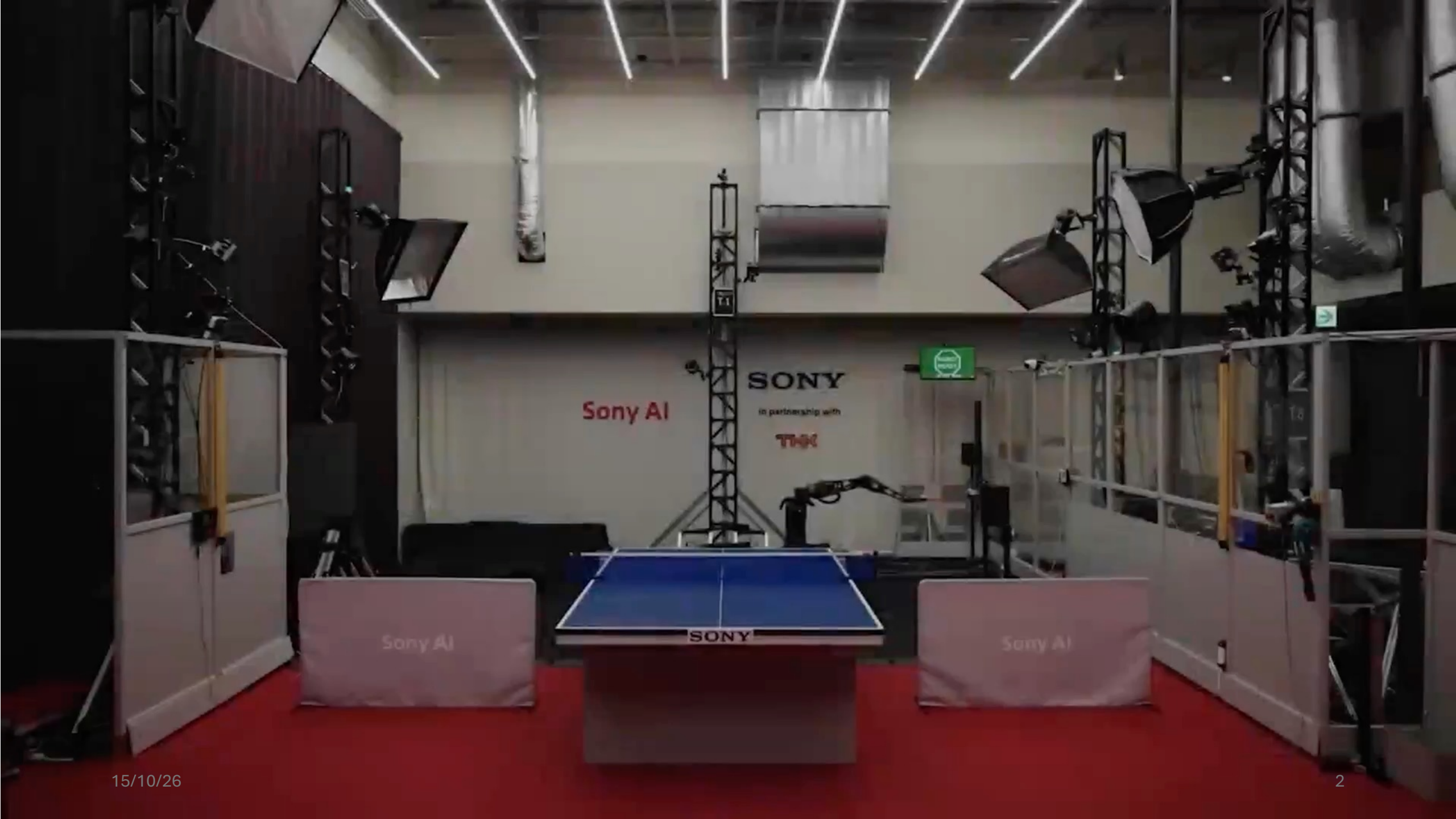
Learning to Play at Human Speed

Mireille El Gheche

SoftBank robotics (formerly Sony AI)

October 15, 2026


SONY
Sony AI
in partnership with
SONY
Sony AI
Sony AI


Haruki Maehara
Ace wins 1-2
Maehara 6 11 8
Ace 11 9 11

Why Table Tennis? 1/4



Why Table Tennis? 2/4

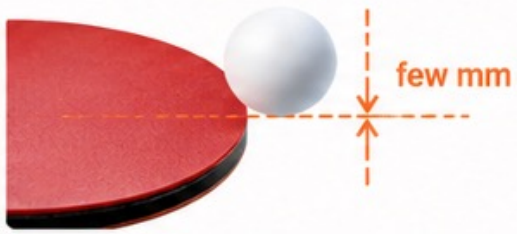
FAST
Extreme dynamics

Ball speeds up to **32 m/s** (~100 km/h).
From perception to action in a few hundred milliseconds.



PRECISE
Small margins

Millimetre-level accuracy in racket position, orientation and timing.
Tiny errors can mean a miss.



Why Table Tennis? 3/4

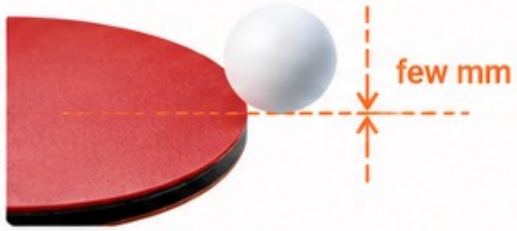
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Ball speeds up to **32 m/s** (~100 km/h).
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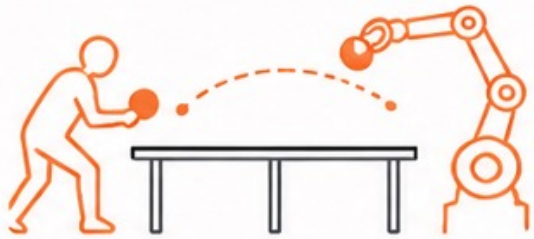
PRECISE
Small margins

Millimetre-level accuracy in racket position, orientation and timing.
Tiny errors can mean a miss.



INTERACTIVE
Dynamic opponent

The next state depends on another **intelligent agent** with diverse and unpredictable shots. Requires real-time adaptation.



Why Table Tennis? 4/4

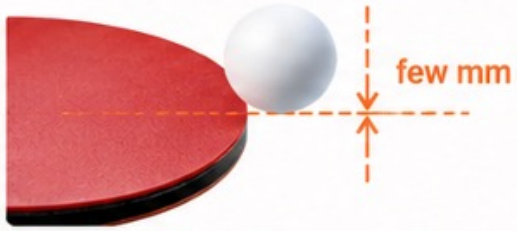
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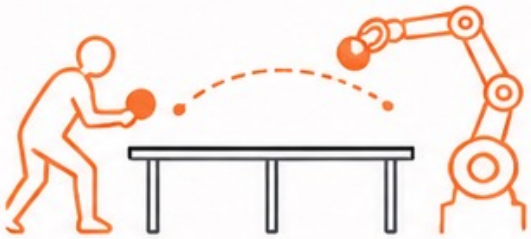
PRECISE
Small margins

Millimetre-level accuracy in racket position, orientation and timing.
Tiny errors can mean a miss.



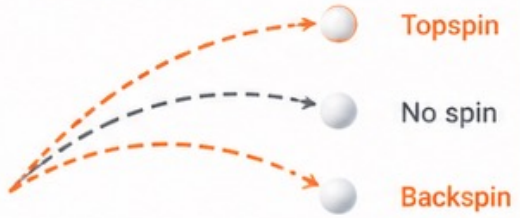
INTERACTIVE
Dynamic opponent

The next state depends on another **intelligent agent** with diverse and unpredictable shots. Requires real-time adaptation.



ADVERSARIAL
Complex physics

Spin up to **160 rot/s**, aerodynamics and contact dynamics make the ball's trajectory difficult to estimate and control. You cannot pause and re-plan.



Why Table Tennis?

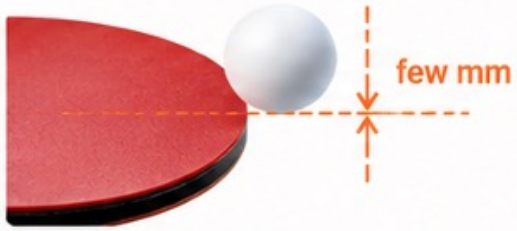
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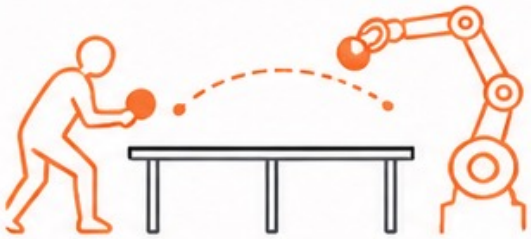
PRECISE
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Millimetre-level accuracy in racket position, orientation and timing.
Tiny errors can mean a miss.



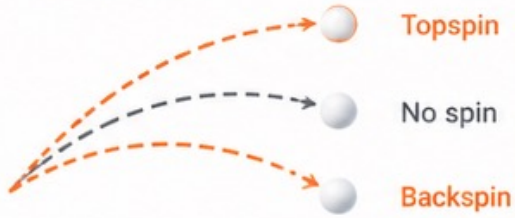
INTERACTIVE
Dynamic opponent

The next state depends on another **intelligent agent** with diverse and unpredictable shots. Requires real-time adaptation.



