Imitation learning to understand behaviour

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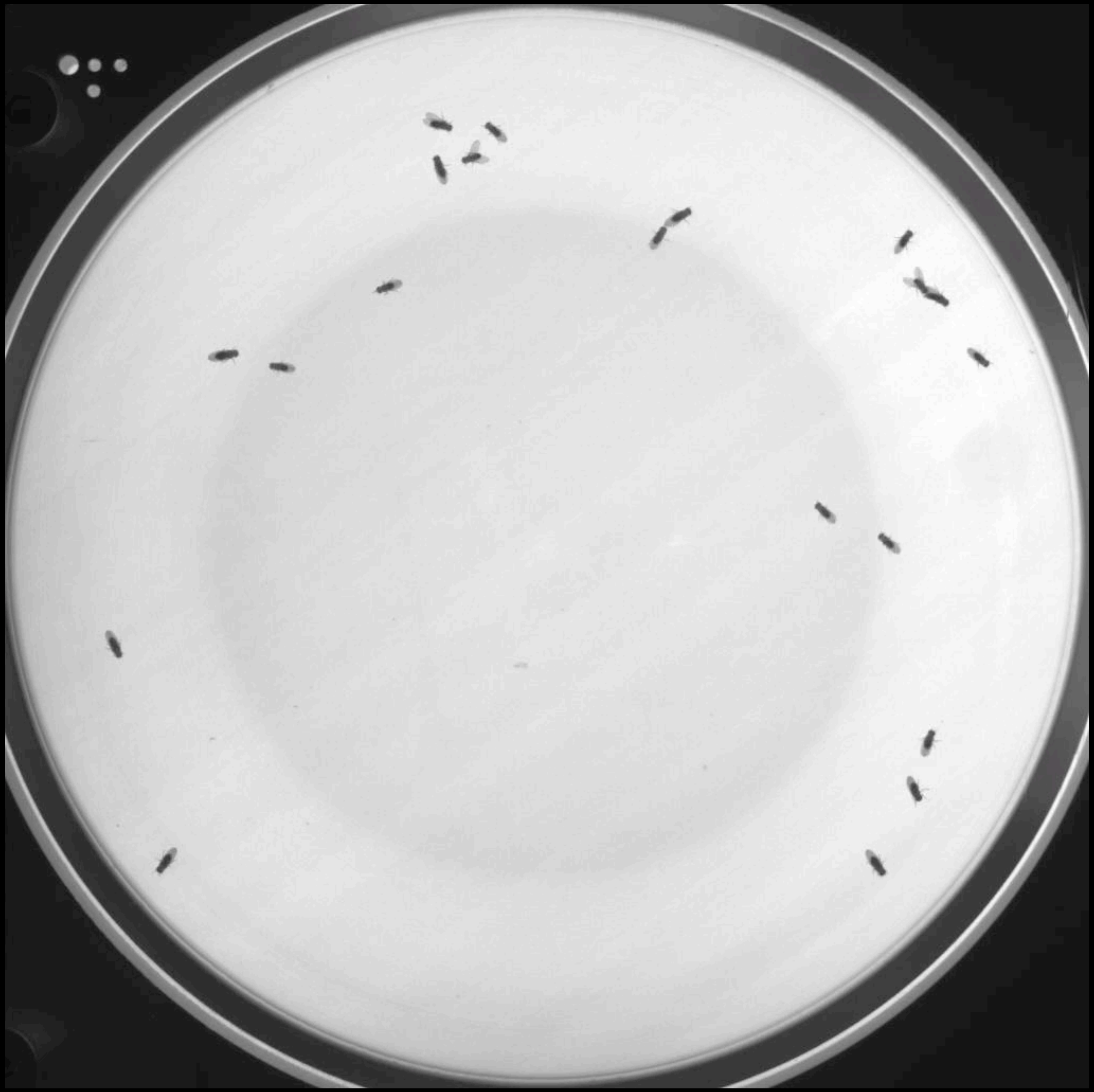
Motivation

fly behaviour are diverse and complex



Goals

To gain insight into the structure and rules governing fly behaviour.

To identify the important components for deciding fly actions.

Predicting behaviour

Pedestrian prediction for self-driving cars

Stock market forecast

Sports Analytics

Our Approach (Outline)

1. Simulate an artificial fly that behaves like a fly.

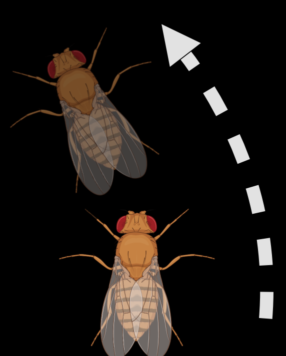
    - Using machine learning (ML), we build a black box model that produce fly behaviours without explicit rules, instead by pattern recognition and inference from the data

2. Interpret and understand the behaviour of artificial fly

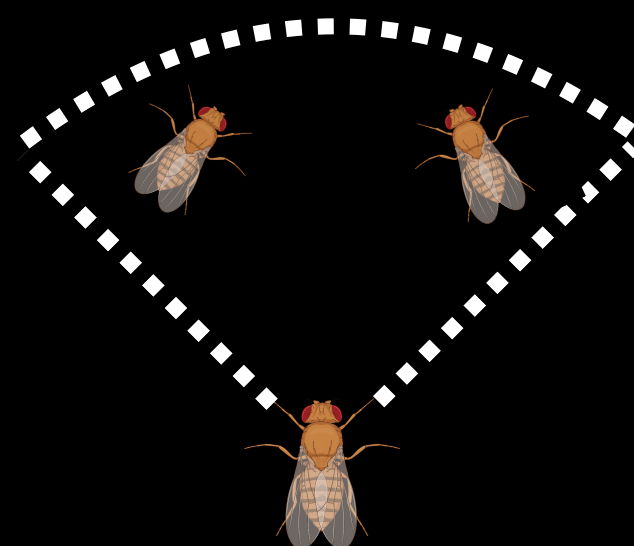
    - Do controlled experiments: psychophysics studies and look into how black box model functions

Quantifying behaviour

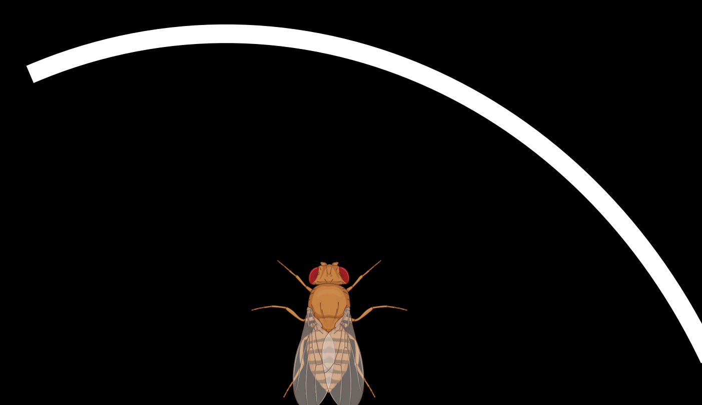
Approximate ...



what fly is doing

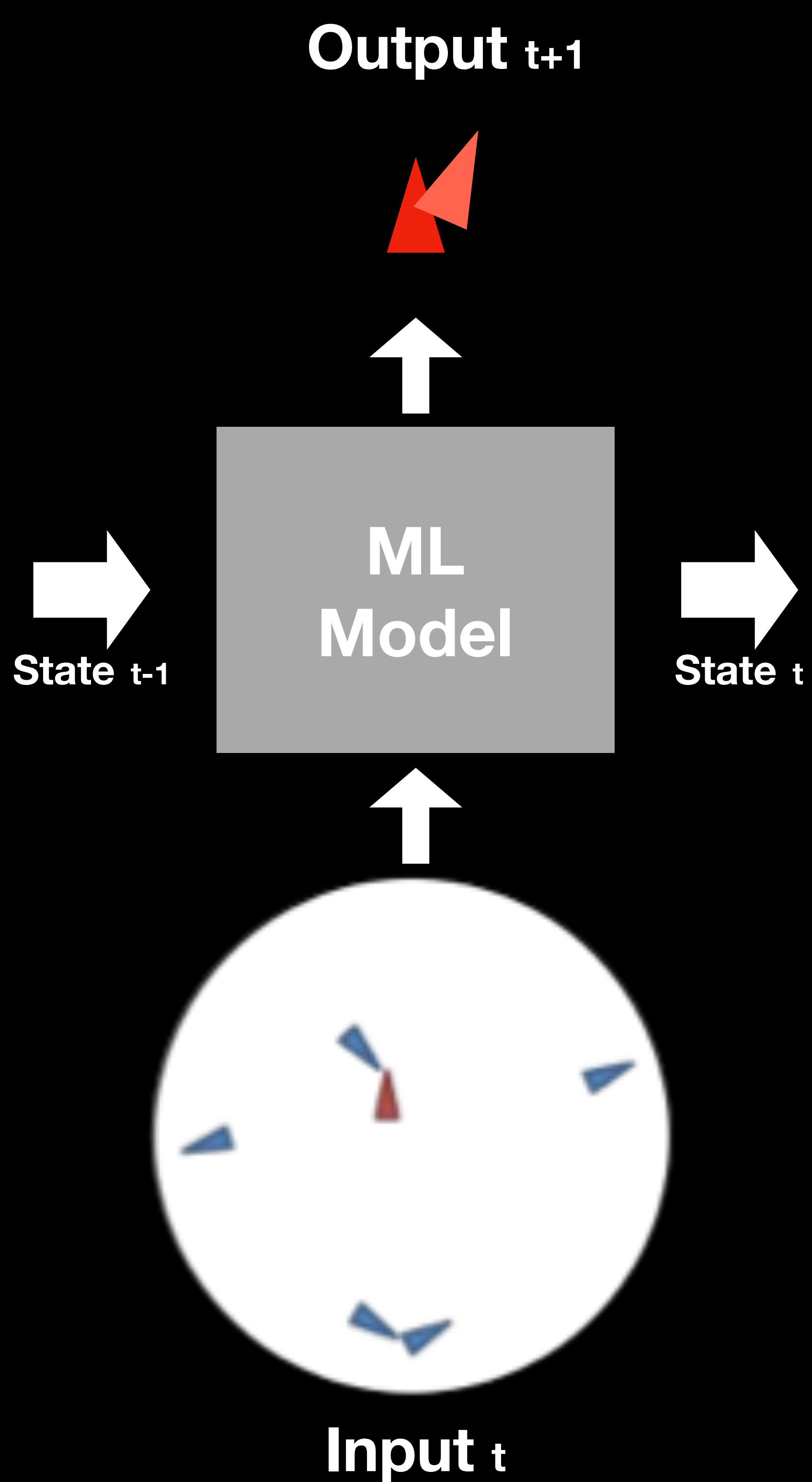


what fly is seeing



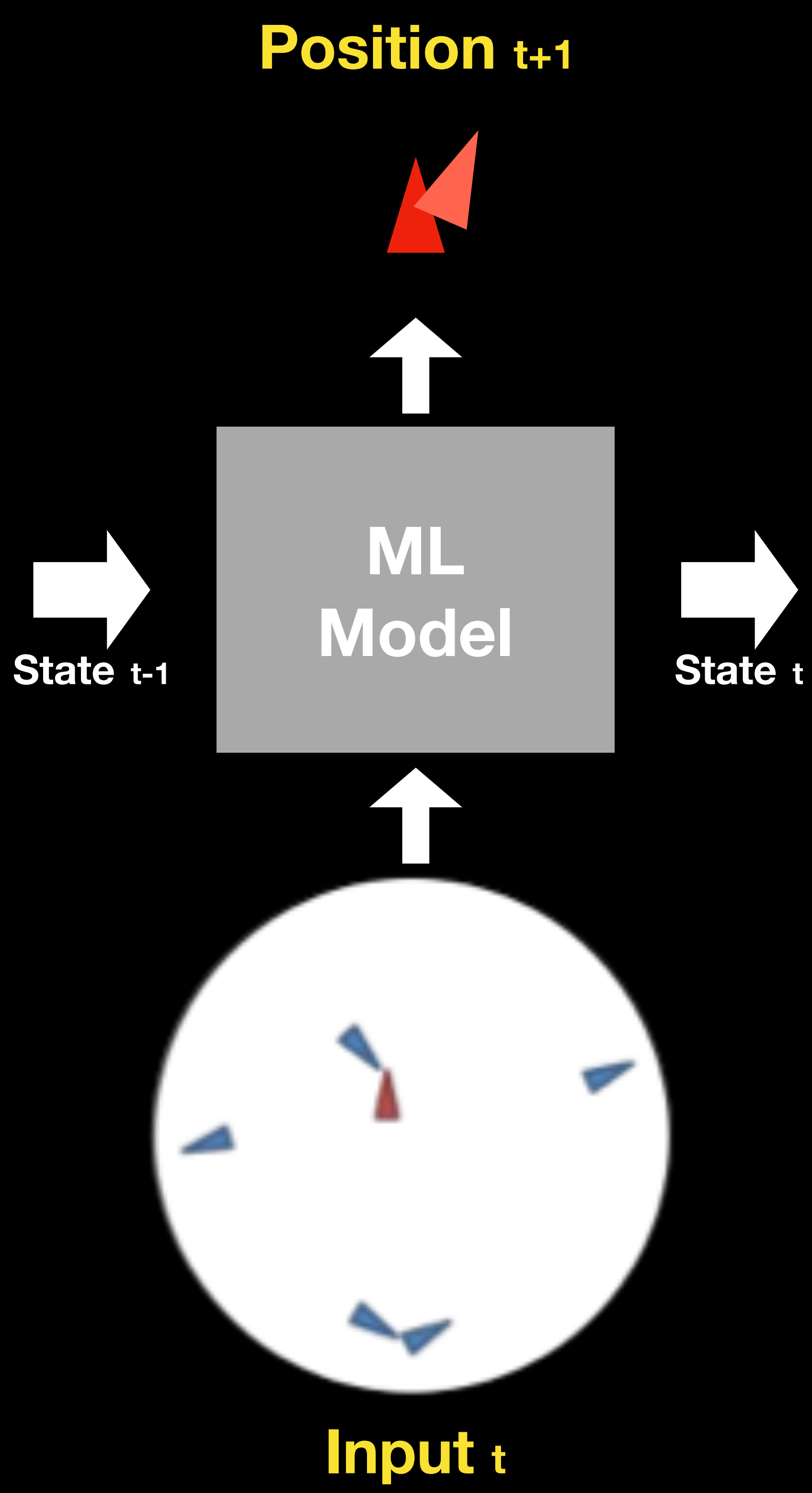
its relative position to the chamber

Predicting the next movement



State t-1 : Learned representation of past

Predicting the next movement



Predicts 8 motion features:

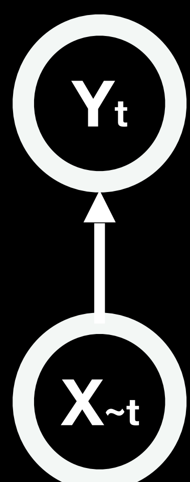
- Forward velocity
- Side velocity
- angular velocity
- Left & right wing length
- Left & right wing angle
- Body length

Model Architectures

X_t - Output
X_t - Input
U_t, L_t - Intermediate layers

Model Architectures

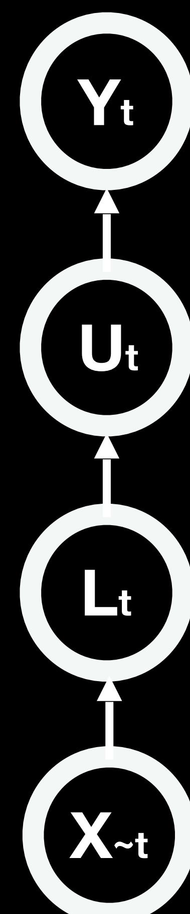
LINEAR



Simple model:

Linear Regression

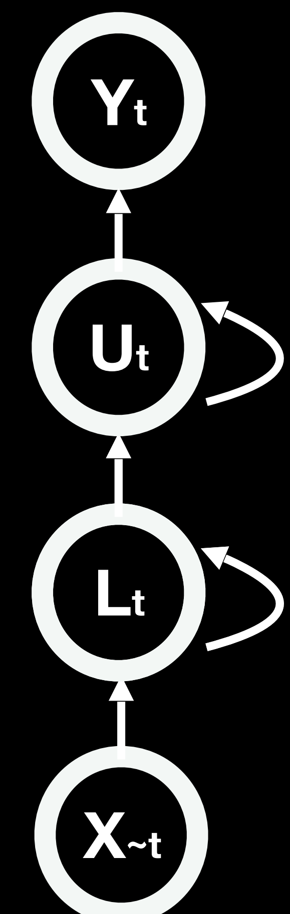
CNN



Feedforward model:

Convolutional neural network

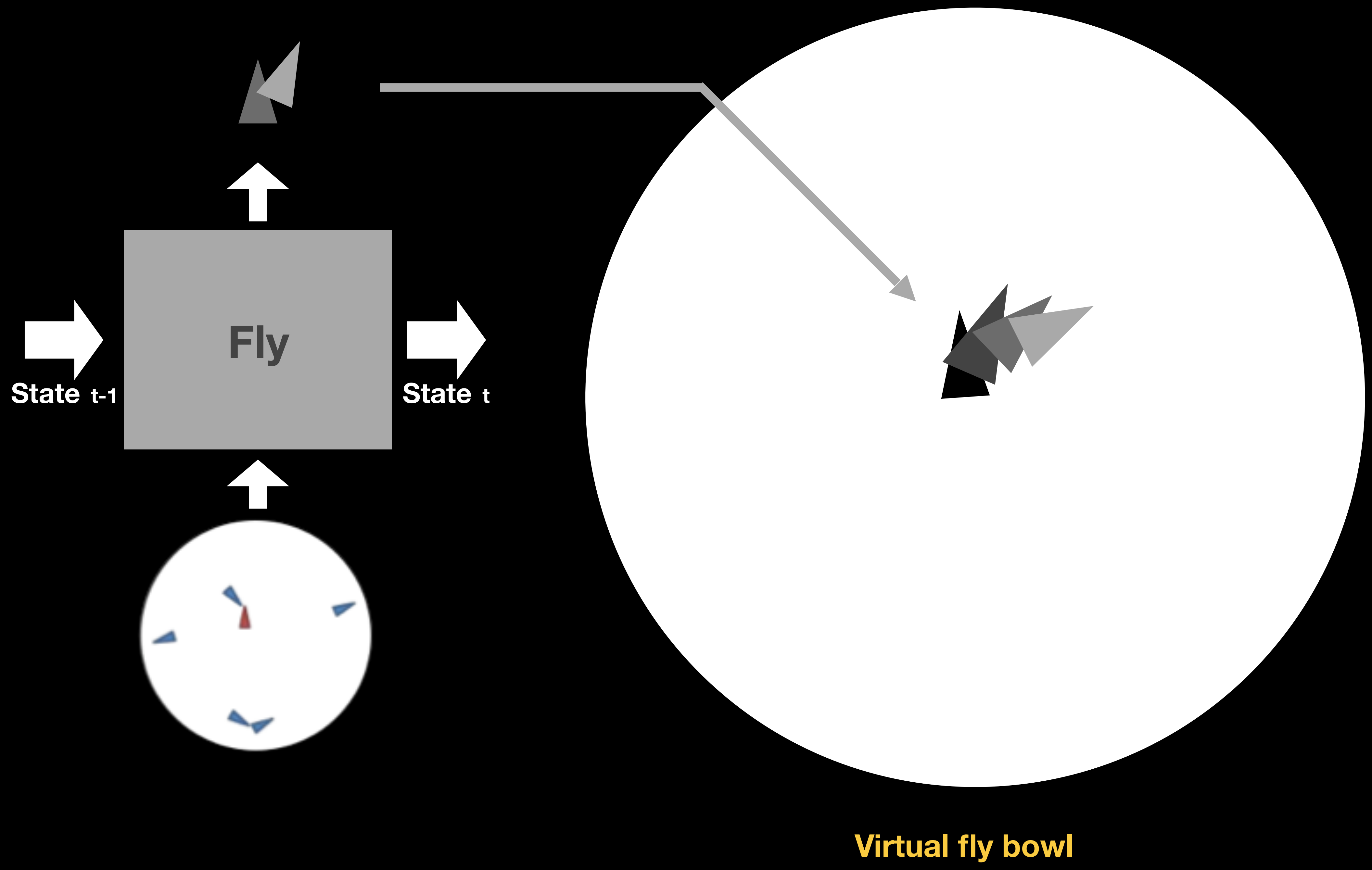
RNN



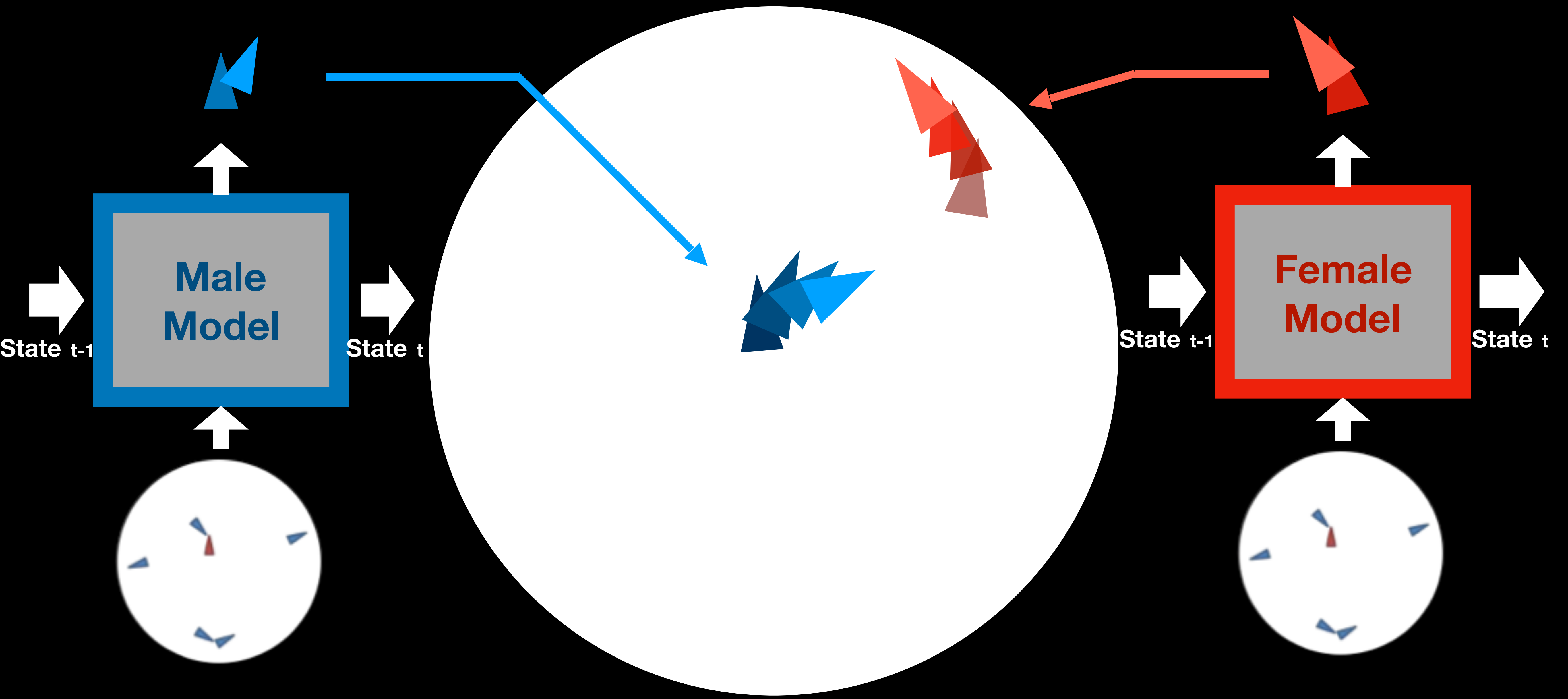
Model with memory:

Recurrent neural network

Artificial fly is an agent

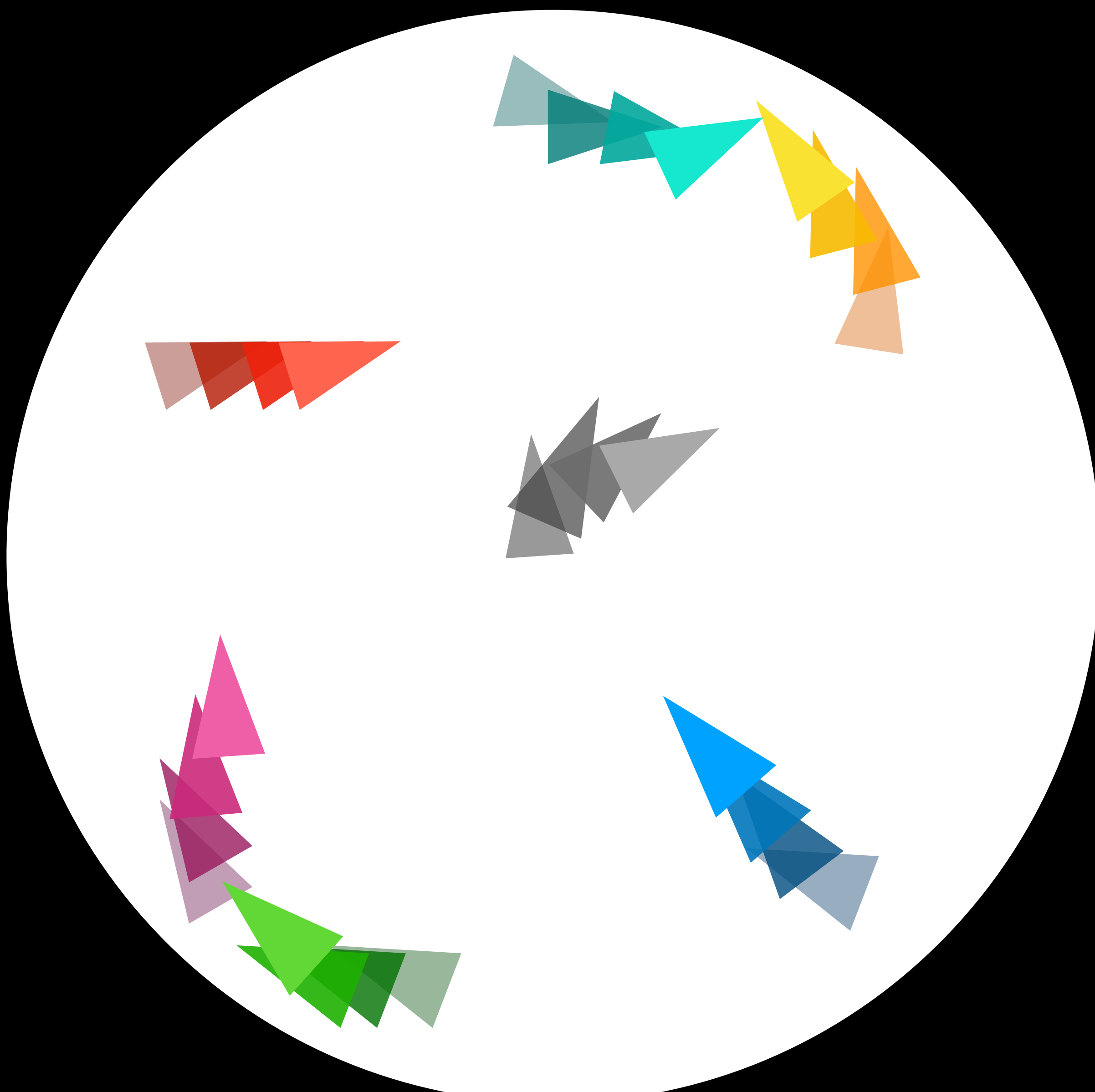


Artificial male & female fly



Multi-agent system

Social interaction system



The behaviours that we consider to differentiate between real versus simulated flies:

- Movement patterns
- Avoiding obstacles
- Exploring the edge of the arena
- Social interactions

Simulations

Simulations

Videos

RNN

Real Data

CNN

LINEAR

Artificial Fly Evaluation

Goal: Simulated fly to use mechanisms that real fly is using.
How to measure how true this is?

Artificial Fly Evaluation

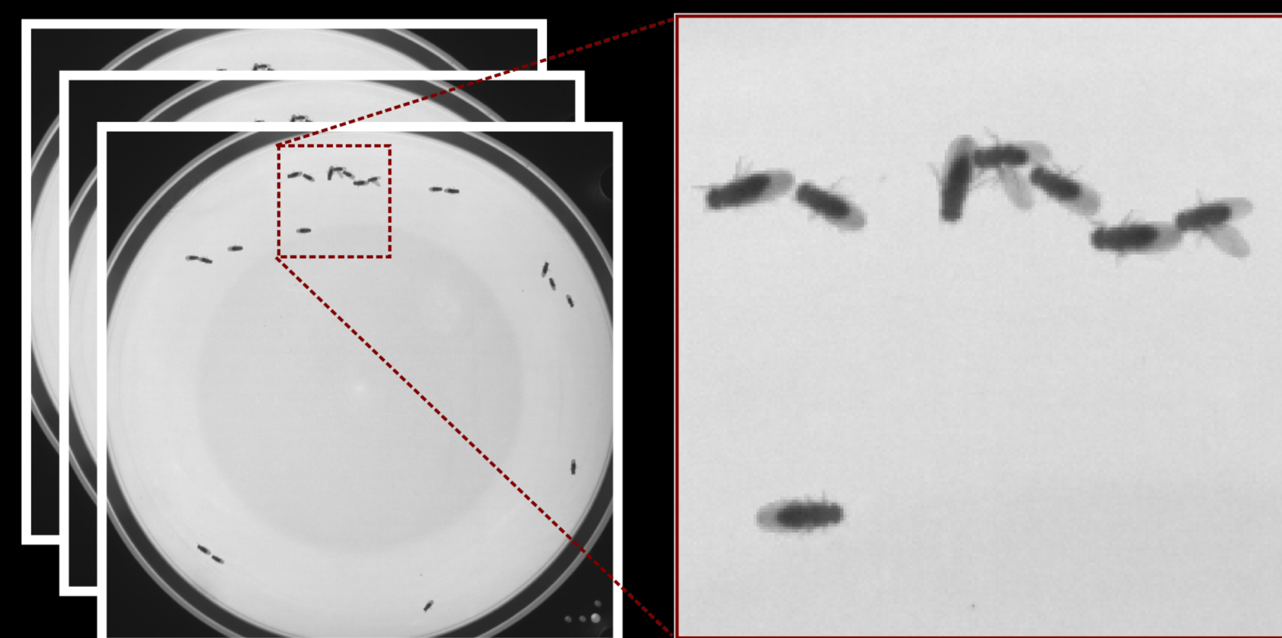
Self-driving car

Performance Metrics:

Is it hitting the pedestrians?

VS

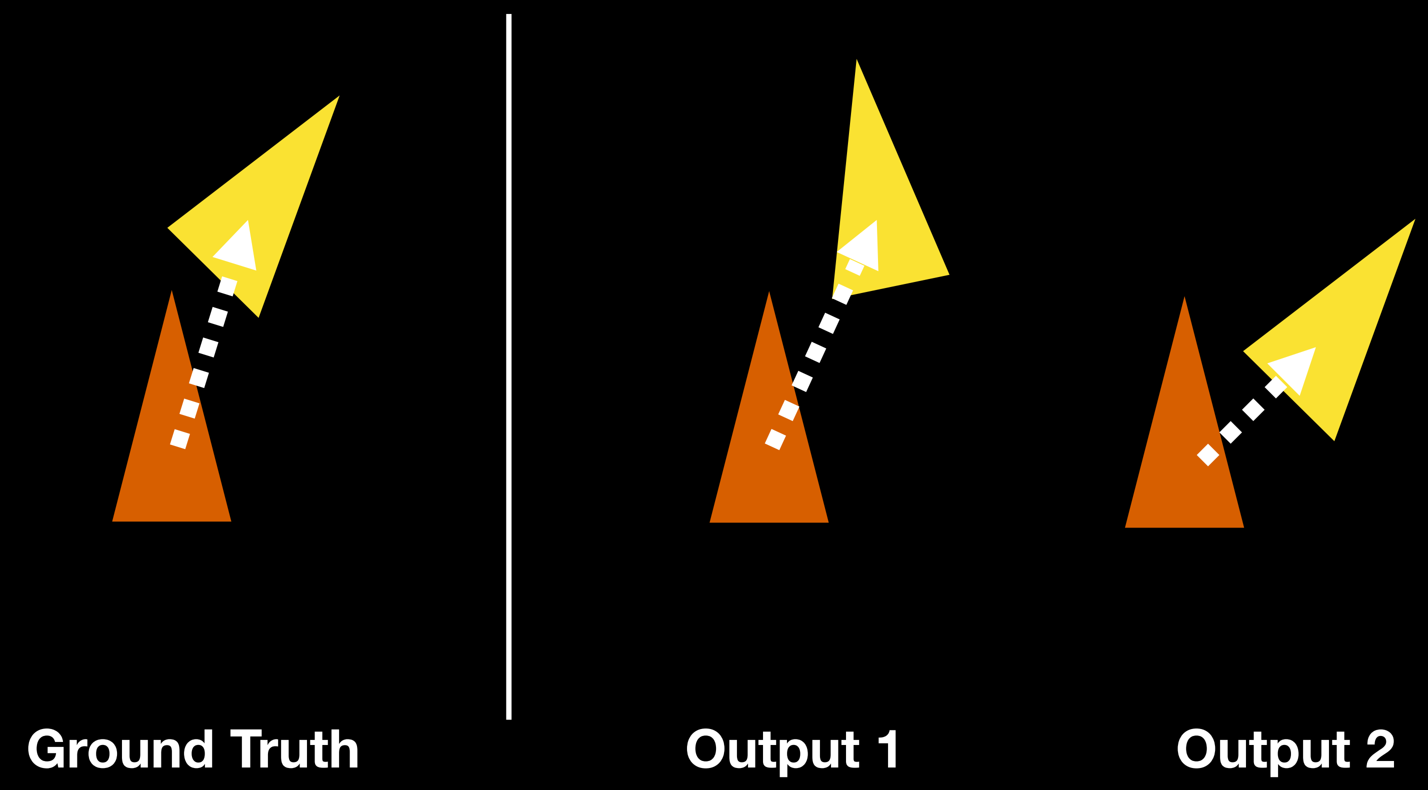
Fruit fly



What metric is meaningful for predicting behaviour?

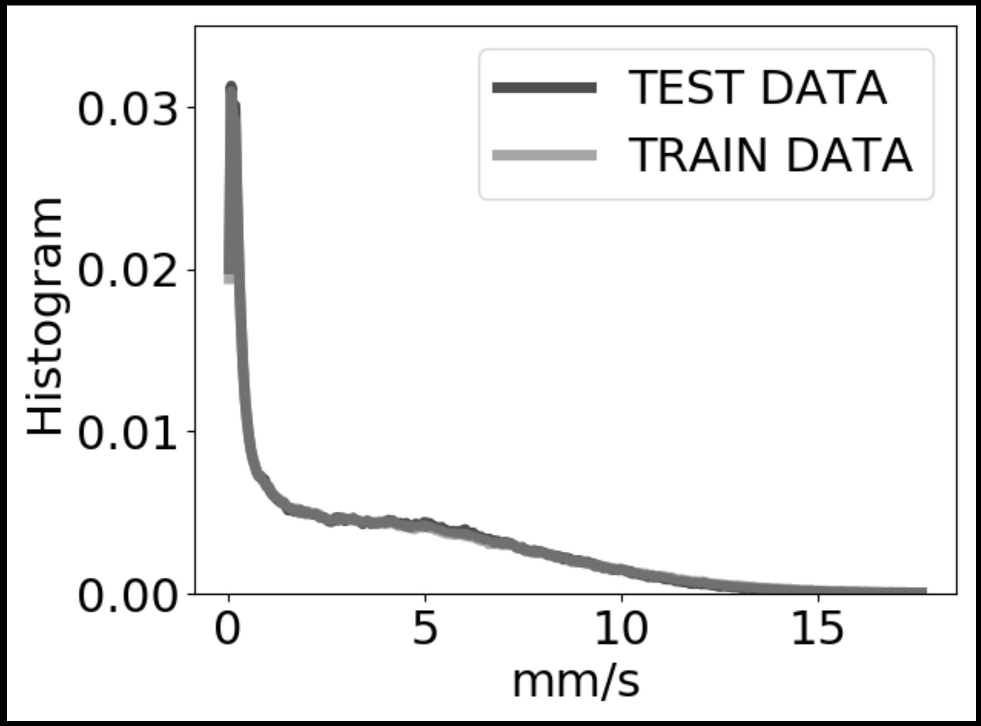
Artificial Fly Evaluation

What type of difference matters more?

