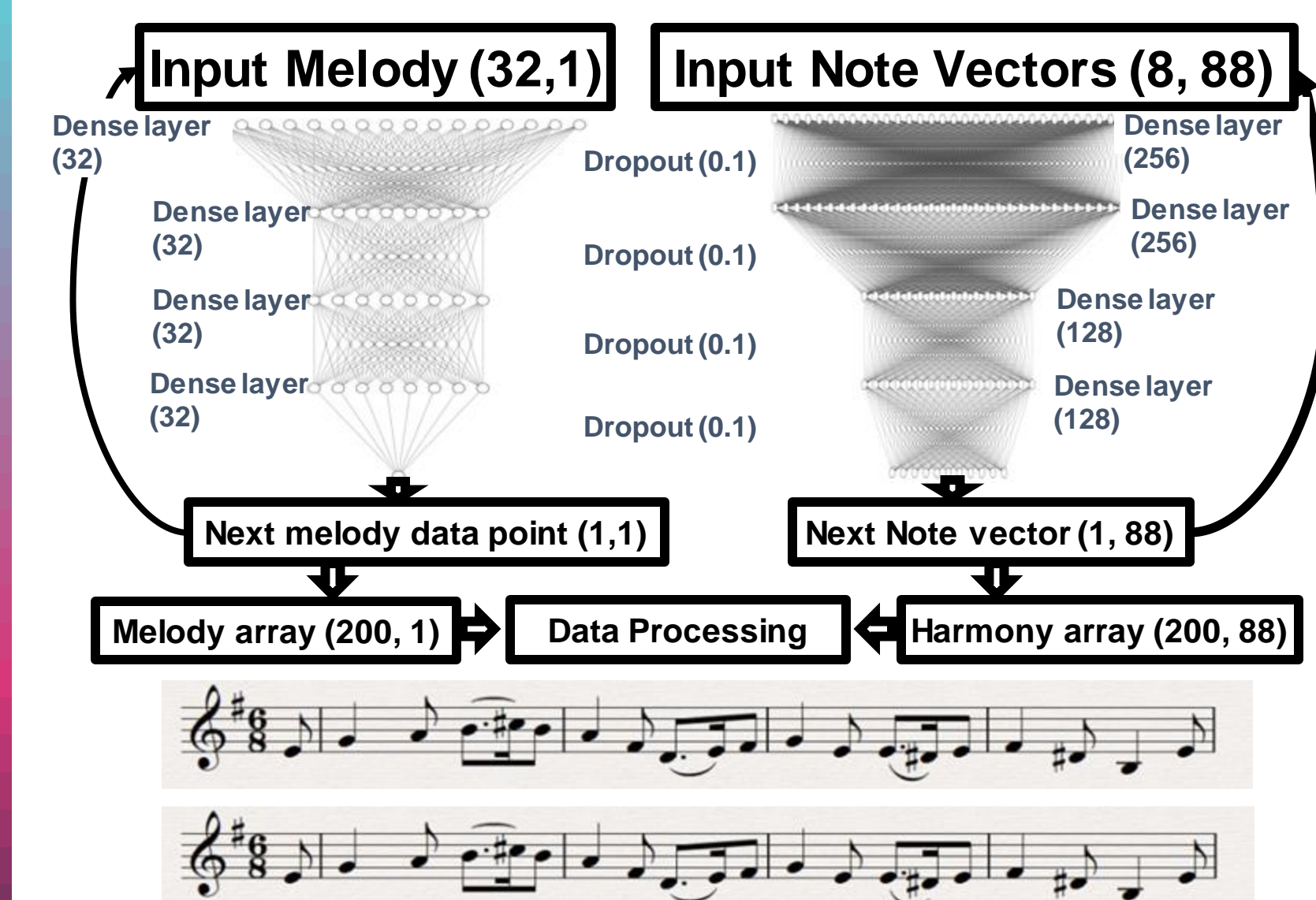
Challenge: a smart mechatronic system that creatively generates and solves a problem, and executes the solution by learning the dynamics of its environment

Goals:

- > Develop a generative AI model to produce new music
- > Reinforcement learning model that learns the dynamics of playing the music
- > Physical biomimetic model that plays the piano