ADVERSARIAL
Complex physics

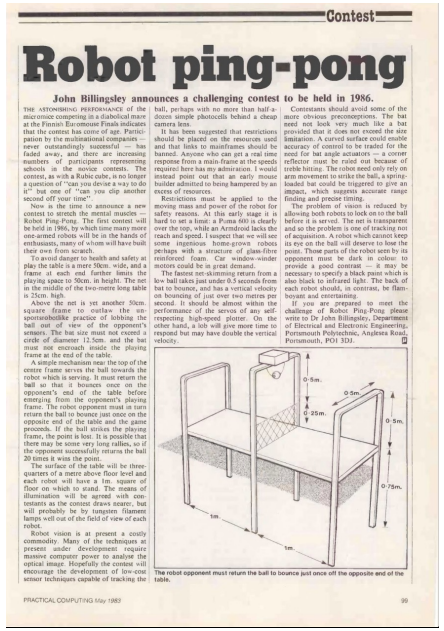
Spin up to **160 rot/s**, aerodynamics and contact dynamics make the ball's trajectory difficult to estimate and control. You cannot pause and re-plan.



A uniquely challenging benchmark for physical intelligence

A Long-Standing Challenge in Robotics

Decades of research. No one had demonstrated head-to-head games with expert human players



Contest

Robot ping-pong

John Billingsley announces a challenging contest to be held in 1986.

THE ASTONISHING PERFORMANCE of the micromice competing in a diabolical maze at the Finnish Eurotronic Finals indicates that the contest has come of age. Participation by five multinational companies — never outstandingly successful — has faded away, and there are increasing numbers of participants representing schools in the novice contests. The contest, as with a Rubic cube, is no longer a question of "can you devise a way to do it" but one of "can you clip another second off your time".

Now is the time to announce a new contest to stretch the mental muscles — Robot Ping-Pong. The first contest will be held in 1986, by which time many more one-armed robots will be in the hands of enthusiasts, many of whom will have built their own from scratch.

To avoid danger to health and safety at play the table is a mere 50cm. wide, and a frame at each end further limits the playing space to 50cm. in height. The net in the middle of the two-metre long table is 25cm. high.

Above the net is yet another 50cm. square frame to outlaw the unsportsmanlike practice of lobbing the ball out of view of the opponent's sensors. The bat size must not exceed a circle of diameter 12.5cm. and the bat must not encroach inside the playing frame at the end of the table.

A simple mechanism near the top of the centre frame serves the ball towards the robot which is serving. It must return the ball so that it bounces once on the opponent's end of the table before emerging from the opponent's playing frame. The robot opponent must in turn return the ball to bounce just once on the opposite end of the table and the game proceeds. If the ball strikes the playing frame, the point is lost. It is possible that there may be some very long rallies, so if the opponent successfully returns the ball 20 times it wins the point.

The surface of the table will be three-quarters of a metre above floor level and each robot will have a 1m. square of floor on which to stand. The means of illumination will be agreed with contestants as the contest draws nearer, but will probably be by tungsten filament lamps well out of the field of view of each robot.

Robot vision is at present a costly commodity. Many of the techniques at present under development require massive computer power to analyse the optical image. Hopefully the contest will encourage the development of low-cost sensor techniques capable of tracking the ball, perhaps with no more than half-a-dozen simple photocells behind a cheap camera lens.

It has been suggested that restrictions should be placed on the resources used and that links to mainframes should be banned. Anyone who can get a real time response from a main-frame at the speeds required here has my admiration. I would instead point out that an early mouse builder admitted to being hampered by an excess of resources.

Restrictions must be applied to the moving mass and power of the robot for safety reasons. At this early stage it is hard to set a limit: a Puma 600 is clearly over the top, while an Armdroid lacks the reach and speed. I suspect that we will see some ingenious home-grown robots perhaps with a structure of glass-fibre reinforced foam. Car window-winder motors could be in great demand.

The fastest net-skimming return from a low ball takes just under 0.5 seconds from bat to bounce, and has a vertical velocity on bounding of just over two metres per second. It should be almost within the performance of the servos of any self-respecting high-speed plotter. On the other hand, a lob will give more time to respond but may have double the vertical velocity.

Contestants should avoid some of the more obvious gimmicks. The bat need not look very much like a bat provided that it does not exceed the size limitation. A curved surface could enable accuracy of control to be traded for the need for bat angle actuators — a corner reflector must be ruled out because of treble hitting. The robot need only rely on arm movement to strike the ball, a spring-loaded bat could be triggered to give an impact, which suggests accurate range finding and precise timing.

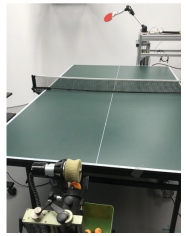
The problem of vision is reduced by allowing both robots to lock on to the ball before it is served. The net is transparent and so the problem is one of tracking not of acquisition. A robot which cannot keep its eye on the ball will deserve to lose the point. Those parts of the robot seen by its opponent must be dark in colour to provide a good contrast — it may be necessary to specify a black paint which is also black to infrared light. The back of each robot should, in contrast, be flamboyant and entertaining.

If you are prepared to meet the challenge of Robot Ping-Pong please write to Dr John Billingsley, Department of Electrical and Electronic Engineering, Portsmouth Polytechnic, Anglesea Road, Portsmouth, PO1 3DJ.

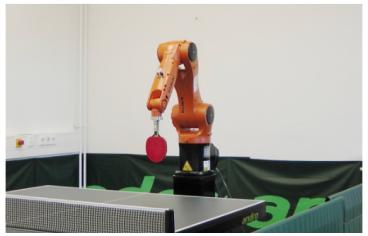
The robot opponent must return the ball to bounce just once off the opposite end of the table.

PRACTICAL COMPUTING May 1983 99

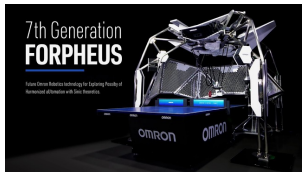
[Billingsley et al. 1983]



[Büchler et al. 2020]



[Tebbe et al. 2020]



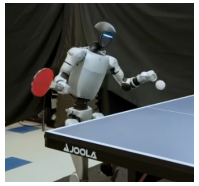
[Asai et al. 2020]



[Su et al. 2025]



[Ambrosio et al. 2024]



[Su et al. 2025]
UC Berkeley



Sharpa, 2025

First Competitive Table Tennis Robot

Table Tennis Game:

- Ball speed: up to 32 m/s
- Extreme spin control: up to 160 rot/s

Competitive Games vs. **Elite-level** Opponents including Professional Players

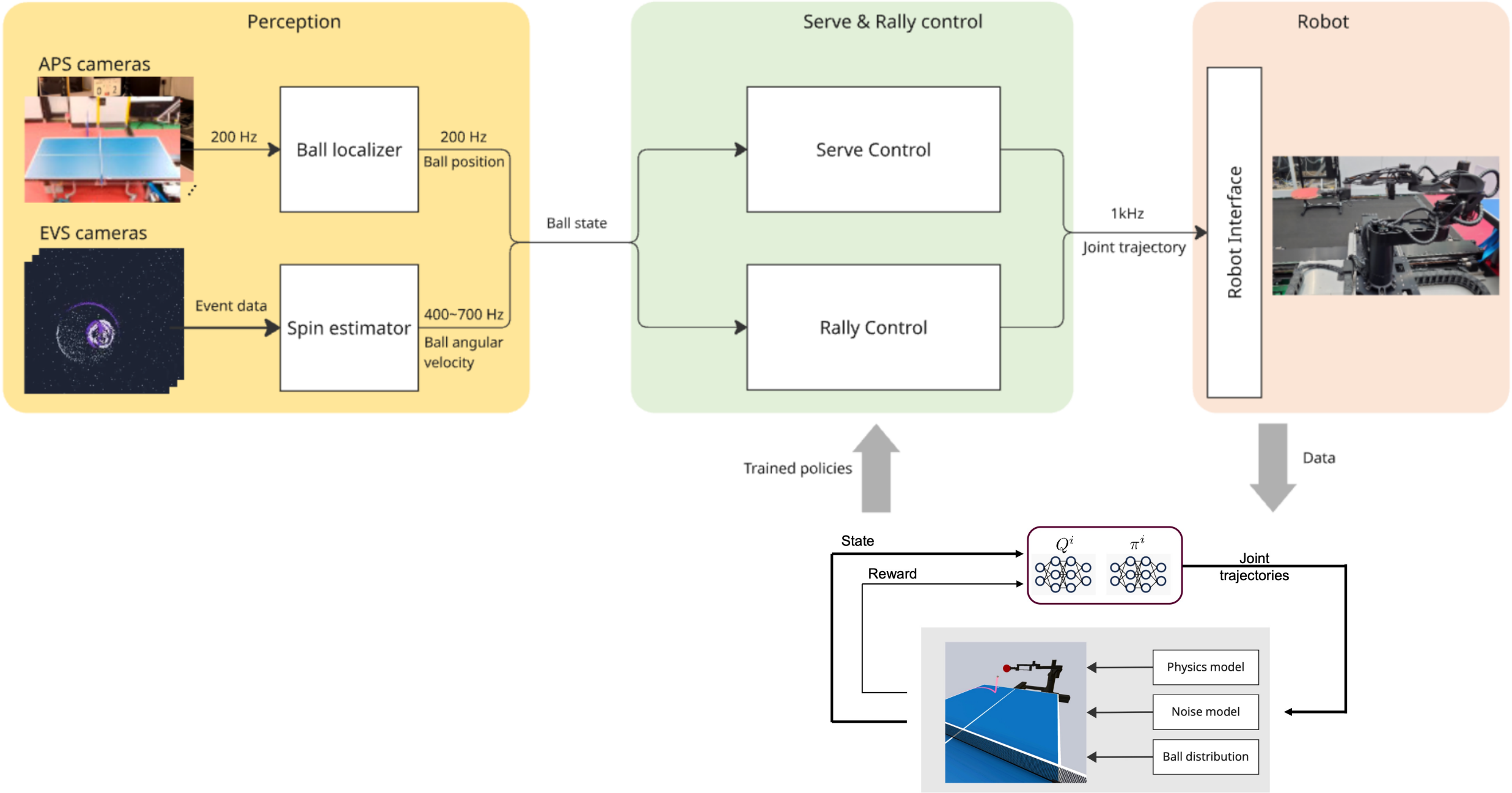
Standard Table Tennis Rules, **Olympic-Size** Court, Licensed Umpires