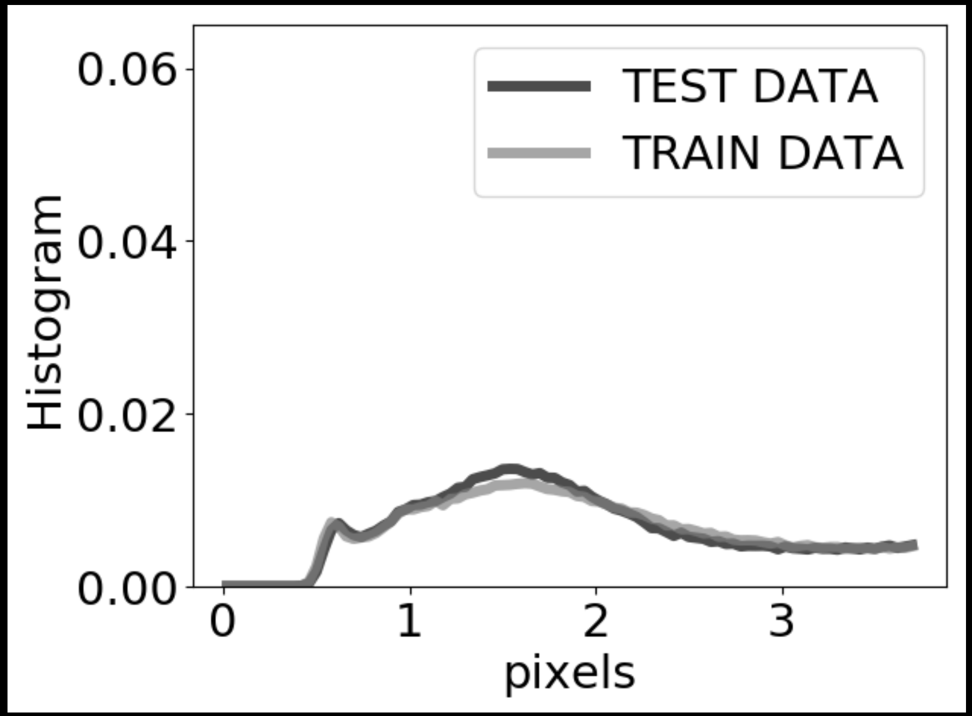


Evaluation : Distribution Distance

Velocity

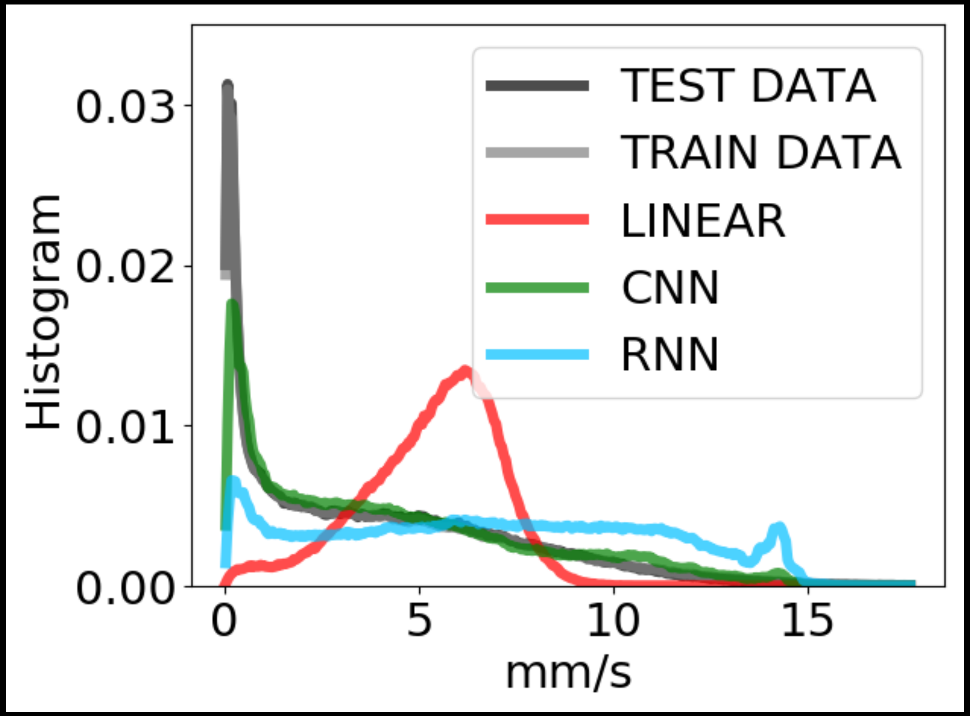


Closest distance between flies

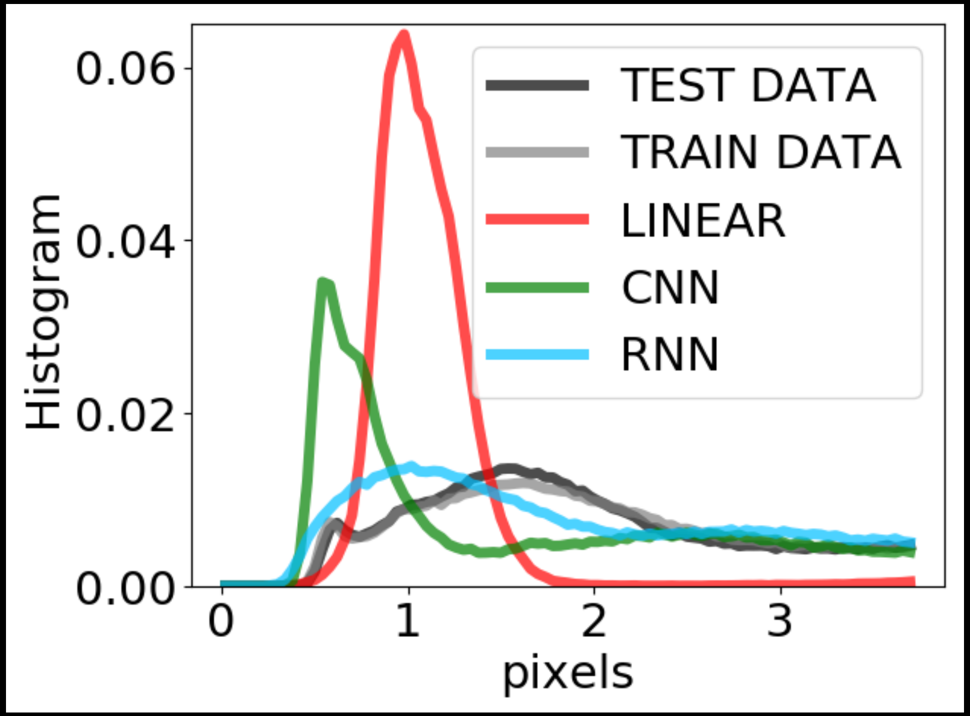


Evaluation : Distribution Distance

Velocity

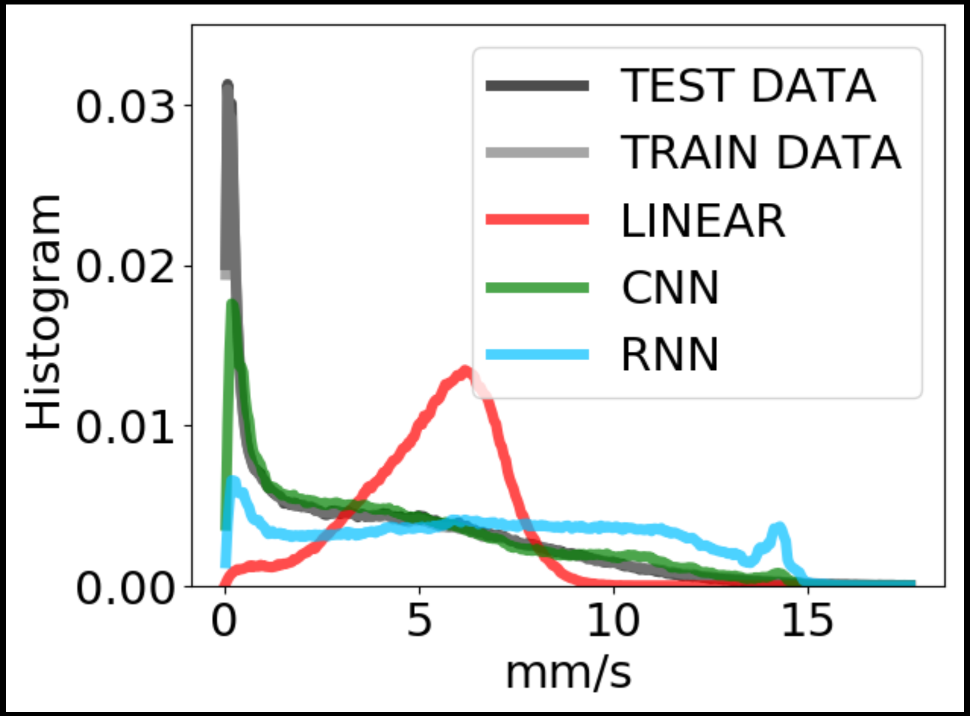


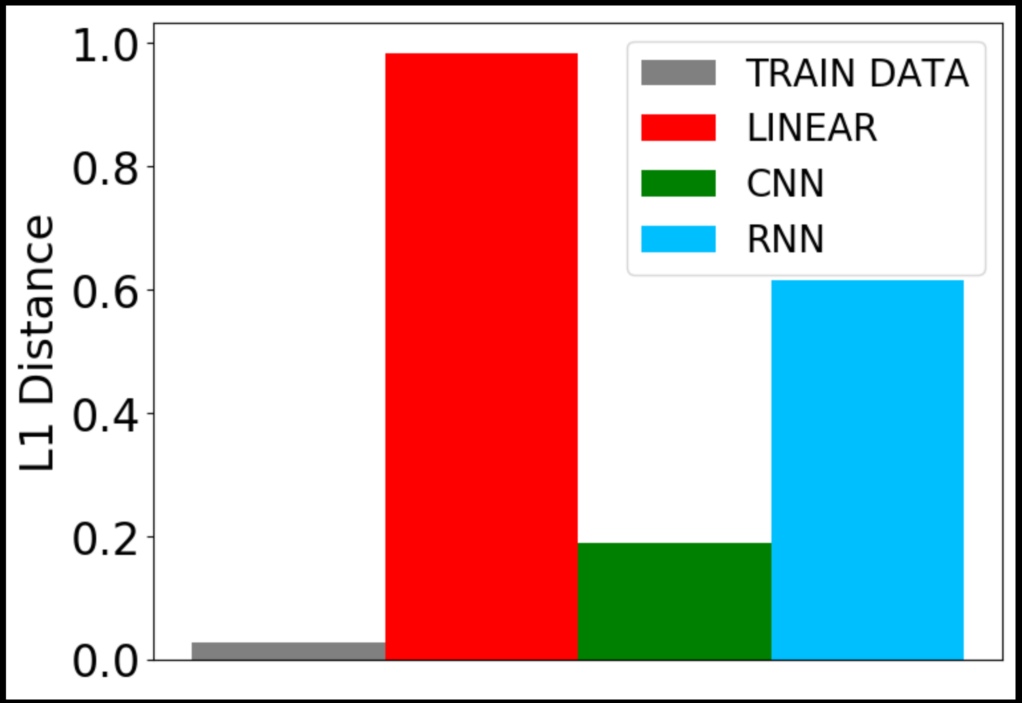
Closest distance between flies



Evaluation : Distribution Distance

Velocity

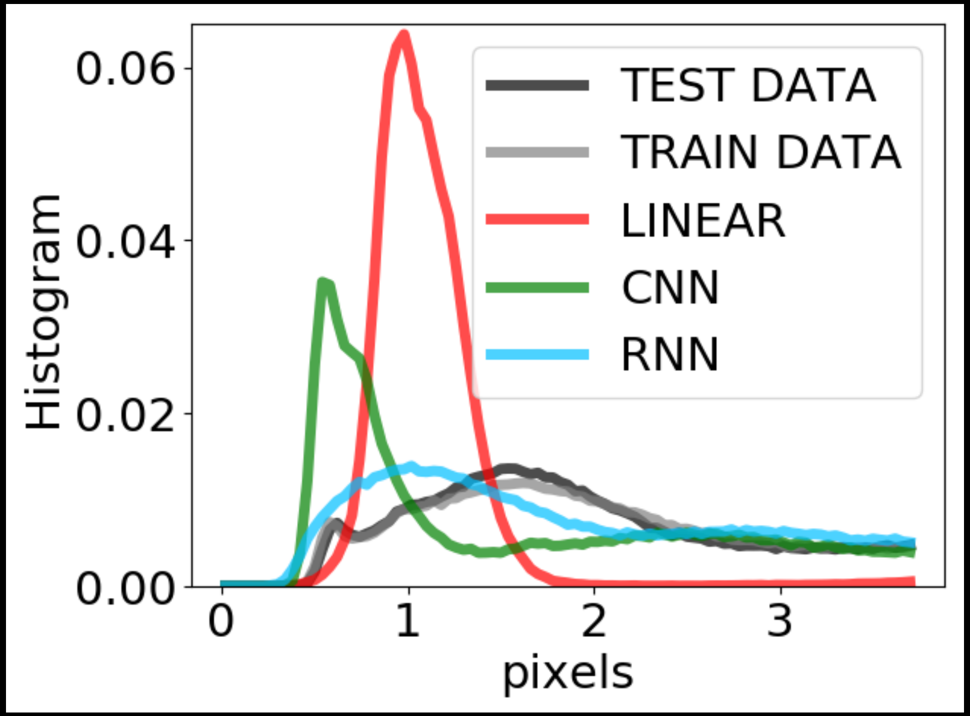


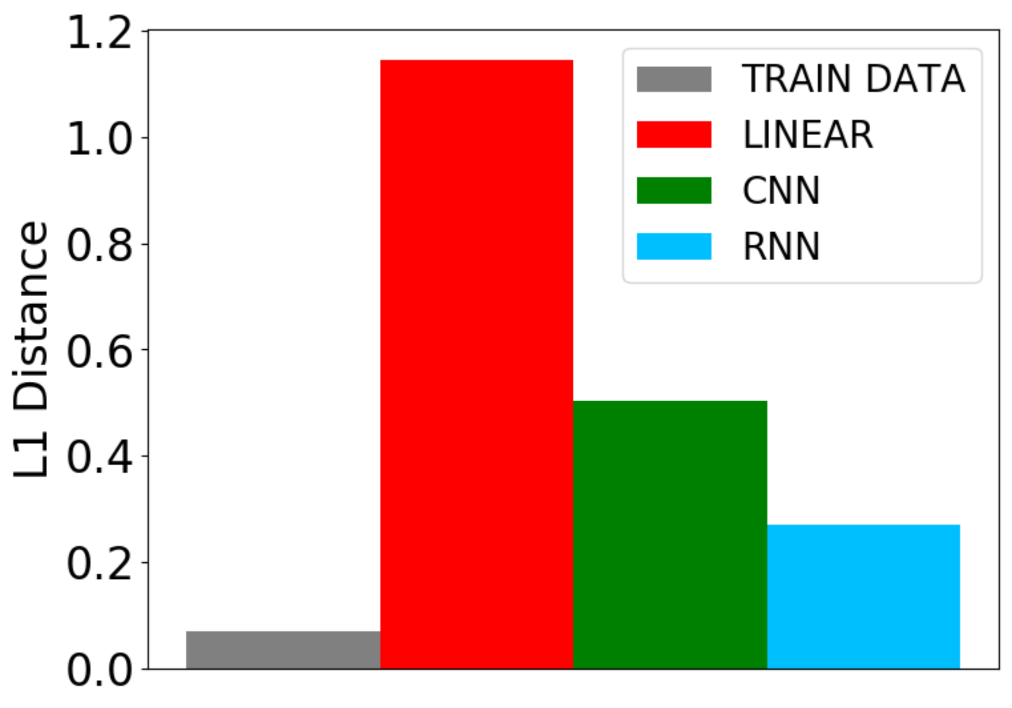


Other Features:

- Distance to wall
- Angular velocities
- Wing angles

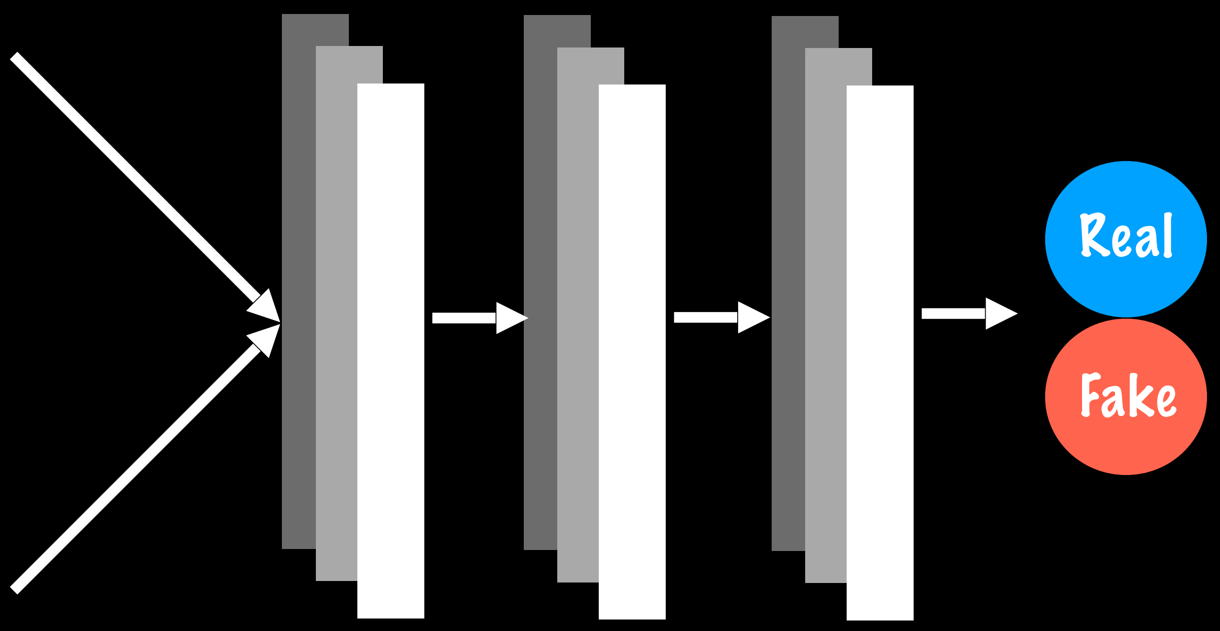
Closest distance between flies





Evaluation : Real / Fake Discrimination

Real Trajectory

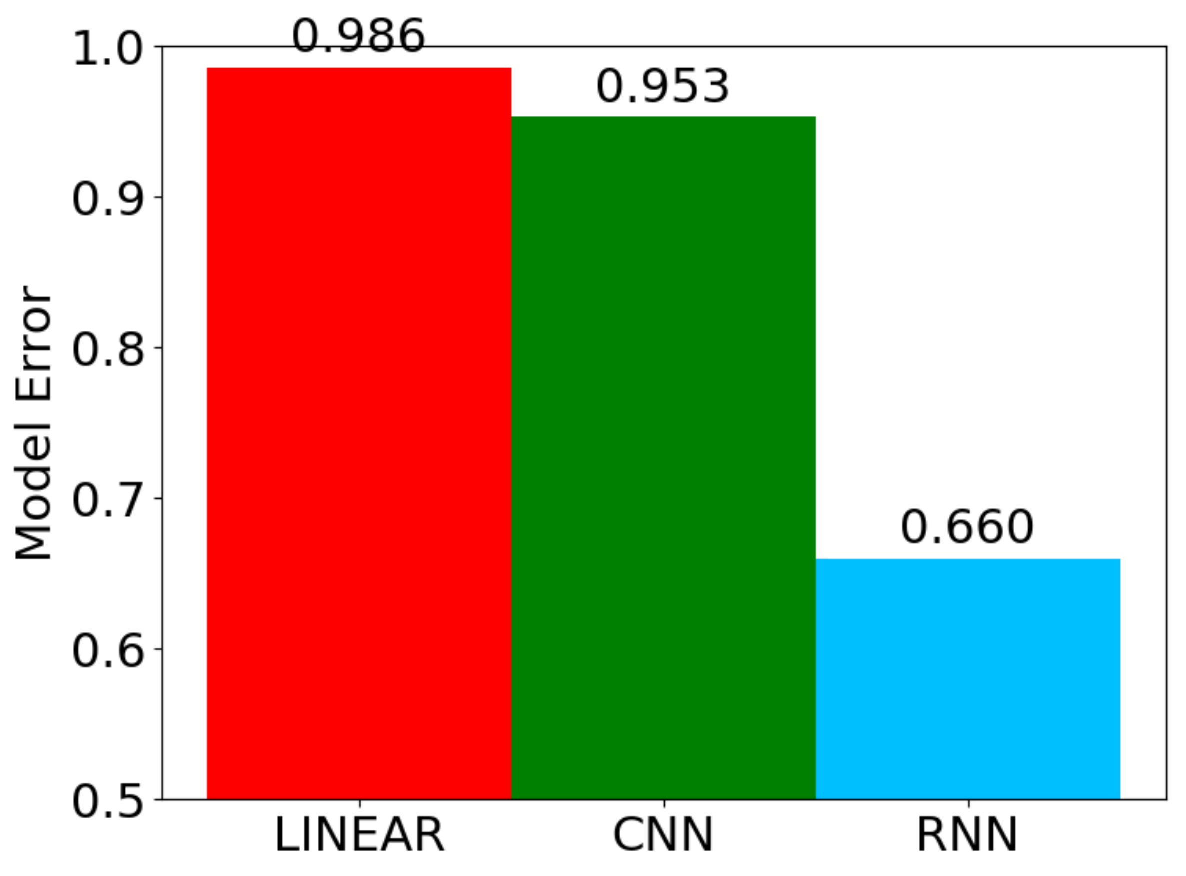


Discriminative Network
Distinguish whether the trajectories are real or fake

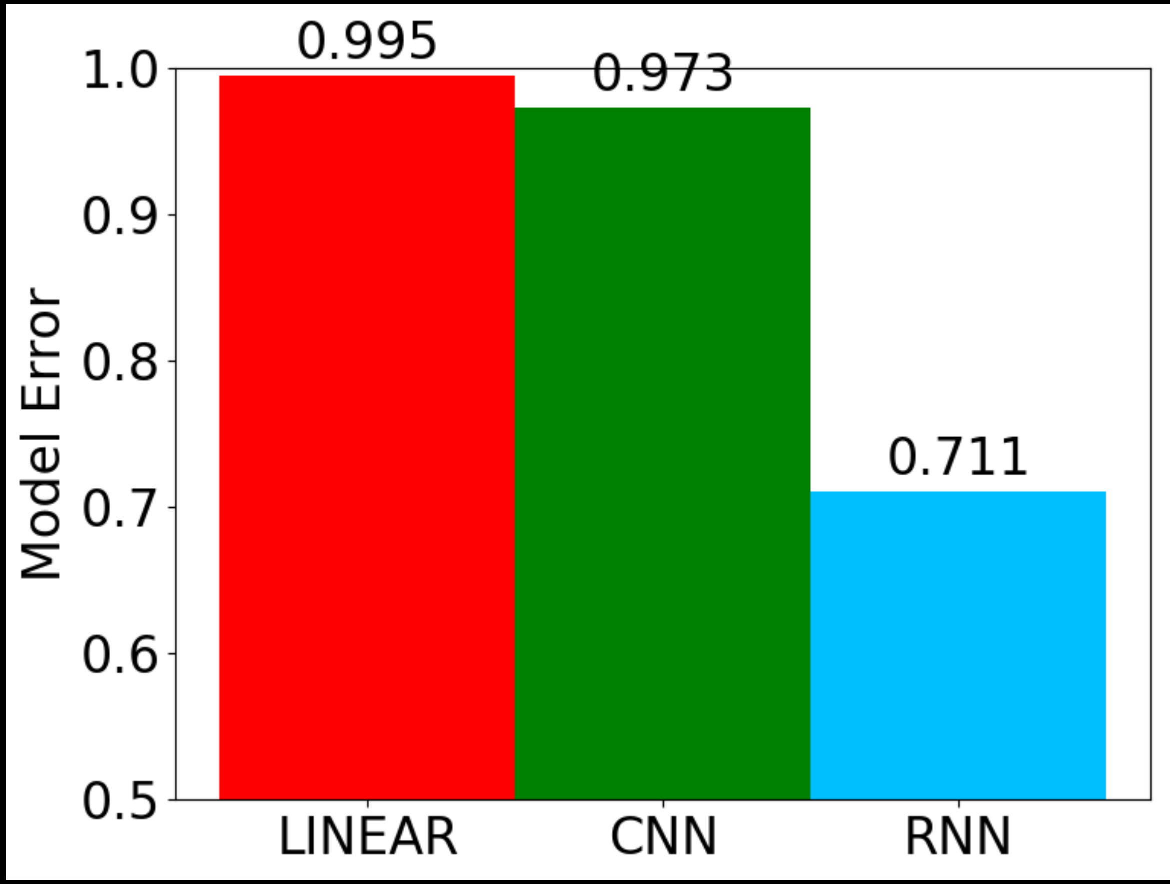
Simulated Trajectory

Evaluation : Real / Fake Discrimination