Smart Robotic Pianist

AI Composer



Input Data

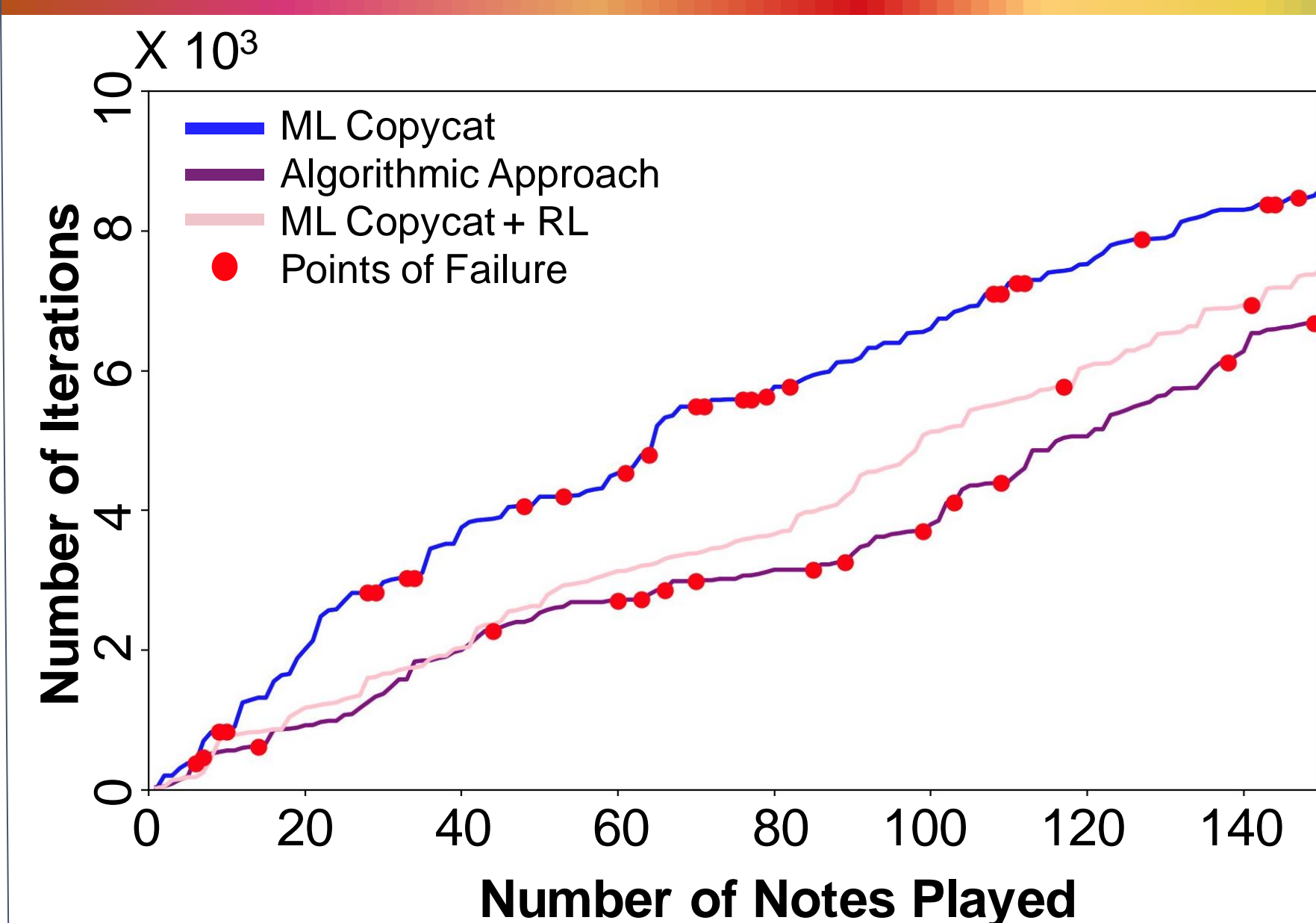
Scrape classical piano song files [1]

Convert input to time-series data (notes to play)