Standard Equipment (ITTF Certified Balls, Players Use their own racket)

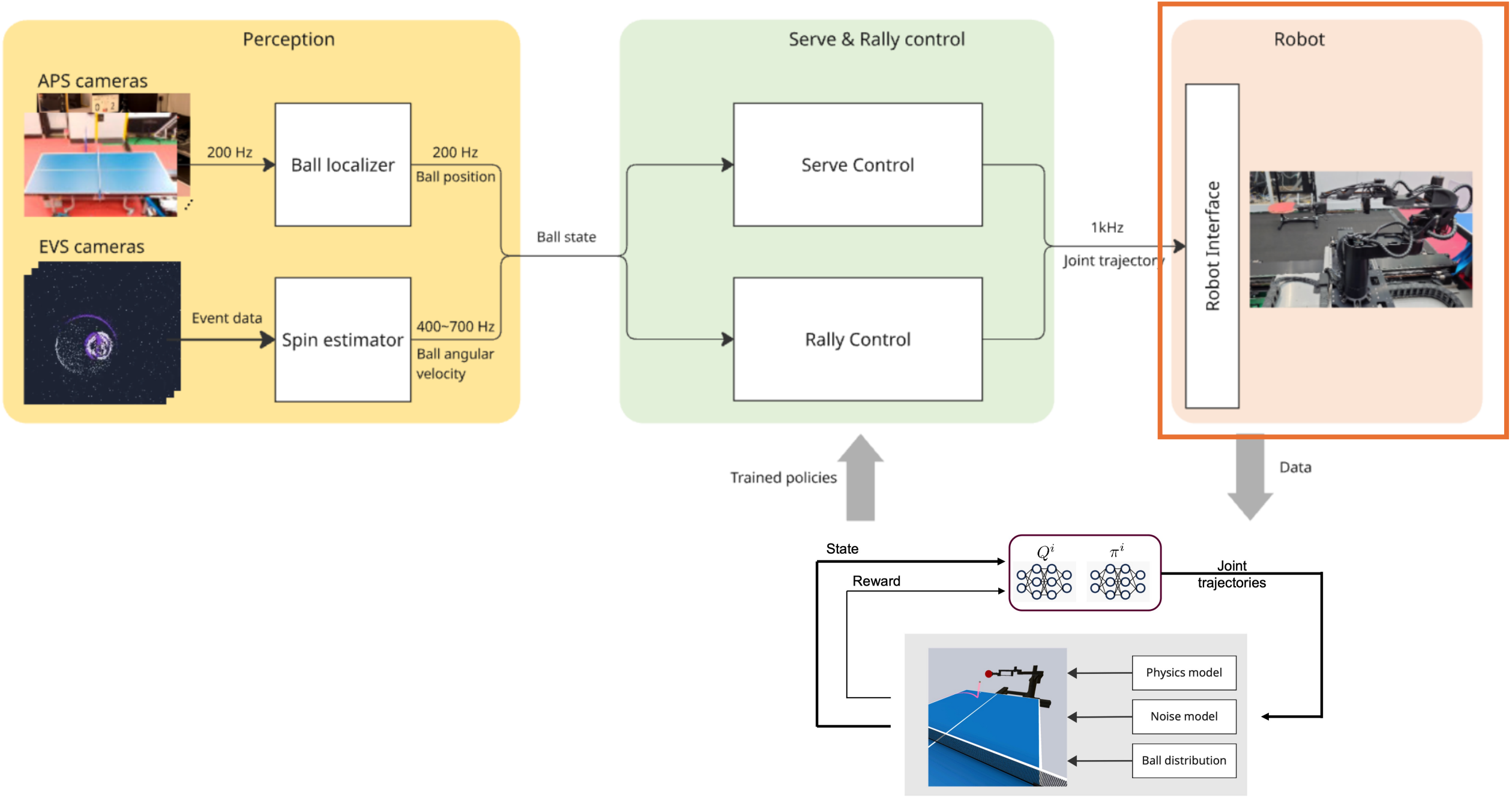



The international journal of science / 23 April 2026
nature
MATCH POINT
AI-controlled robot beats elite players at table tennis

The System


Perception
APS cameras
200 Hz
Ball localizer
200 Hz
Ball position
EVS cameras
Event data
Spin estimator
400~700 Hz
Ball angular velocity
Ball state
Serve & Rally control
Serve Control
Rally Control
1kHz
Joint trajectory
Robot
Robot Interface
Trained policies
Data
State
Reward
Q^i
π^i
Joint trajectories
Physics model
Noise model
Ball distribution

The Hardware


Perception
APS cameras
200 Hz
Ball localizer
200 Hz
Ball position
EVS cameras
Event data
Spin estimator
400~700 Hz
Ball angular velocity
Ball state
Serve & Rally control
Serve Control
Rally Control
1kHz
Joint trajectory
Robot
Robot Interface
Trained policies
Data
State
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Joint trajectories
Physics model
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Ball distribution

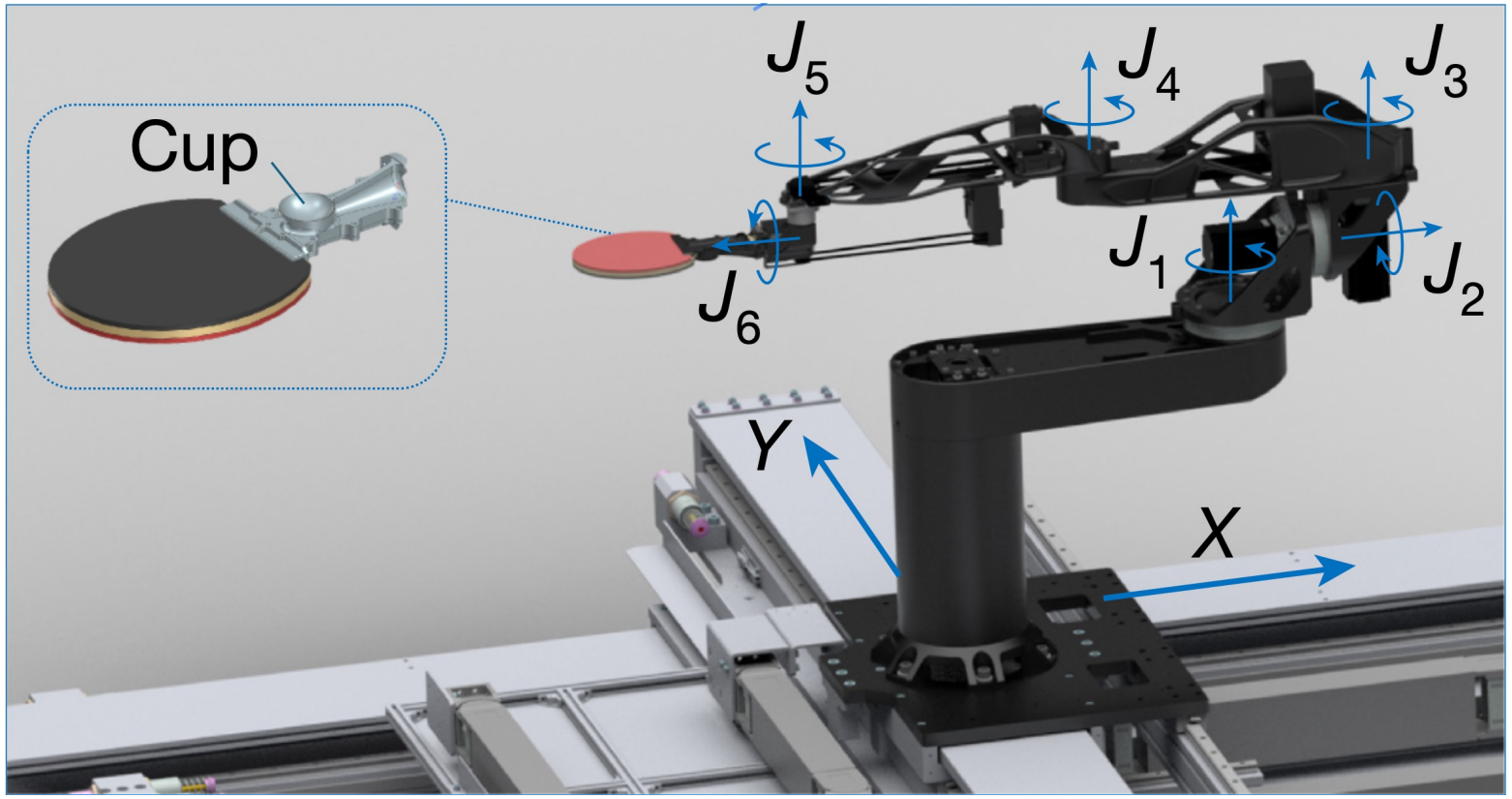
Robot Hardware

Lightweight, Rigid & High-Speed Robot Arm

- 6 revolute joints, swing speed above 20m/s
- Metal 3D printed, organic/skeletal-shaped robot arm