Male



Female

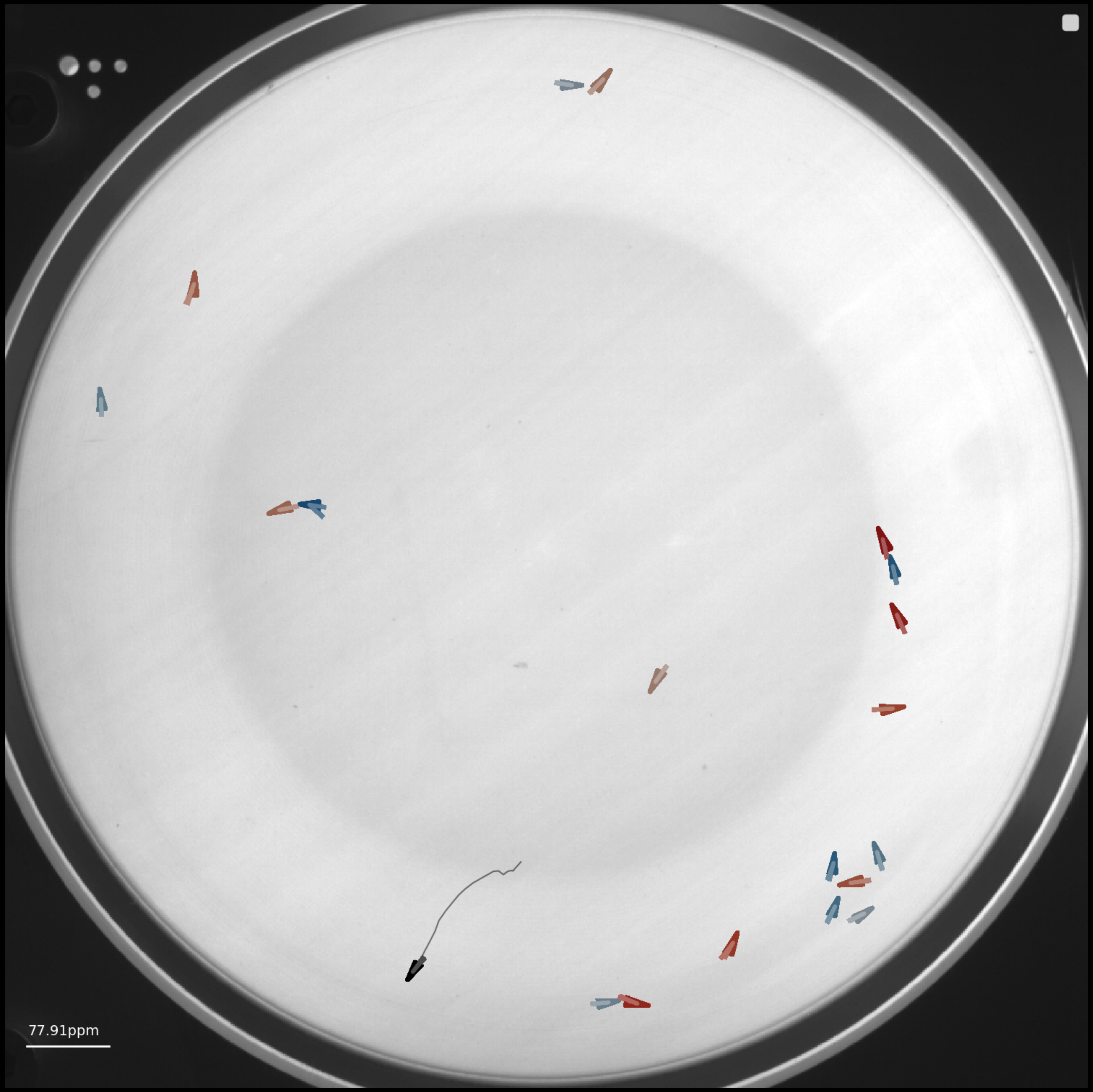


Our Approach (Outline)

1. Simulate an artificial fly that behaves like a fly.

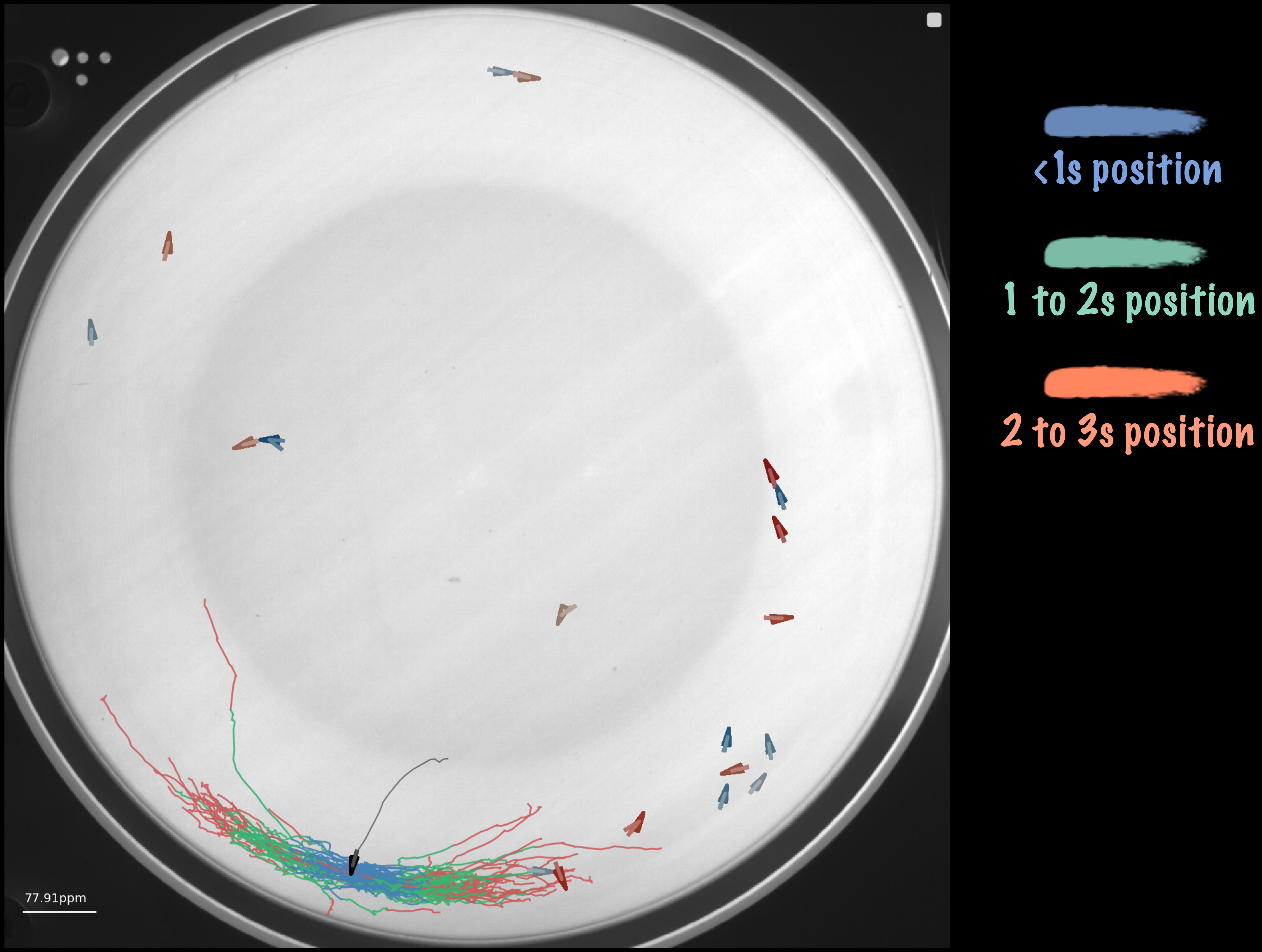
2. Interpret and understand the behaviour of artificial fly

Behaviour Analysis: Look at predictions into the future



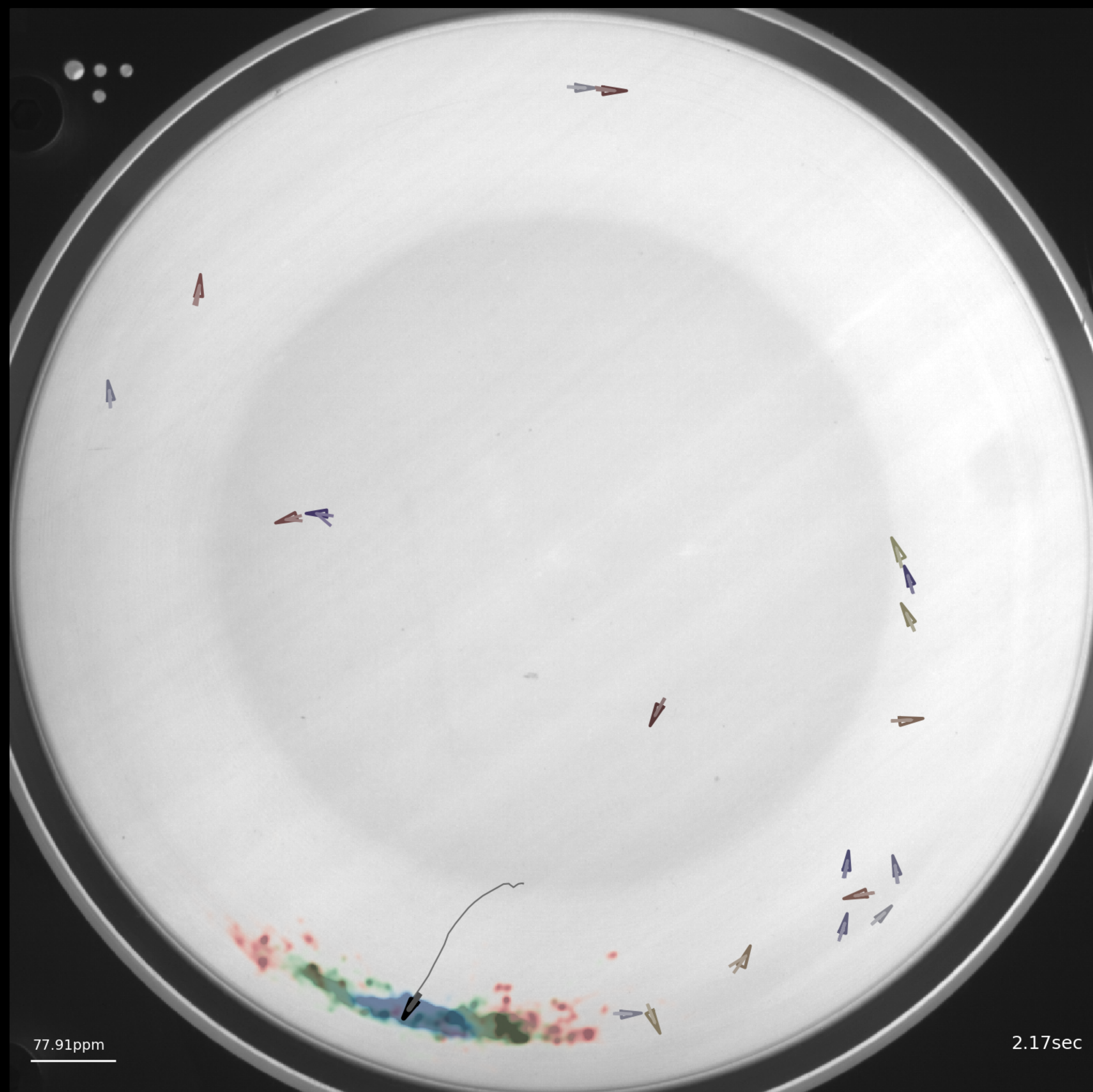
Behaviour Analysis: Look at predictions into the future