- Binary vector of 88 possible notes
- Time intervals between notes

Input to ML model [2]:
Previous notes and time intervals

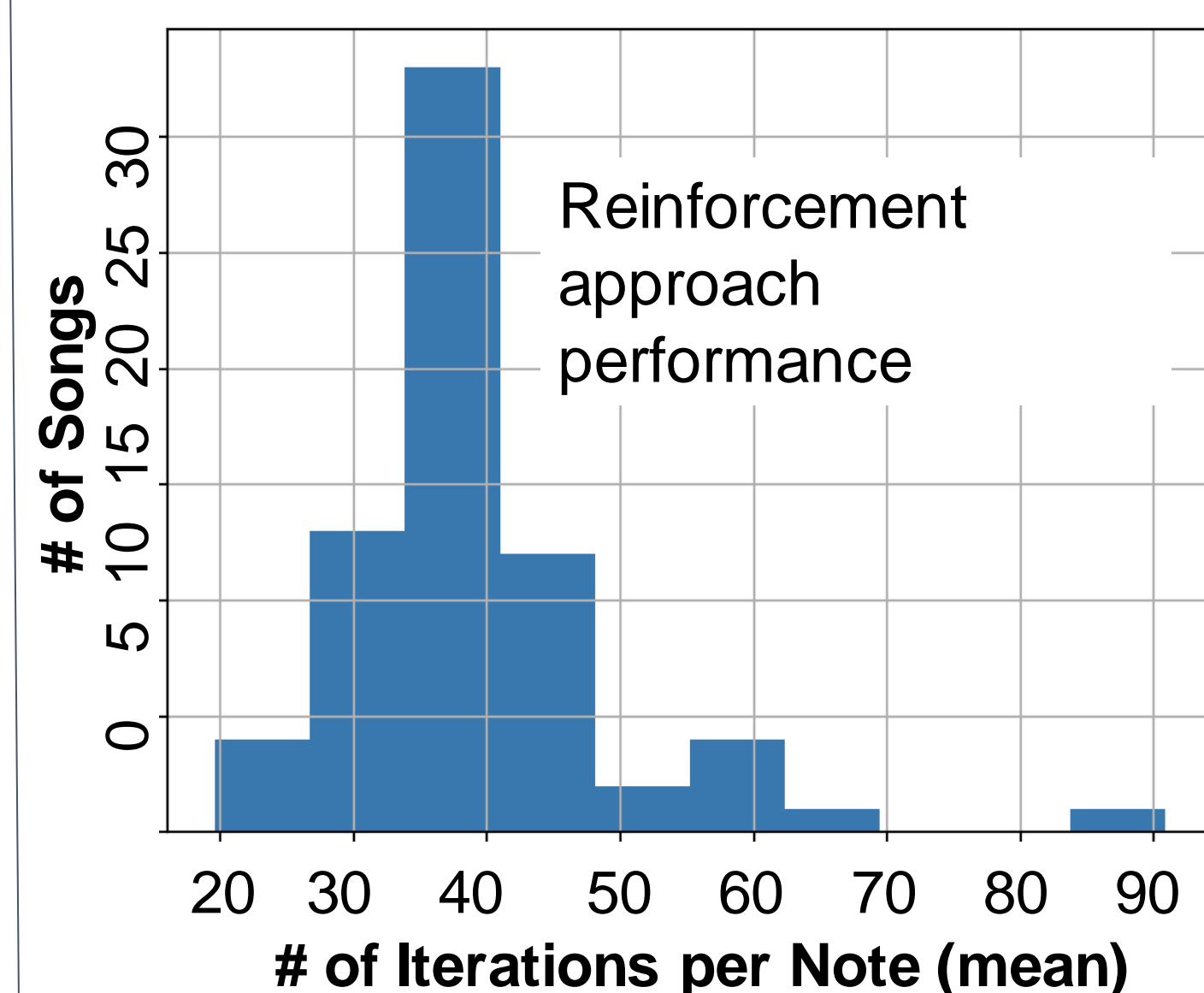