Increased Reach with a Powerful XY-stage

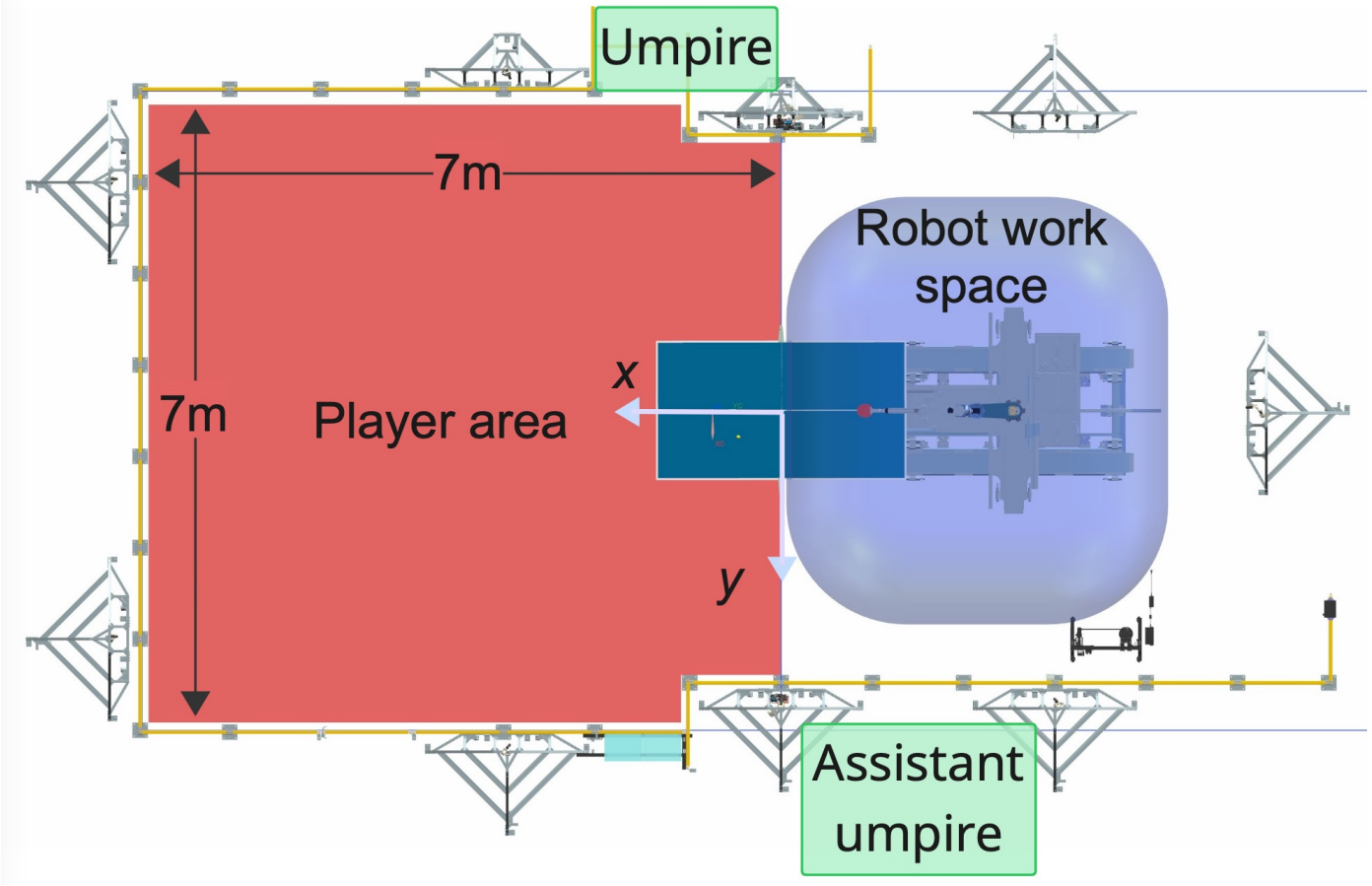
- 3 linear actuators exceeding 340kgf of thrust each
- High acceleration (up to 24.5 m/s^2) and speed (4 m/s)



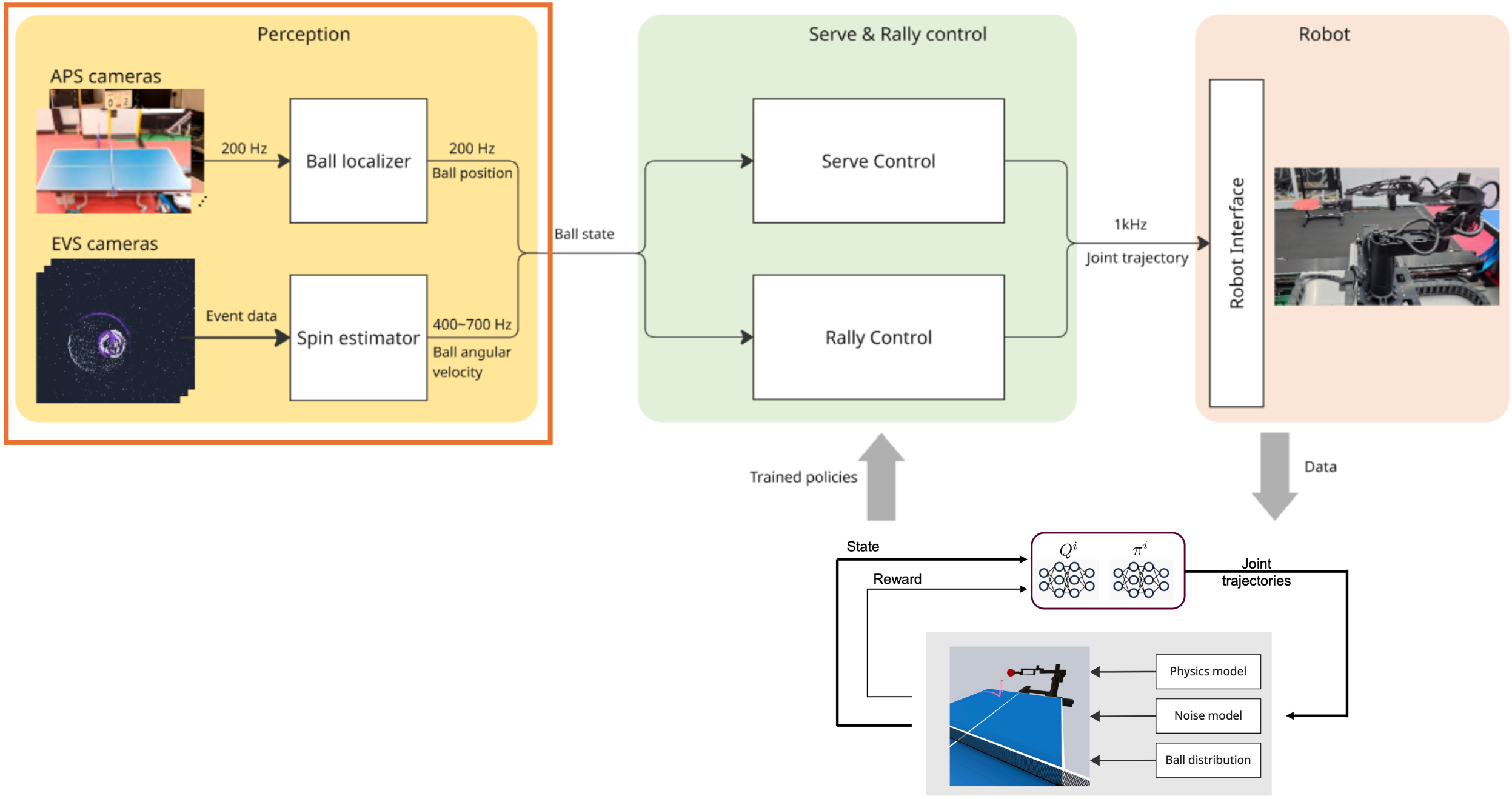
Robot Hardware

World's most advanced Table Tennis Robot

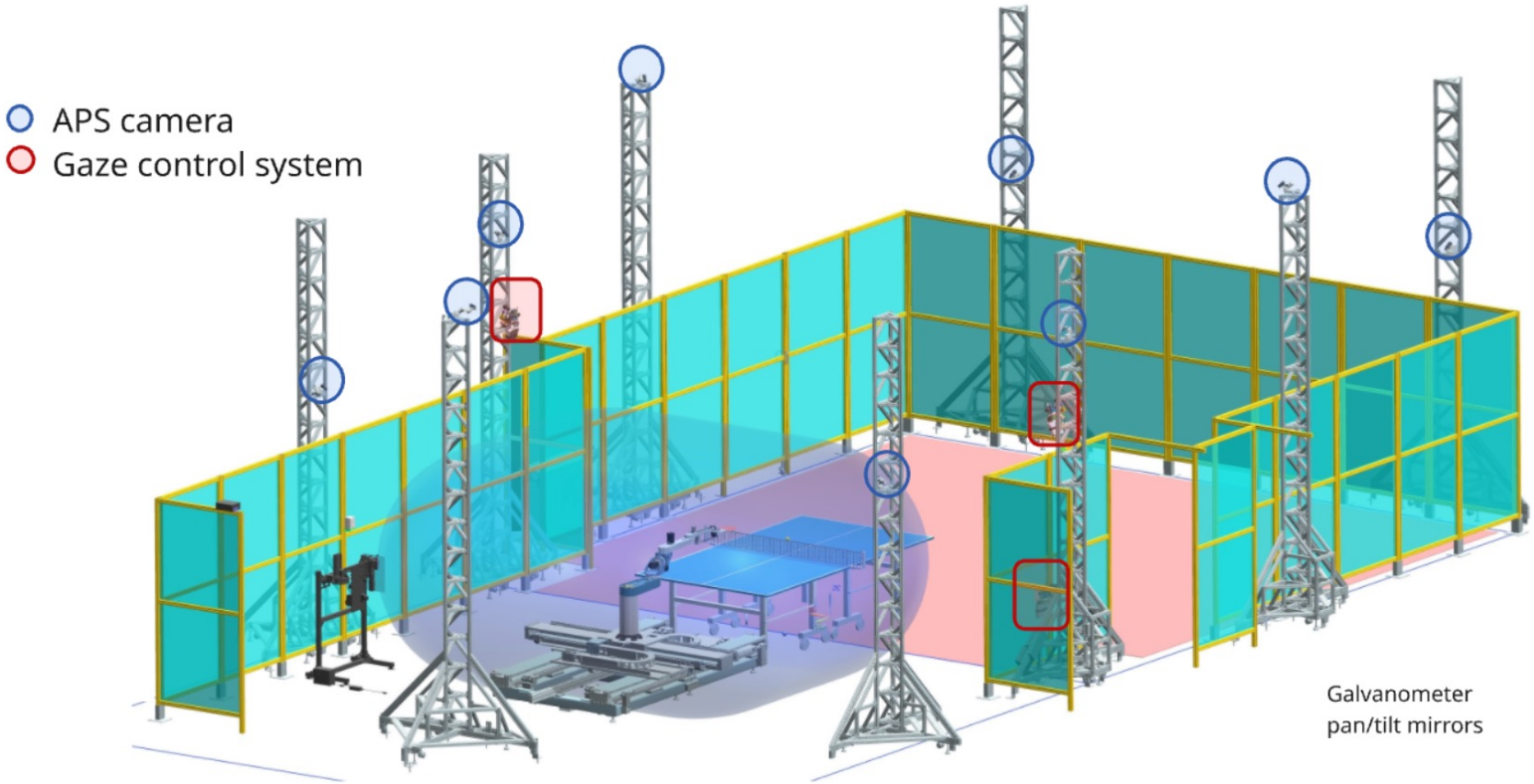
- Total Reach: Full table coverage + 2 meters behind
- Ultra-low latency control (<8ms) via a high-speed 1 kHz real-time network
- Physical capabilities that match those of professional athletes
- Legal serves using a single arm