Predicted trajectories of next 3 seconds



Behaviour Analysis: Look at predictions into the future

Histogram over fly trajectories of next 3 seconds



< 1s position

1 to 2s position

2 to 3s position

Behaviour Analysis: Look at predictions into the future

Fly simulation movie

video

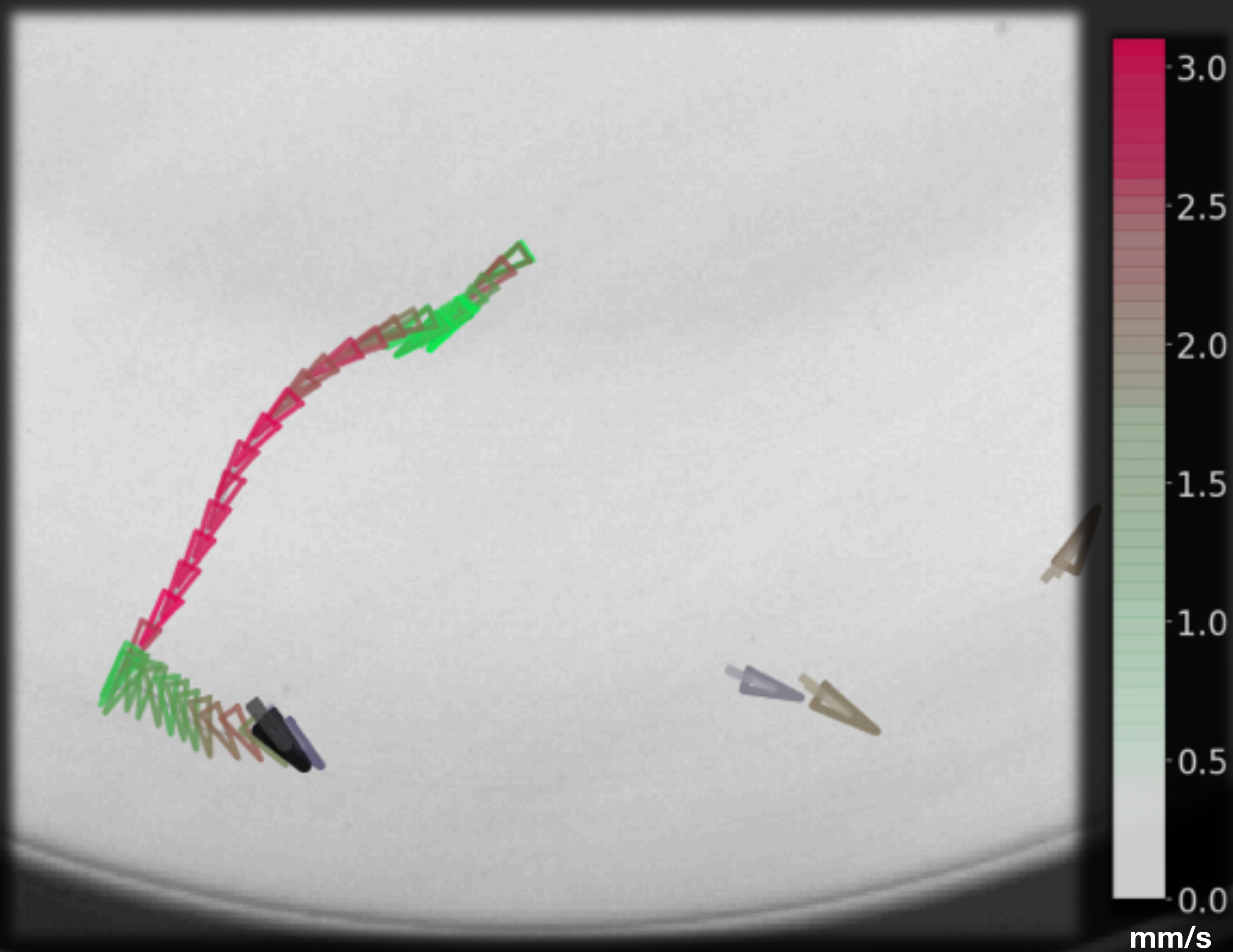
<1s position

1 to 2s position

2 to 3s position

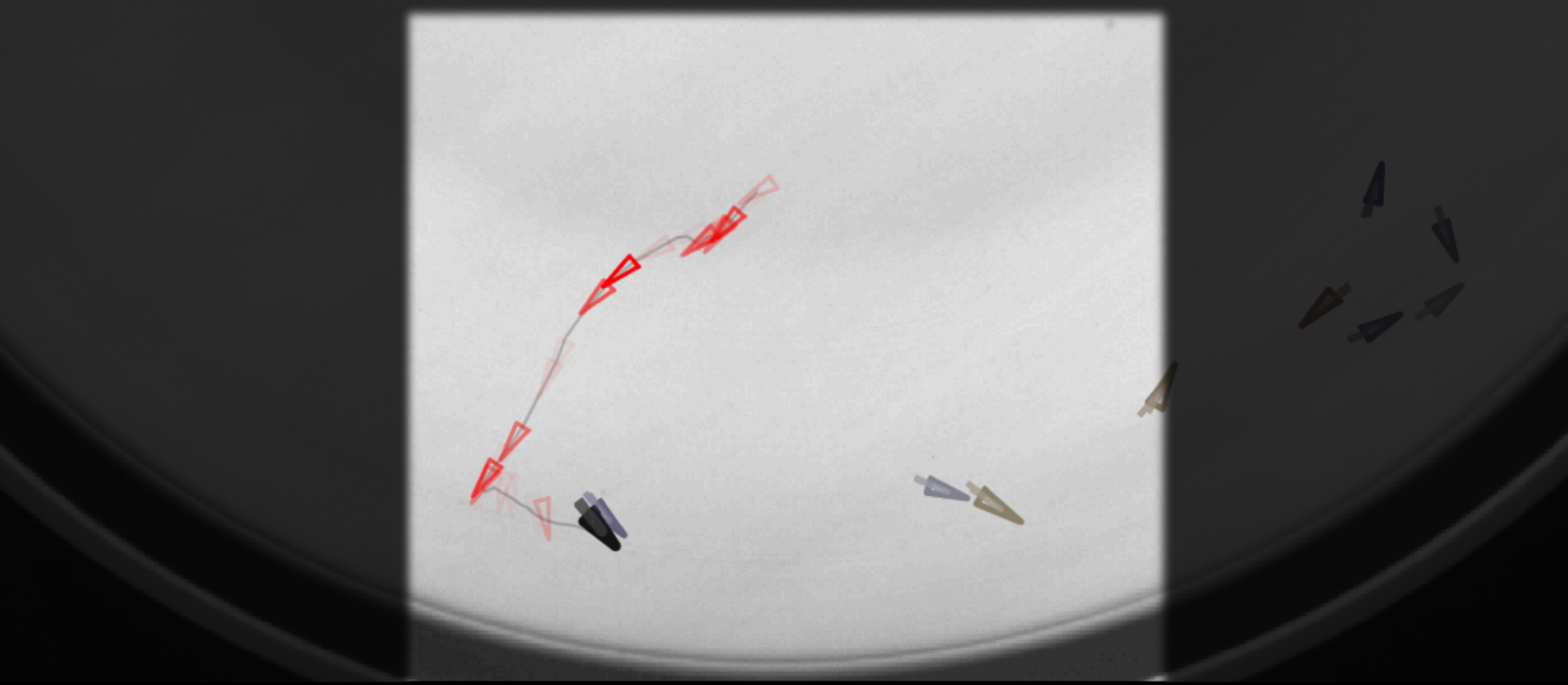
Behaviour Analysis: influential input

Last 50 frames of forward velocity data



Behaviour Analysis: influential input

Contributed forward motions among last 50 motions data

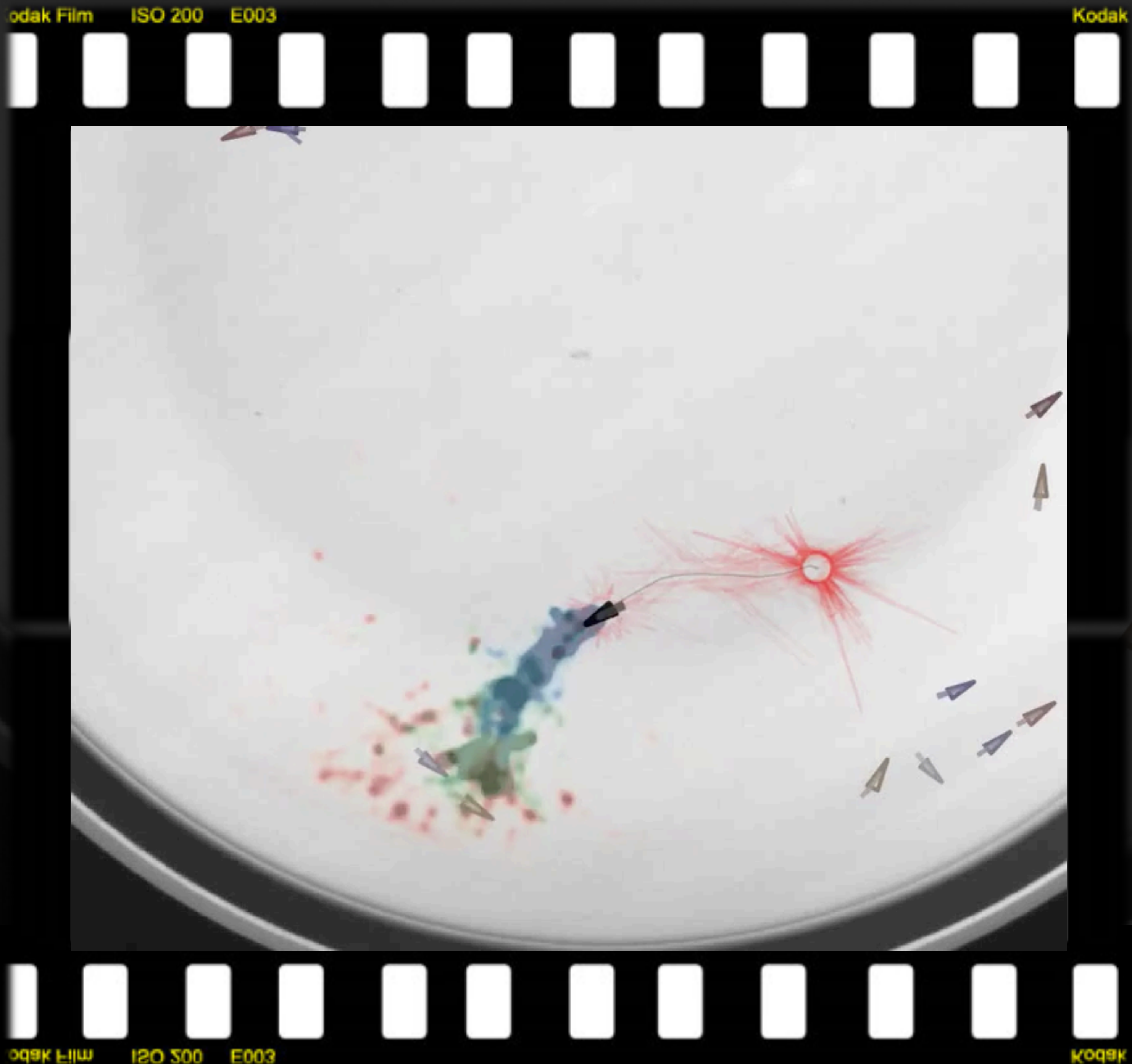


Behaviour Analysis: influential input

Movie of fly simulation with contributed forward motions

Behaviour Analysis: influential input

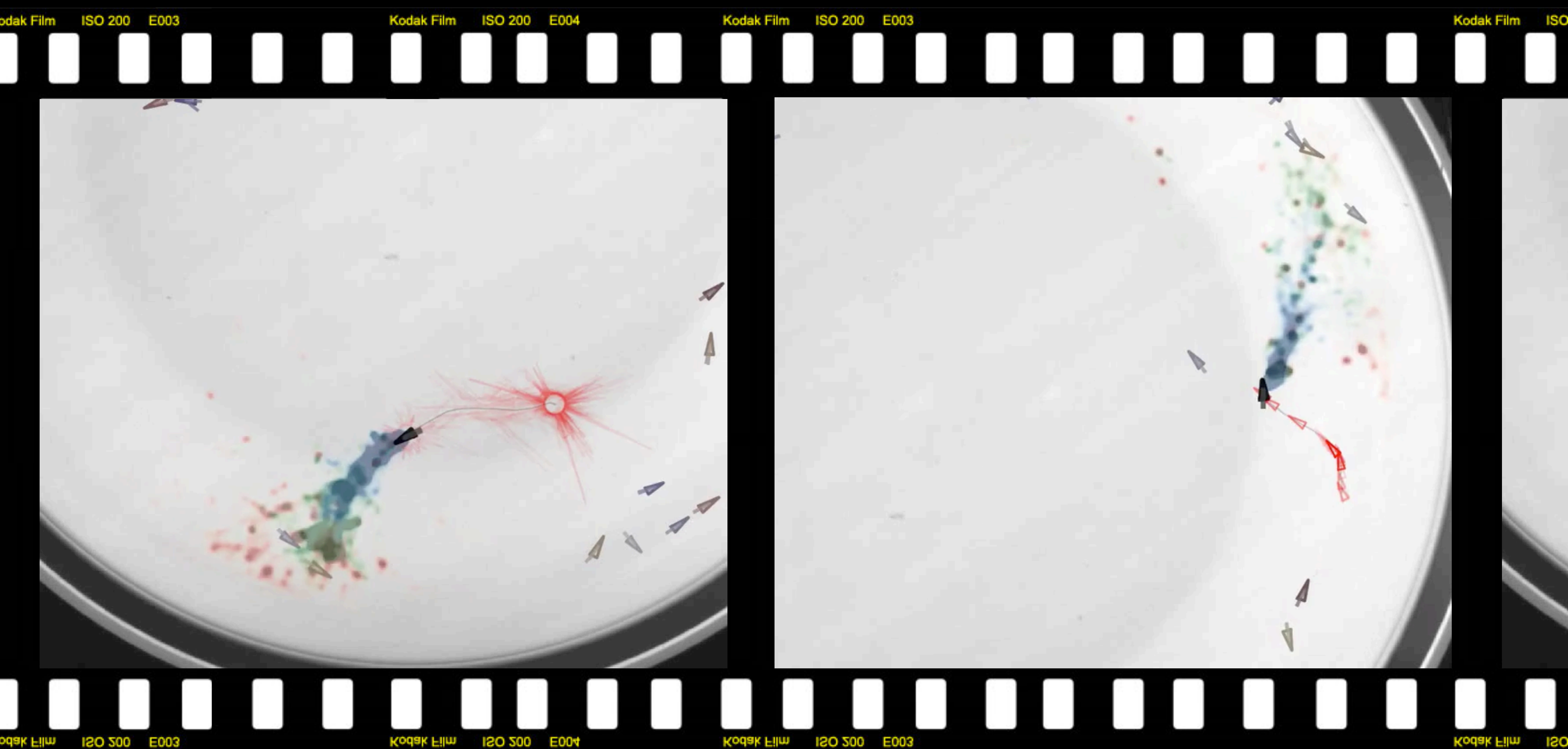
Movie of fly simulation with contributed forward motions



77.91ppm

Behaviour Analysis: Searching for hypothesis

1. Apply the analysis to different situations
2. Look for interesting scenarios
3. Narrow down the set of hypothesis



Summary

- **Observed** that simulated flies behave like real flies
- **Learned** that RNN produces behaviours that are closer to real flies based on our metrics
- **Introduced** visualization tools that help analyze artificial fly predictions