Performance Evaluation



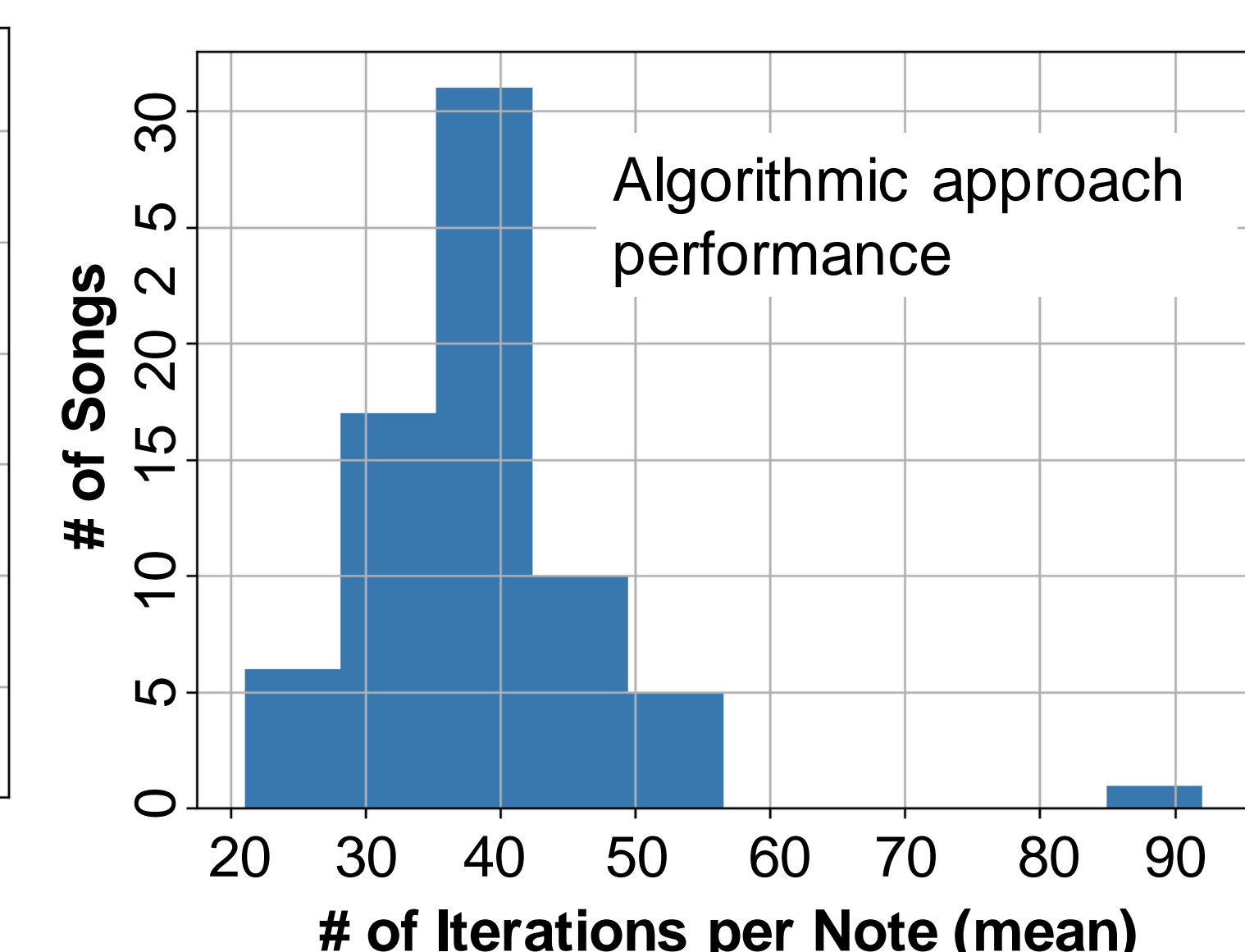
ML copycat: poor

Algorithmic approach: fast but fails to play many sections of a song