Where is the ball?


Perception
APS cameras
200 Hz
Ball localizer
200 Hz
Ball position
EVS cameras
Event data
Spin estimator
400~700 Hz
Ball angular velocity
Ball state
Serve & Rally control
Serve Control
Rally Control
1kHz
Joint trajectory
Robot
Robot Interface
Trained policies
Data
State
Reward
Q^i
π^i
Joint trajectories
Physics model
Noise model
Ball distribution

Perception System

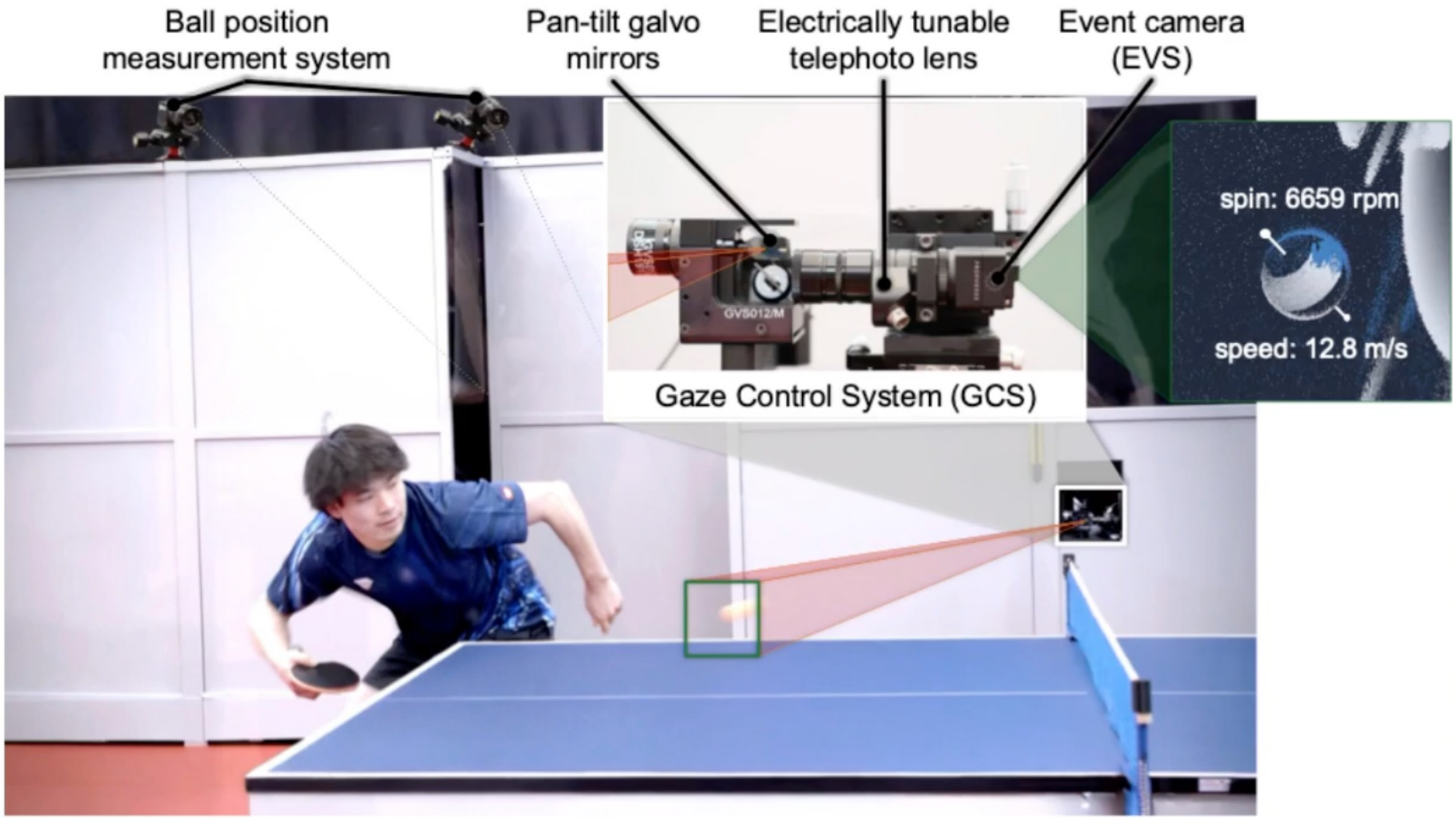


Nine active pixel sensor (**APS**) cameras with **Sony IMX273** to cover the whole playing area

- Ball in 3D space at 200 Hz with 3.0 mm error and 10.2 ms latency on average.

Three gaze control systems (**GCSs**) to estimate the spin in real time

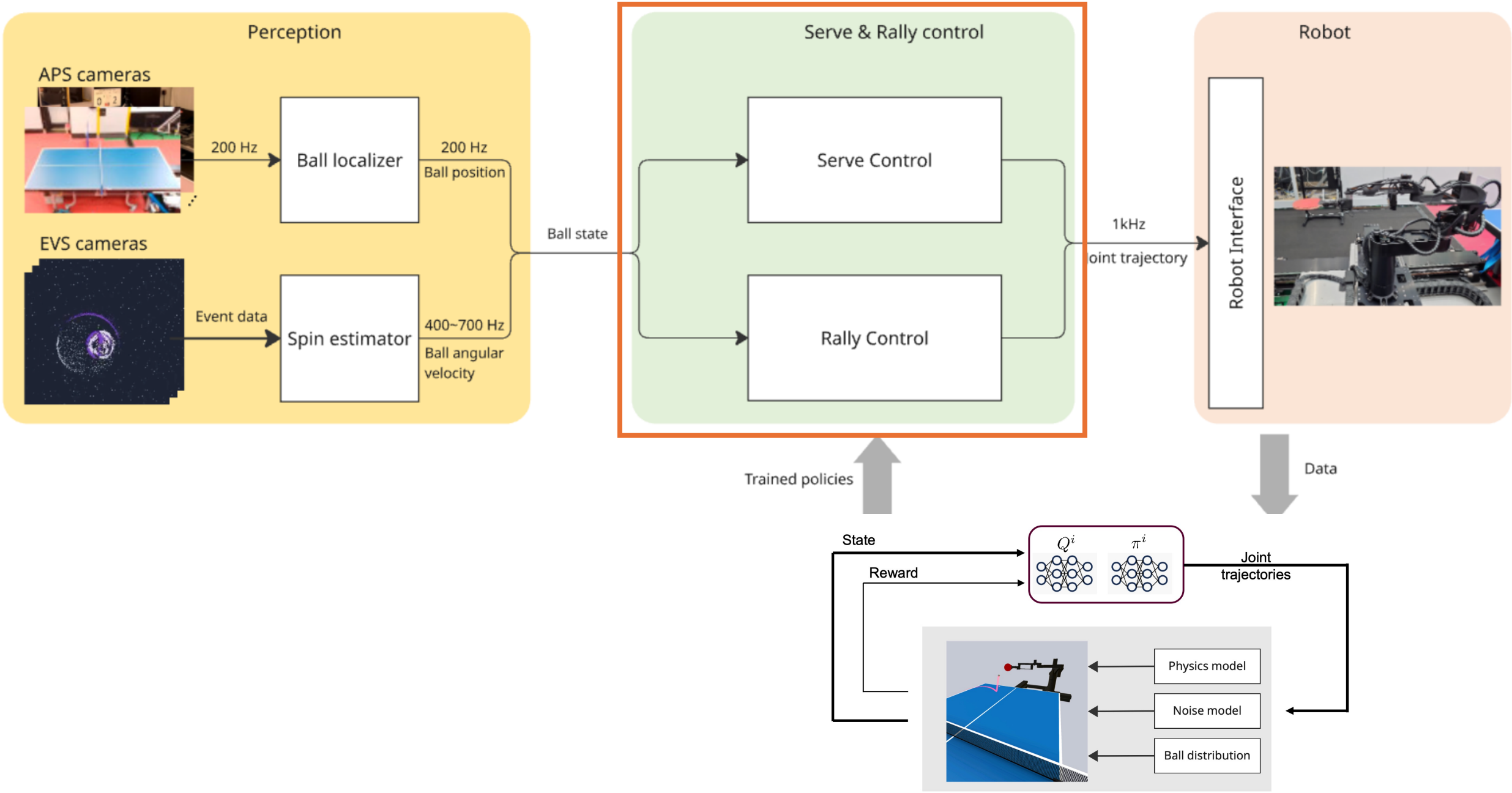
- Frequency of approximately 400 to 700 Hz with 24.8 rad/s average error.