Future work

- **Analyze** internal representations of artificial fly to understand the key components
- **Apply** on different genotypes of flies to look for difference in behaviours

Acknowledgements

Kristin Branson

Alice Robie

Roian Egnor

Sam Kwak

Mayank Kabra

Rutuja Patil

Allen Lee

Elizabeth Gillette

Heejun Choi

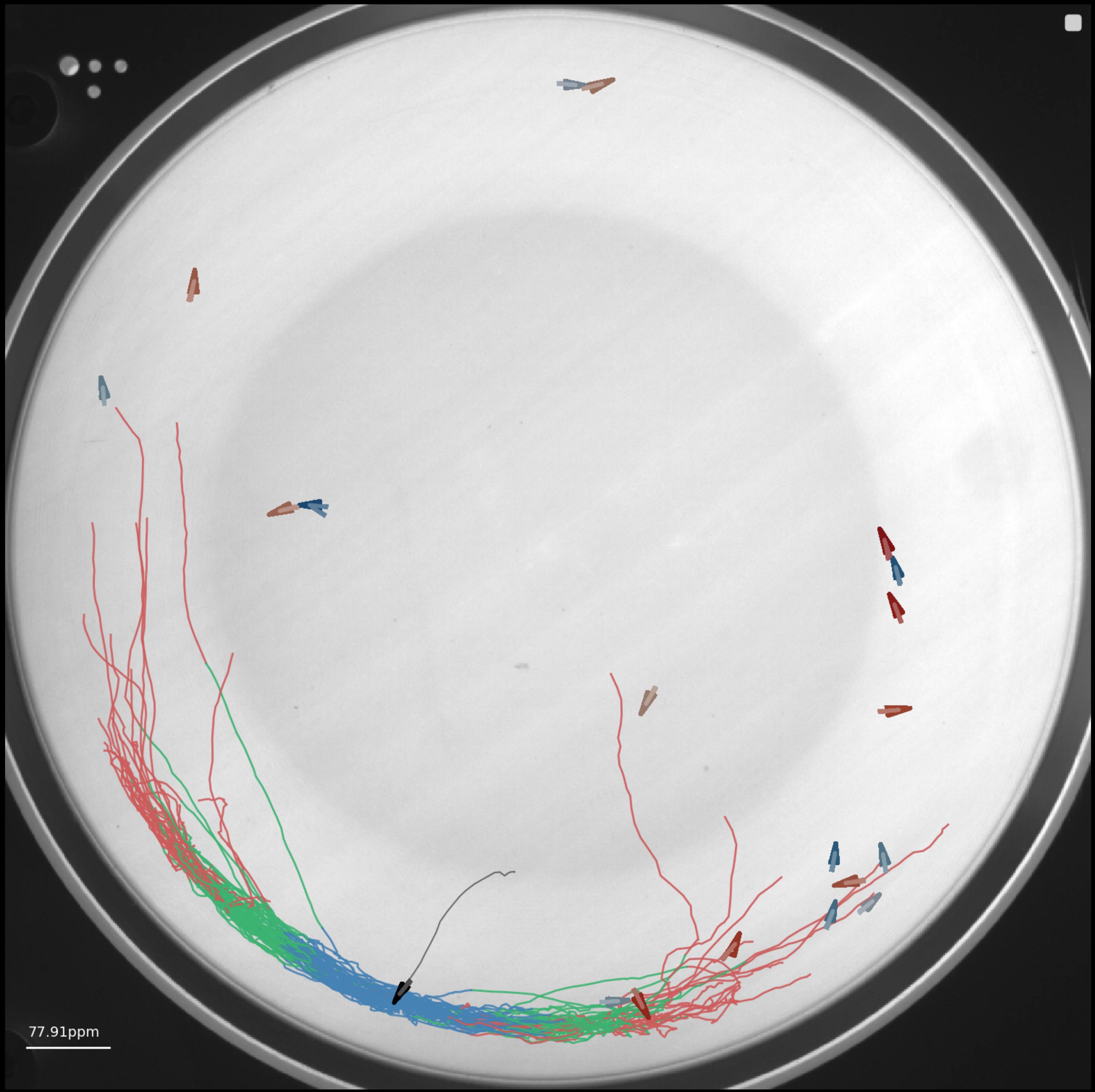
Paola Correa

Robert Lines

CVML
Scientific Computing
IT
Eyrun Eyjolfdottir
Nakul Verma
Rinat Mohar
Natalie Falco
Monet Weldon
Najla Masoodpanah
Andrew Evans

Behaviour Analysis: Look at predictions into the future

Predicted trajectories of next 3 seconds

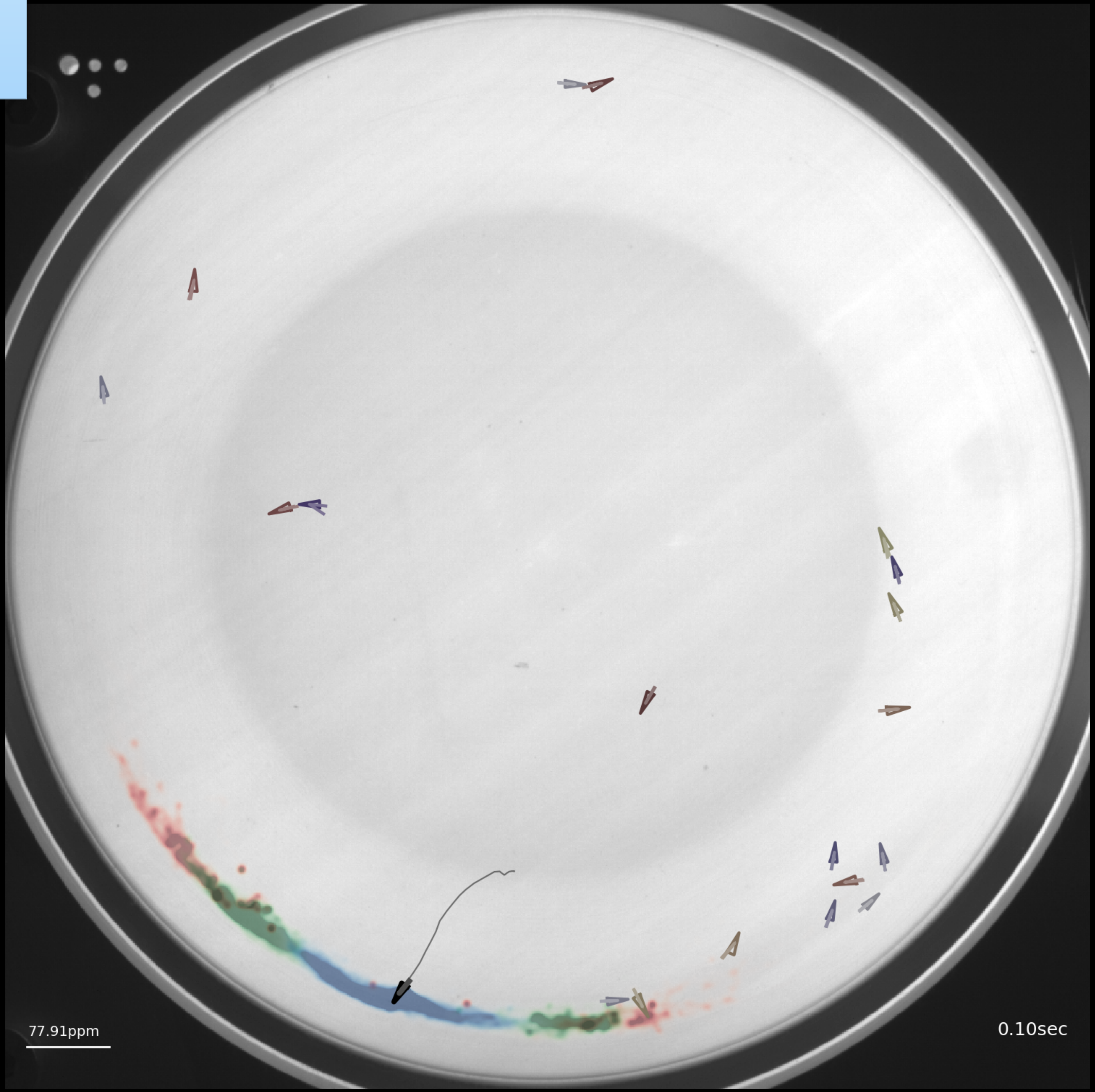


Behaviour Analysis: Look at ...edictions into the future

Ref Tie back to real goals.

Identify prediction change dramatically

Histogram over fly trajectories of next 3 seconds



Still frame of lines and then heatmap

Now we show movies of next 3 seconds

haviour Analysis: Look at edictions into the future

Fly simulation movie

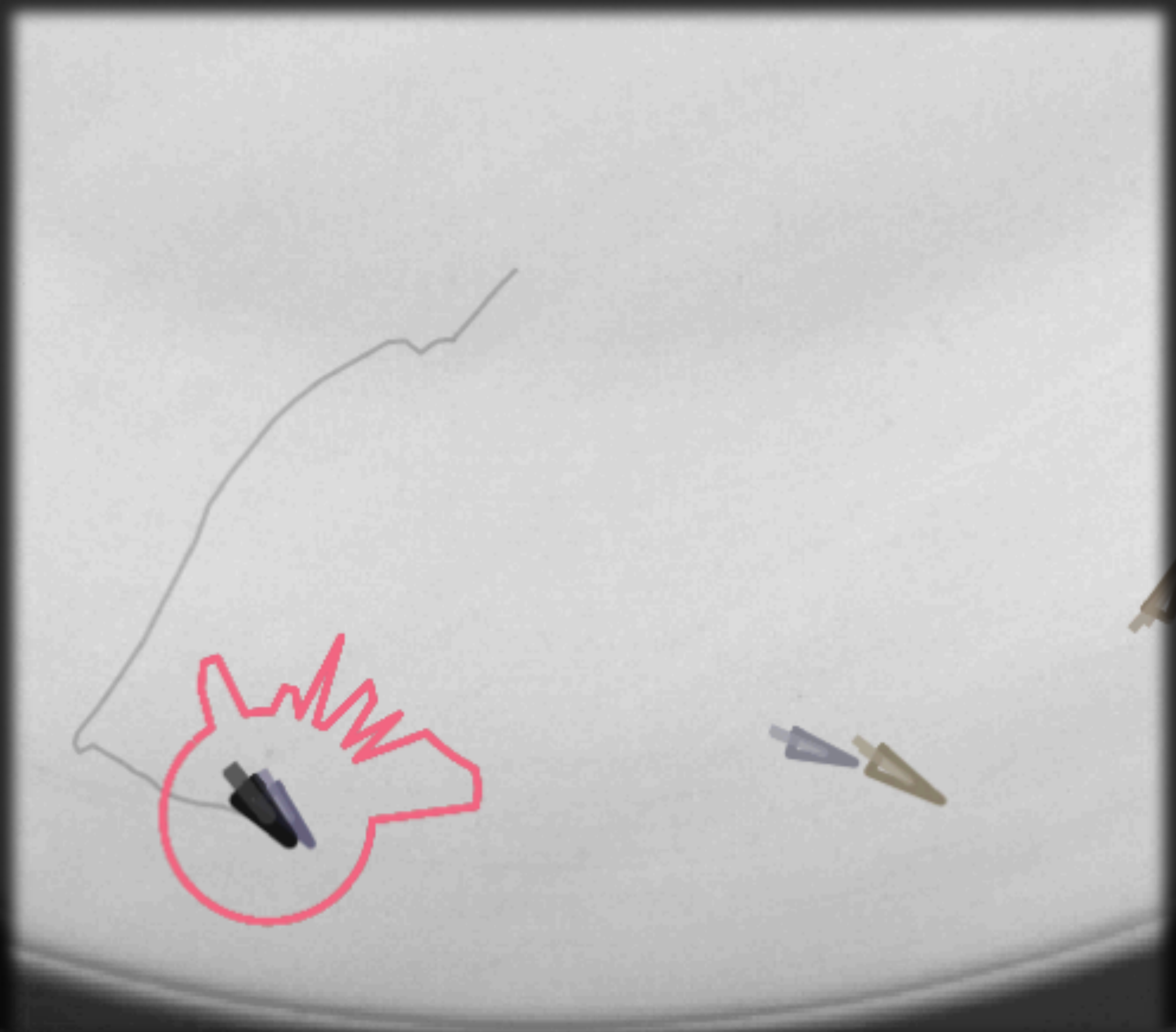
<1s position

1 to 2s position

2 to 3s position

Behaviour Analysis: input contribution analysis

Vision features - approximation of what fly sees (pink)



Behaviour Analysis: input contribution analysis

Last 50 frames of vision features (pink)

Behaviour Analysis: input contribution analysis

Contributed visions among last 50 vision features