Reinforcement learning: plays both slower and with higher fidelity

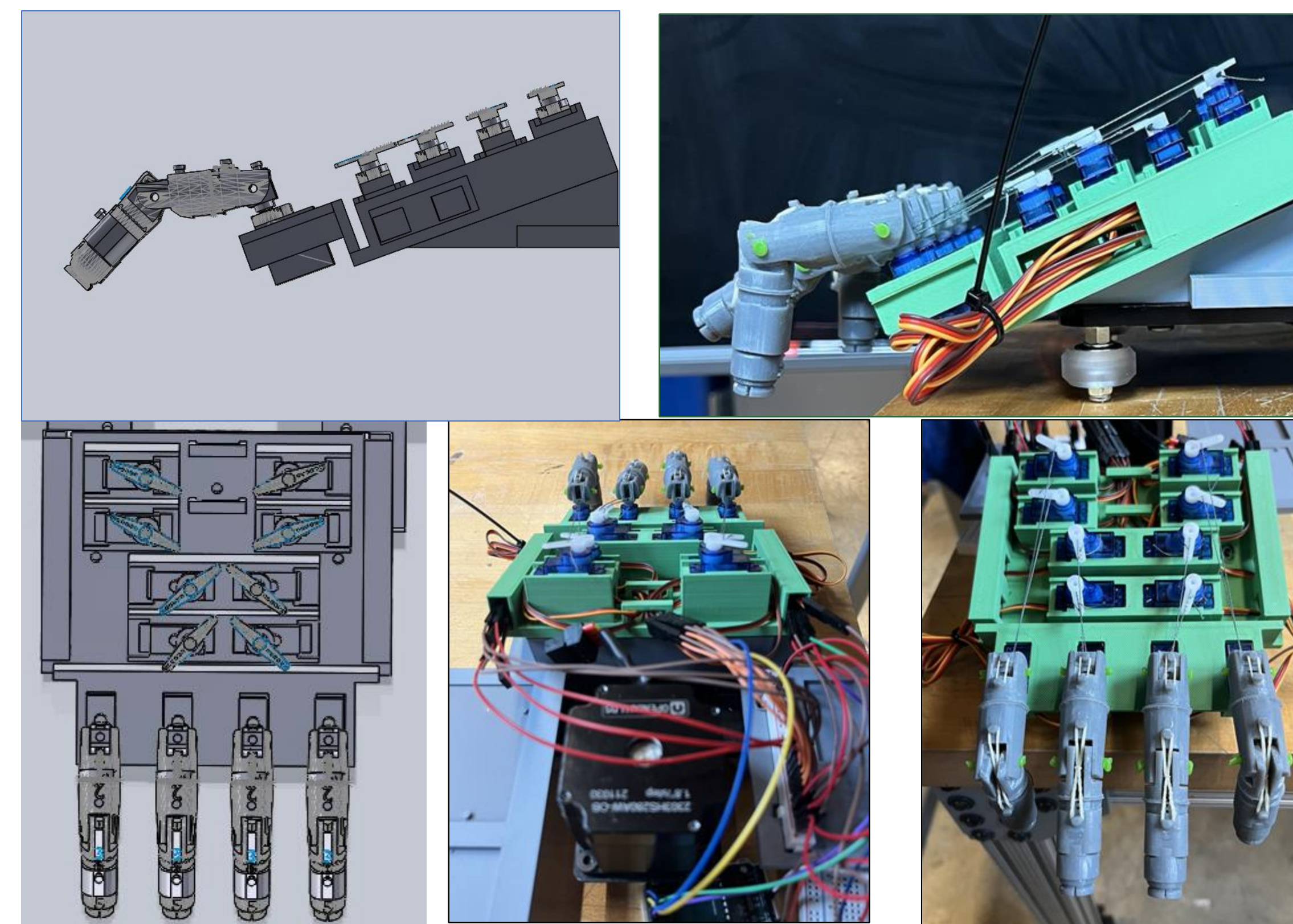


of Iterations per Note (mean)



of Iterations per Note (mean)