Ball position measurement system
Pan-tilt galvo mirrors
Electrically tunable telephoto lens
Event camera (EVS)
GV5012/M
Gaze Control System (GCS)
spin: 6659 rpm
speed: 12.8 m/s

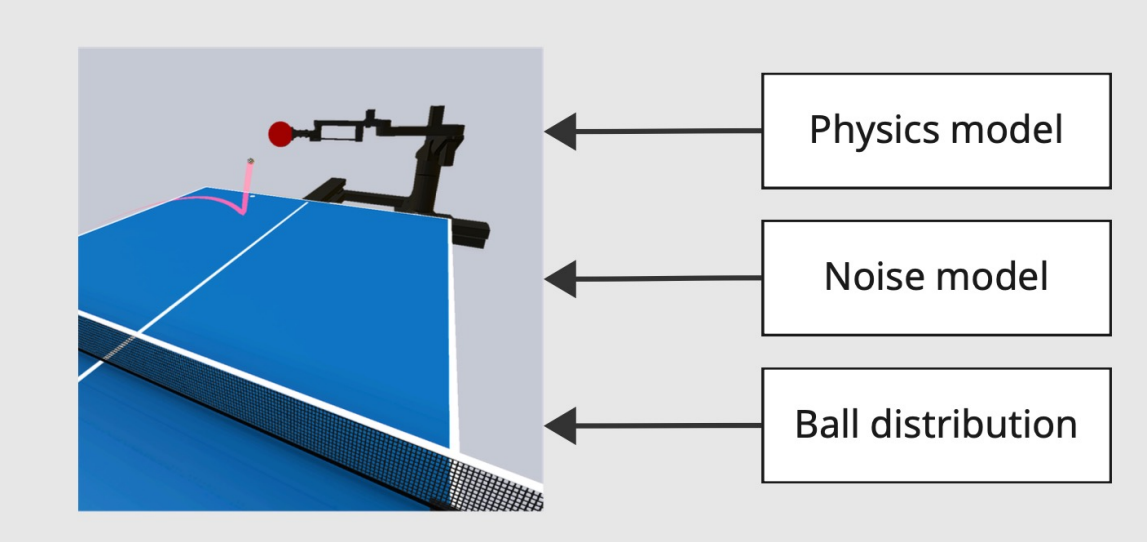

6
8



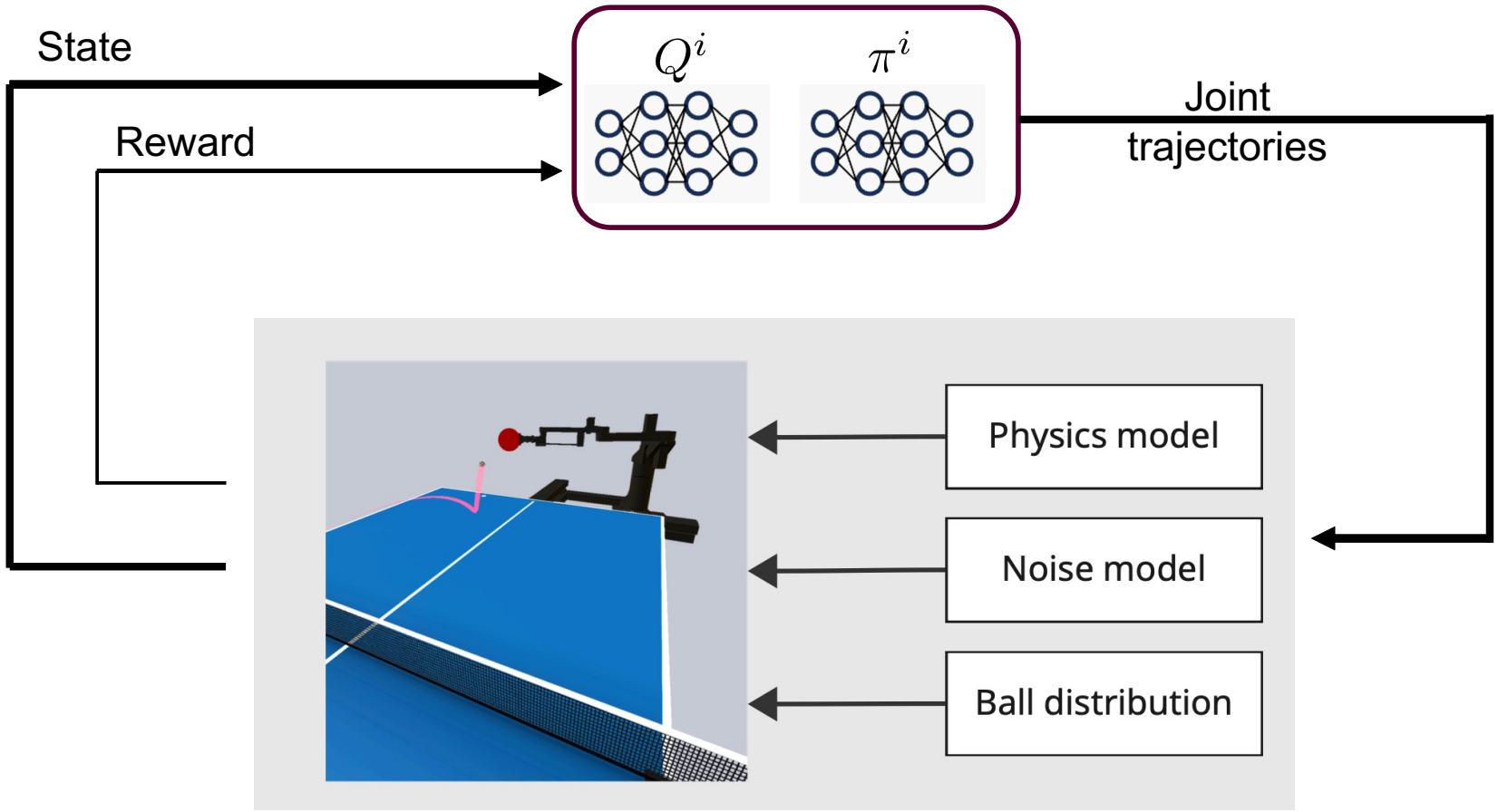
How should the robot hit the ball?


Perception
APS cameras
200 Hz
Ball localizer
200 Hz
Ball position
EVS cameras
Event data
Spin estimator
400~700 Hz
Ball angular velocity
Ball state
Serve & Rally control
Serve Control
Rally Control
1kHz
Joint trajectory
Robot
Robot Interface
Trained policies
Data
State
Reward
Q^i
π^i
Joint trajectories
Physics model
Noise model
Ball distribution