Mechatronics

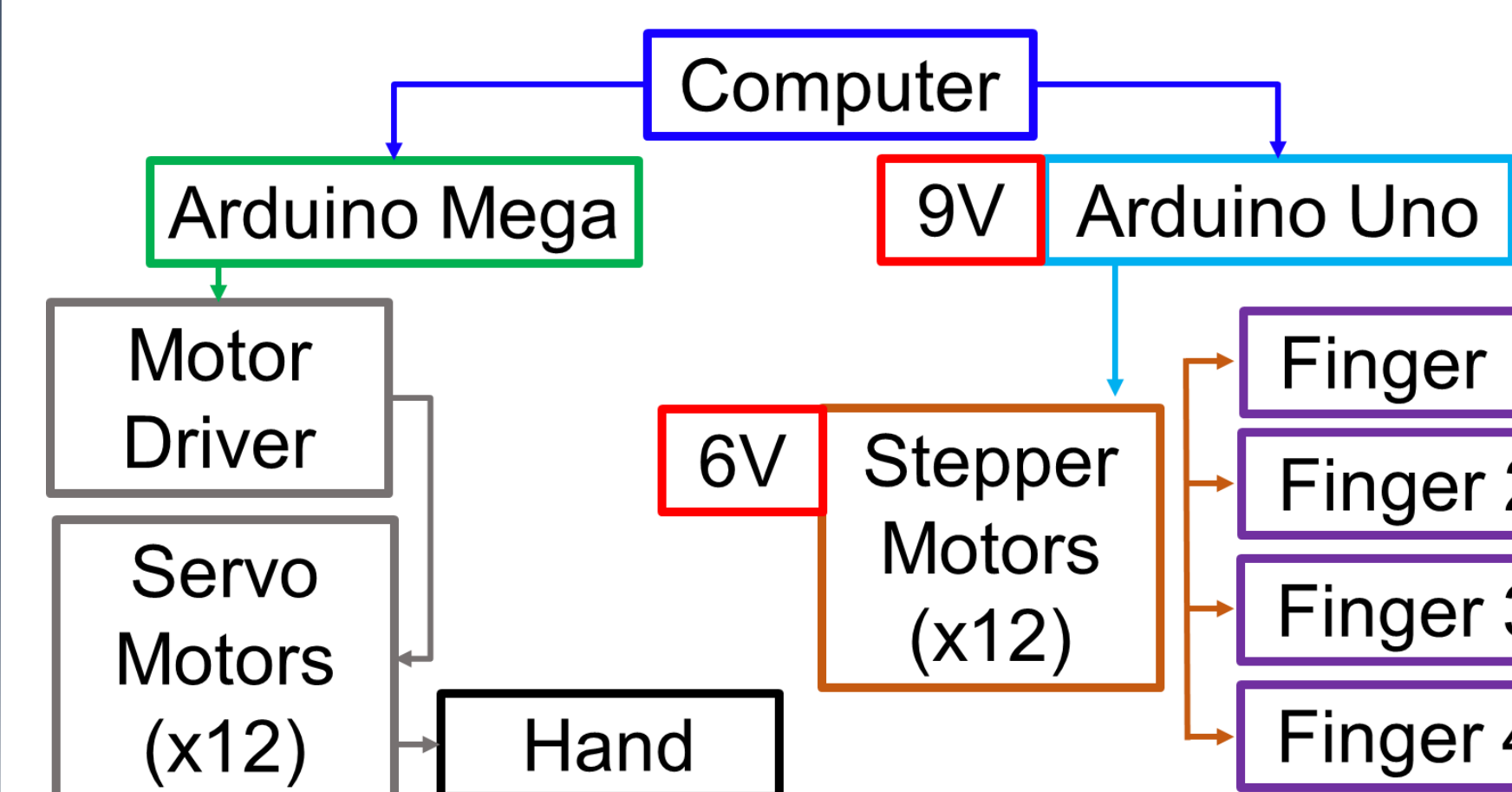


Each string system = gear reduction

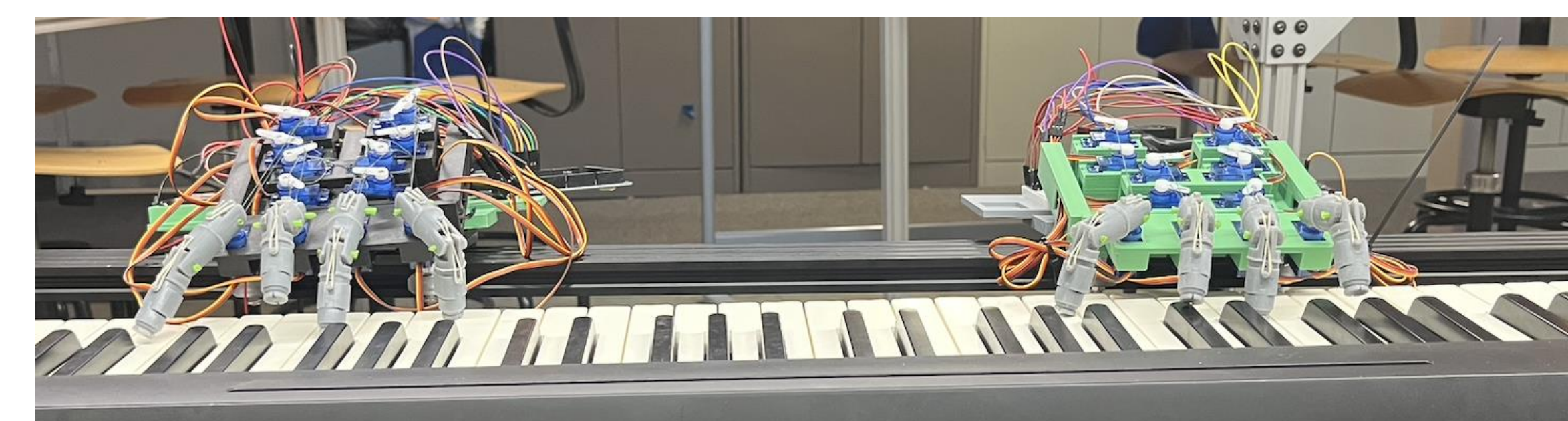
$$\frac{d\theta_p}{d\theta_s} = \frac{d\theta_p}{dL} \cdot \frac{dL}{d\theta_s}$$

$$\text{Kinematics: } \frac{dL}{d\theta_s}$$

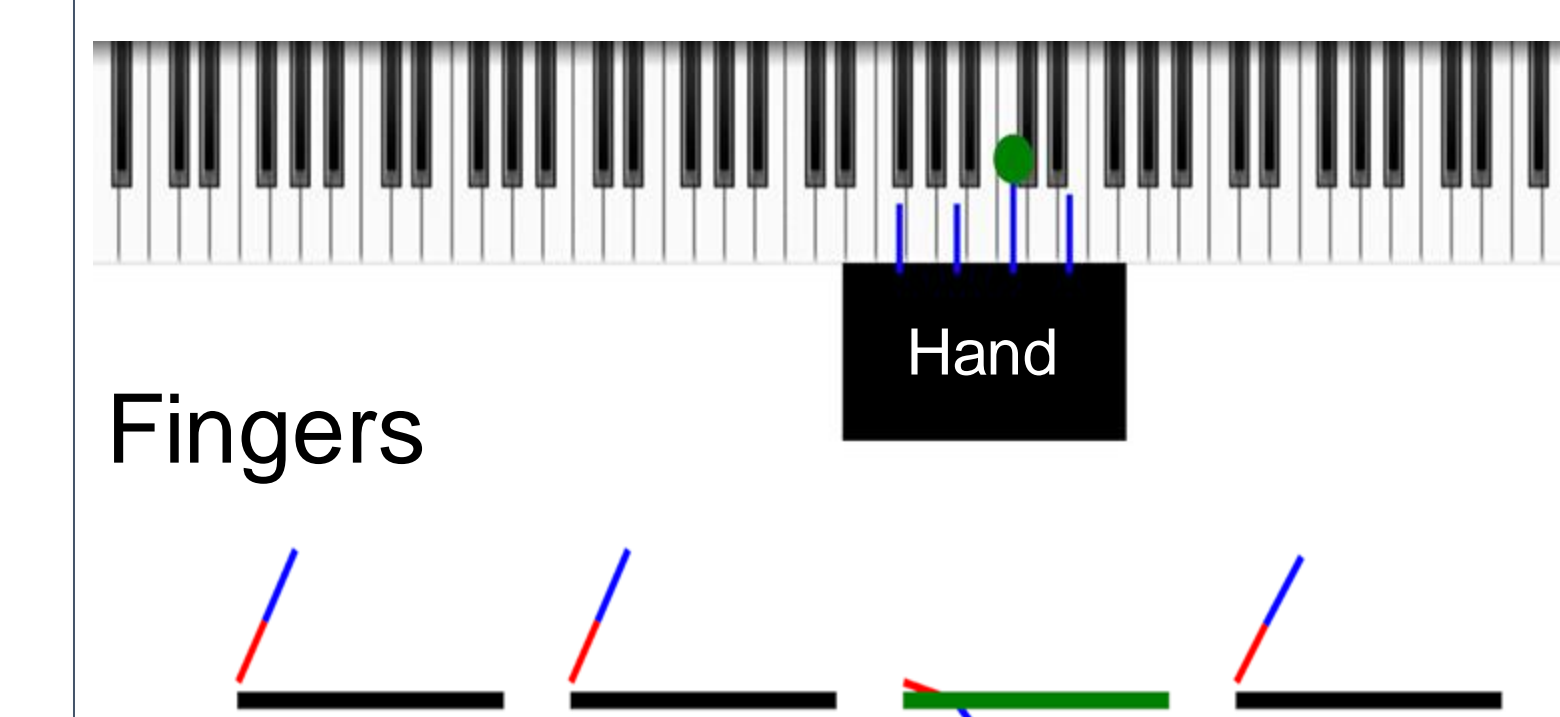
$$\text{Curve fitting: } \frac{d\theta_p}{dL}$$



Full Mechanical Model



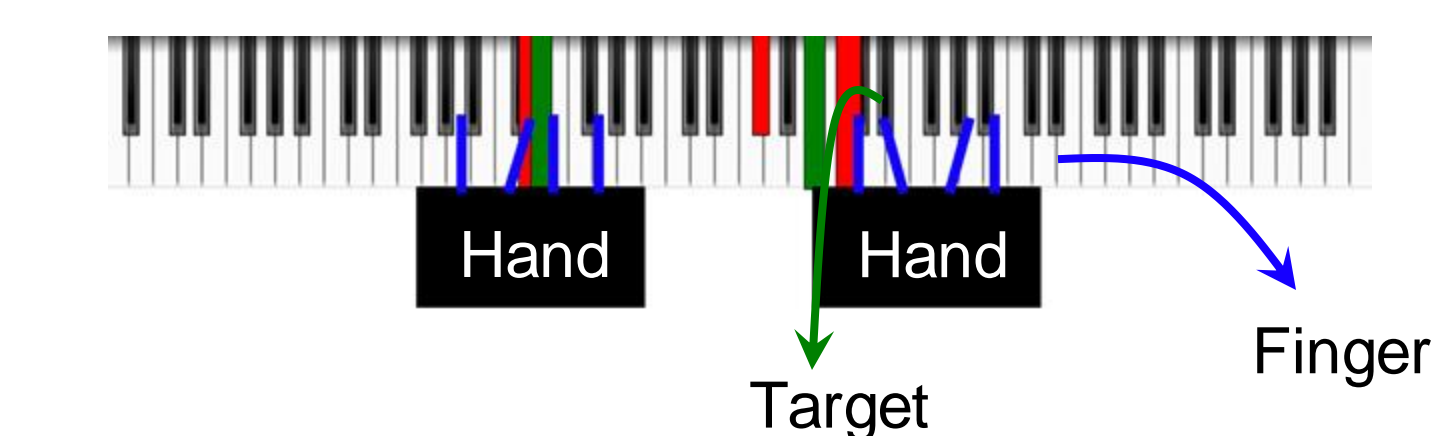
Simulation Space



- > Keys mapped into simulation space
- > Movement according to equation of motion
- > Relative position of a finger follows hand position