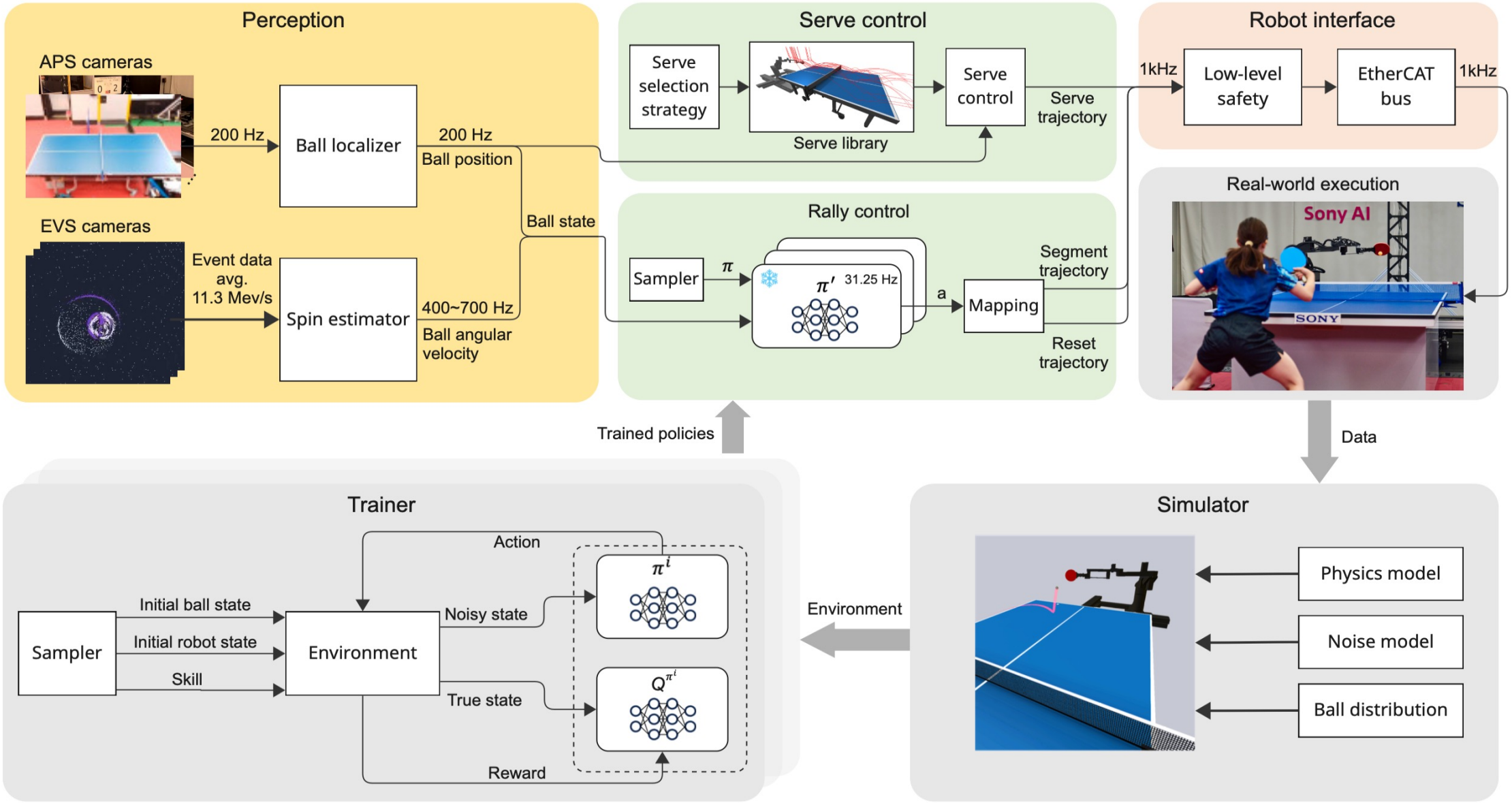
The Simulator



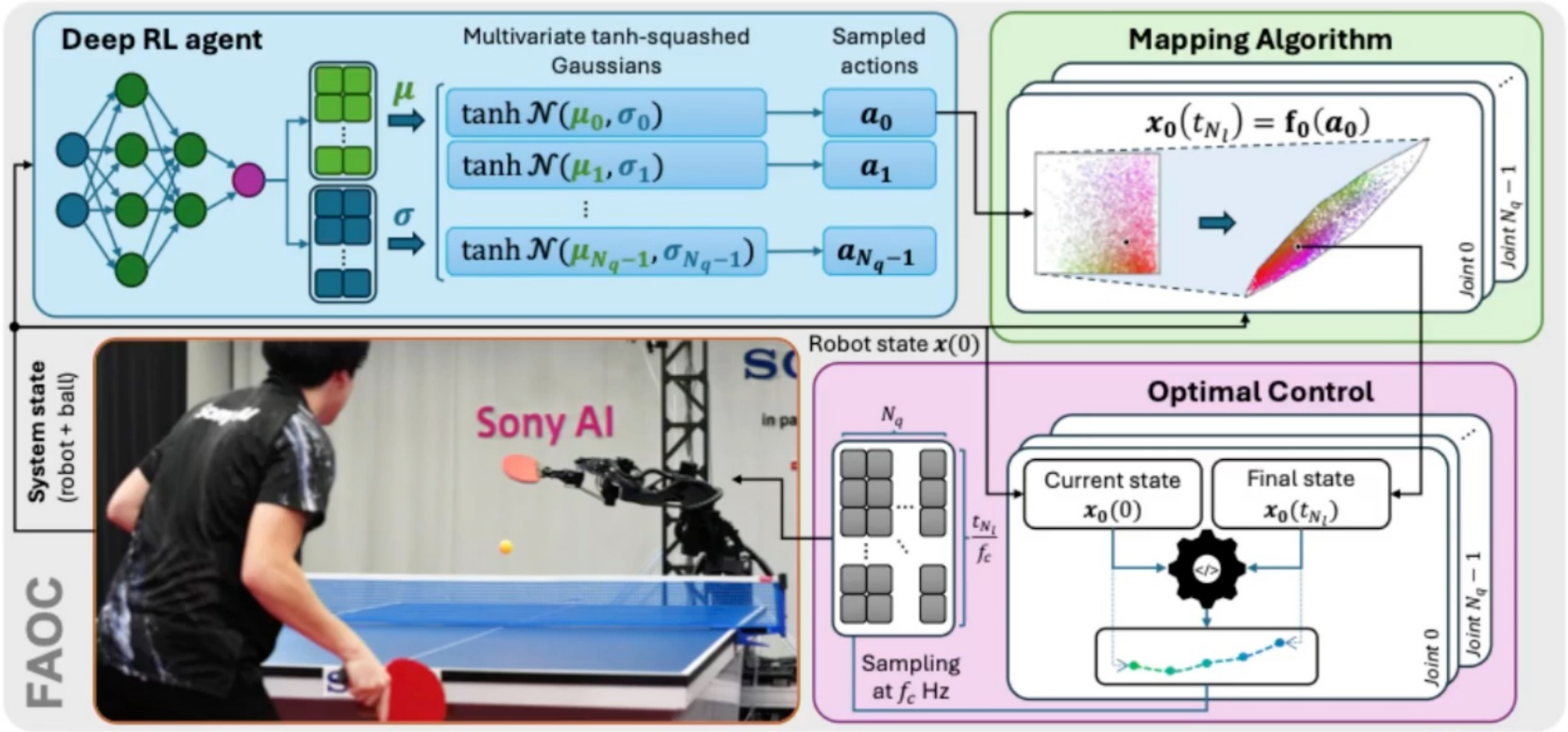
The Trainer



Training: single shot scenario using SAC algo. To return the ball with a desired skill


Perception
APS cameras
200 Hz
Ball localizer
200 Hz
Ball position
EVS cameras
Event data
avg.
11.3 Mev/s
Spin estimator
400~700 Hz
Ball angular
velocity
Ball state
Serve control
Serve
selection
strategy
Serve library
Serve
control
Serve
trajectory
Rally control
Sampler
π
π'
31.25 Hz
a
Mapping
Segment
trajectory
Reset
trajectory
Robot interface
1kHz
Low-level
safety
EtherCAT
bus
1kHz
Real-world execution
Sony AI
SONY
Data
Trained policies
Trainer
Action
Initial ball state
Initial robot state
Skill
Sampler
Environment
Noisy state
True state
Reward
Environment
Simulator
Physics model
Noise model
Ball distribution

Feasible Action for Optimal Control



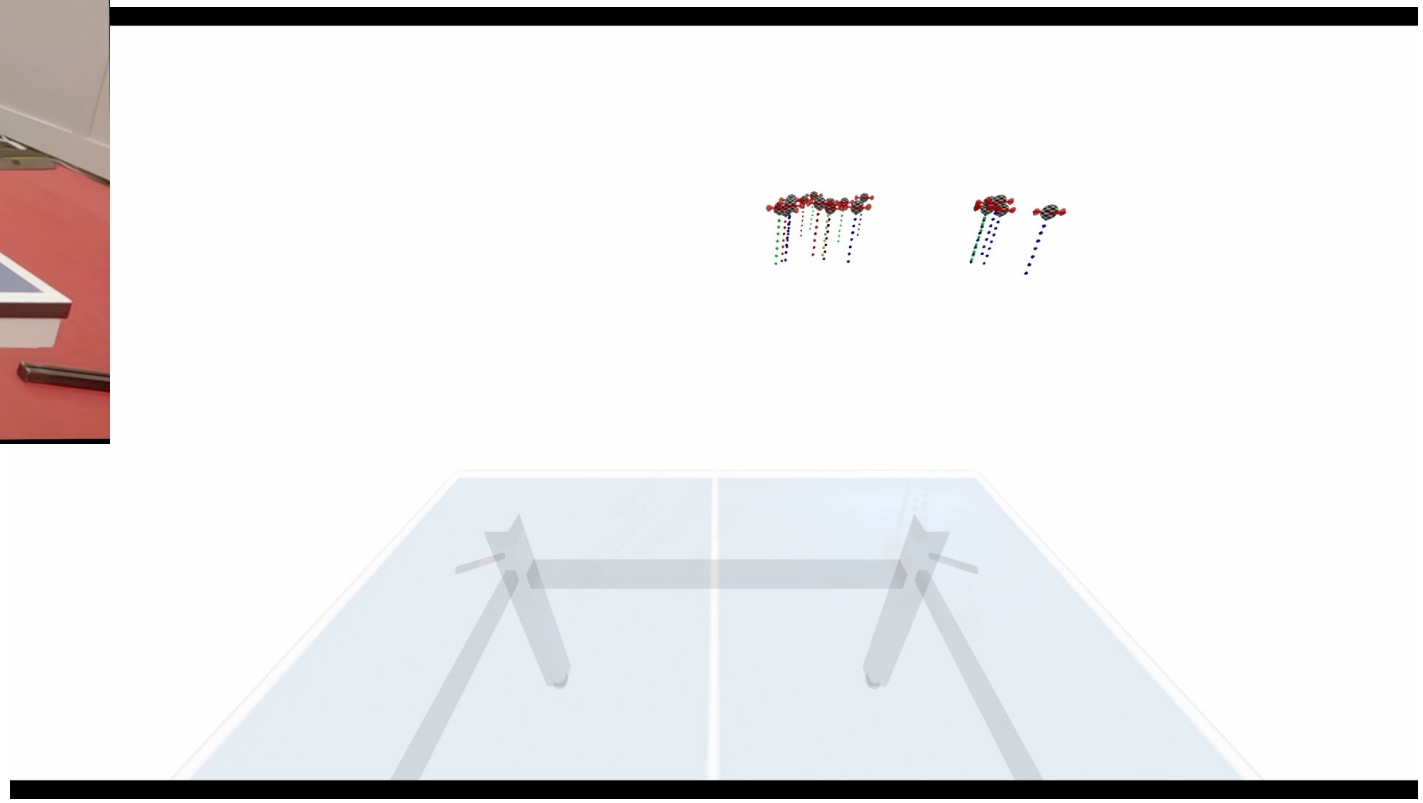


Fast Reaction to Surprising Situation

ace_vs_takenaka_game_1

Serves






19:02:55
10 10
tt_ace_vs_abe_game_0


15:31:52
7
5
tt-ace_vs_sone_game_1

Evaluation

Results vs. World-Class Athletes

Lost

Won at least 1 Match (Bo3)

T-League player (active)

Minami Ando
ITTF Highest: #29
(May 2019)