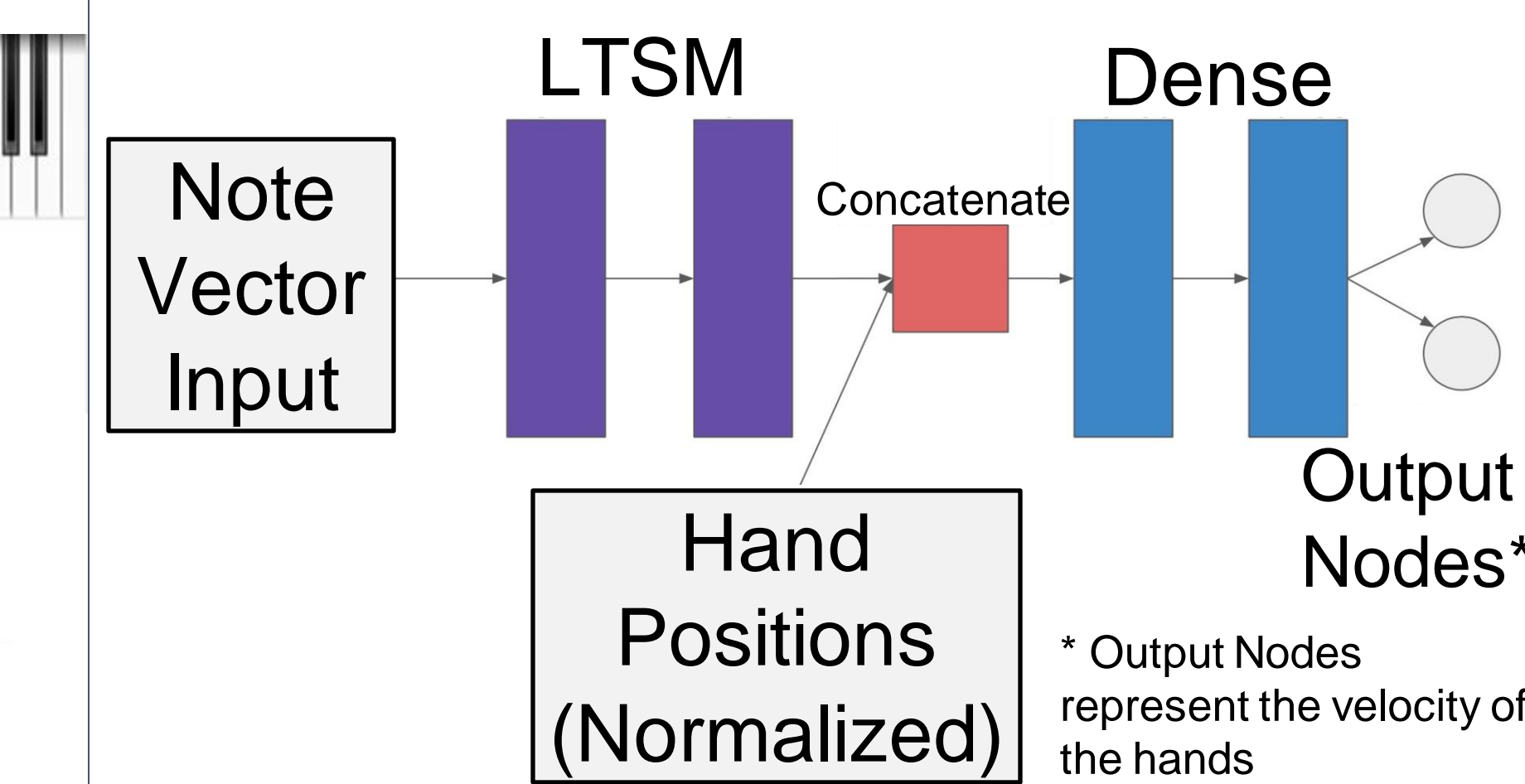
Algorithmic Player

- > Break notes into clusters for both hands
- > Hands move towards center of mass of corresponding cluster
- > Search through finger to note mappings to minimize cumulative distance
- > Repeat for next set of notes



1. Hands move to follow target
2. Fingers move to play notes

AI Player



- > Train model to mimic the algorithmic player with standard supervised learning approach

- > Train with reinforcement learning [3] using a dense reward emphasizing speed and finger fidelity

- > Train model in sparse reward environment considering future time steps

Future Work

- > Additional degrees of freedom
- > Improve the mechanical design
- > Integrate a feedback controller

- > Use the Robot Pianist to help humans learn how to play songs on the piano faster by teaching them optimal finger placement, for any song, in real time.

References

- [1] <https://www.mutopiaproject.org/>
- [2] Liang, F.T., Gotham, M., Johnson, M., Shotton, J., 2017. Automatic stylistic composition of Bach chorales with deep LSTM. In: ISMIR, pp. 449–456
- [3] Arulkumaran, K., Deisenroth, M.P., Brundage, M. and Bharath, A.A., 2017. Deep reinforcement learning: A brief survey. *IEEE Signal Processing Magazine*, 34(6), pp.26-38.