Results (14 Apr 2025):
- 1-3 (11-4, 7-1, 6-11, 1-11)

Kakeru Sone
ITTF Highest: #303 (Sept 2024)



Results (14 Apr 2025):
- 0-3 (8-11, 6-11, 9-11)

Mayuka Taira
ITTF Highest: #226
(June 2014)



Results (1-3 Dec 2025):
- 2-0 (11-3, 11-10)
- 2-0 (11-5, 11-10)

Kazuhiro Yoshimura
ITTF Highest: #34 (Sept 2019)



Results (1-3 Dec 2025):
- 0-2 (2-11, 6-11)
- 0-2 (7-11, 9-11)

Takako Nagao
ITTF Highest: #147
(April 2024)



Results (17 Feb 2025)*:
- 2-0 (11-4, 11-7)
- 2-0 (11-9, 11-8)
- 2-0 (11-5, 11-8)

Maki Shiomi
ITTF Highest: #32
(Mar 2018)



Results (18 Mar 2026)*:
- 2-0 (11-9, 11-7)
- 2-0 (11-3, 11-3)
- 2-0 (11-4, 11-4)
- 2-1 (11-4, 11-10)
- 2-0 (11-3, 11-2)

Shunsuke Okano
ITTF Highest: #179 (Jan 2026)



Results (18 Mar 2026)*:
- 2-0 (11-5, 11-5)
- 2-0 (11-0, 11-3)

Miyuu Kihara
ITTF Highest: #13 (Jul 2022)



Results (25 Mar 2026):
- 2-0 (11-1, 11-3)
- 2-0 (11-6, 11-2)
- 2-1 (11-6, 6-11, 11-5)

Tonin Ryuzaki
ITTF Highest: #99 (Jul 2017)



Results (25 Mar 2026):
- 2-0 (11-1, 11-3)
- 0-2 (9-11, 7-11)
- 1-2 (11-5, 7-11, 9-11)

Fumiya Igarashi
ITTF Highest: #211
(Jan 2026)



Results (25 Mar 2026):
- 1-2 (11-8, 5-11, 10-11)
- 2-0 (11-10, 11-5)

Miu Hirano
ITTF Highest: #5 (Nov 2017)



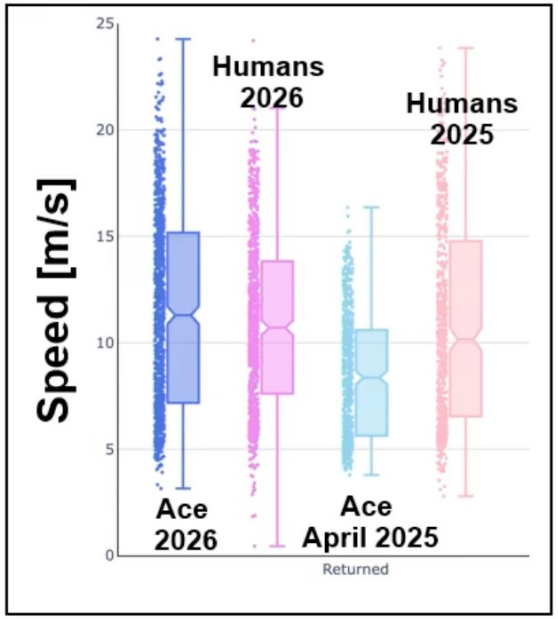
Results (20 Apr 2026):
- 2-0 (11-6, 11-3)
- 2-0 (11-3, 11-7)

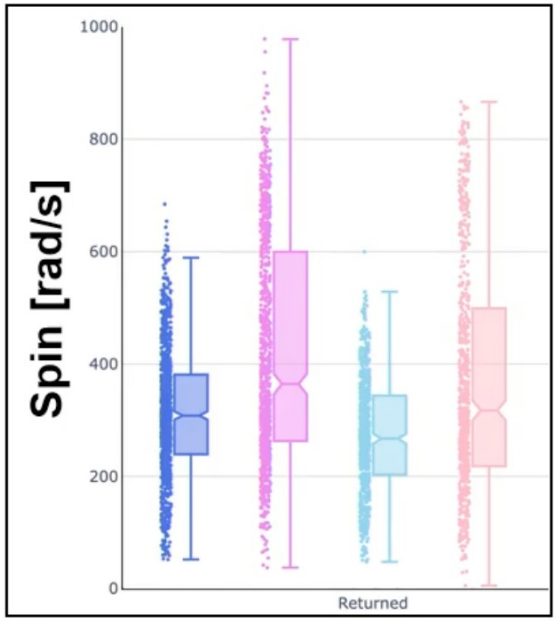
Apr. 2025 | Dec. 2025 | Spring 2026

* Result from match without licensed umpires

Human vs. Robot Table Tennis

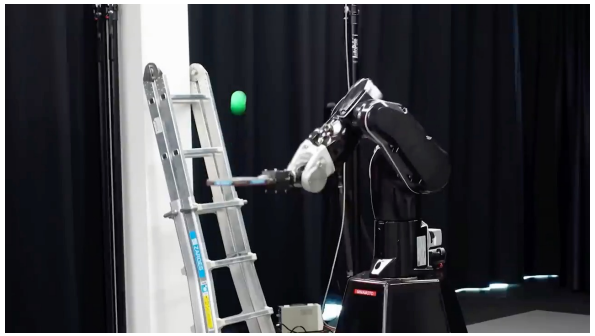
	Ace in April 2025	Ace in April 2026	Human Players
Median speed [m/s]	8.4 Slower than Humans	11.3 Slightly higher than Humans	11.0
Median spin [rad/s]	267 Lower than Humans	317 Lower than Humans	364





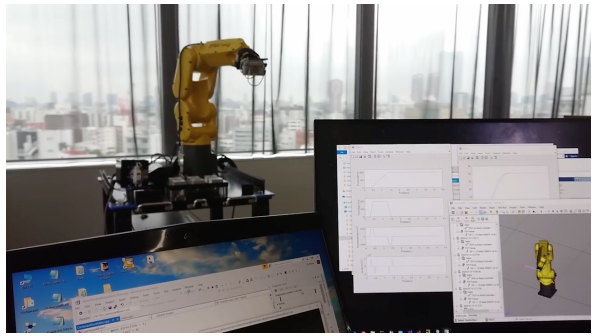

15:18:01
March 25th, 2026
Sony AI
in partnership with
Semiconductor Solutions
Fumiya Igarashi
(World Ranking 211 in January 2026)
ace_r_vs_igarashi_game_1

What did we actually learn?



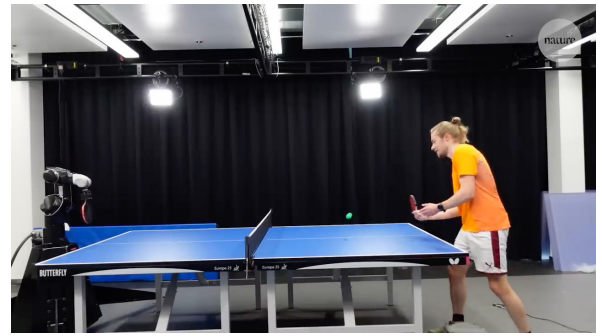
Staubli TX2-60L

Juggling



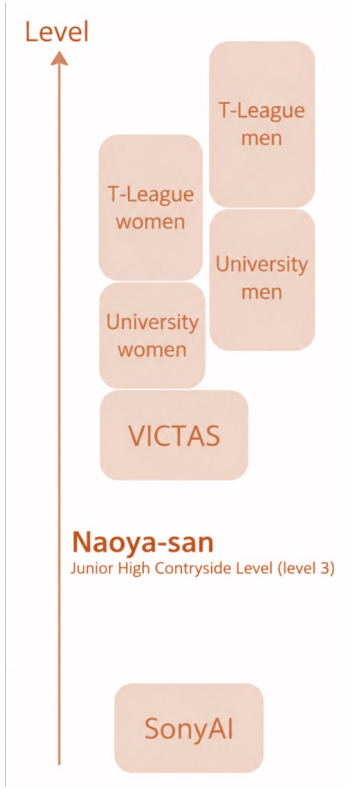
Fanuc LRmate 200iD/4S

Return



Customized Robot

Cooperative





Improved model

My Three Lessons from ACE

1. **The system is the algorithm**

   A strong policy is not enough. **Perception, learning, simulation, control, and hardware have to work as one system.**

2. **Sim-to-real is a loop, not a transfer**

   Real-world failures are valuable data. **Deploy, understand what failed, improve the simulator and training distribution, and learn again.**

3. **Performance changes what you can learn**

   As the robot gets better, it reaches **new and more extreme states that expose limitations you could not see before.**





Warm-up with Miu Hirano （Best World Rk.5）
Olympic silver medalist（Tokyo2020/Paris2024）

THANK YOU!

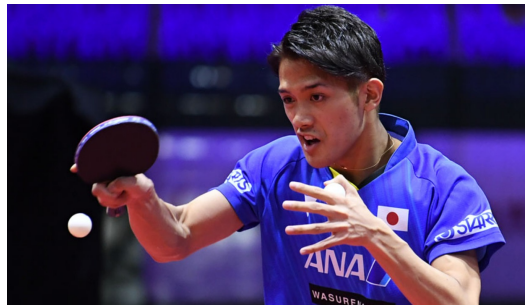


Kinjiro Nakamura,
1992 Olympian

"…no one else would have been able to do that.

I didn't think it was possible.
But the fact that it was possible [...]
means that
there is a possibility that a human could do it too"

"… returns are quite realistic, and it's really interesting.
The robot has returns that humans don't have,
so it's hard to predict, the ball suddenly comes to a place where it's not expected. […]
It was incredibly fun."



Kazuhiro Yoshimura
4~5 in Japan Men's Singles 2026
37 in the world (2019)