Using Learnable Physics for Real-Time Exercise Form Recommendations

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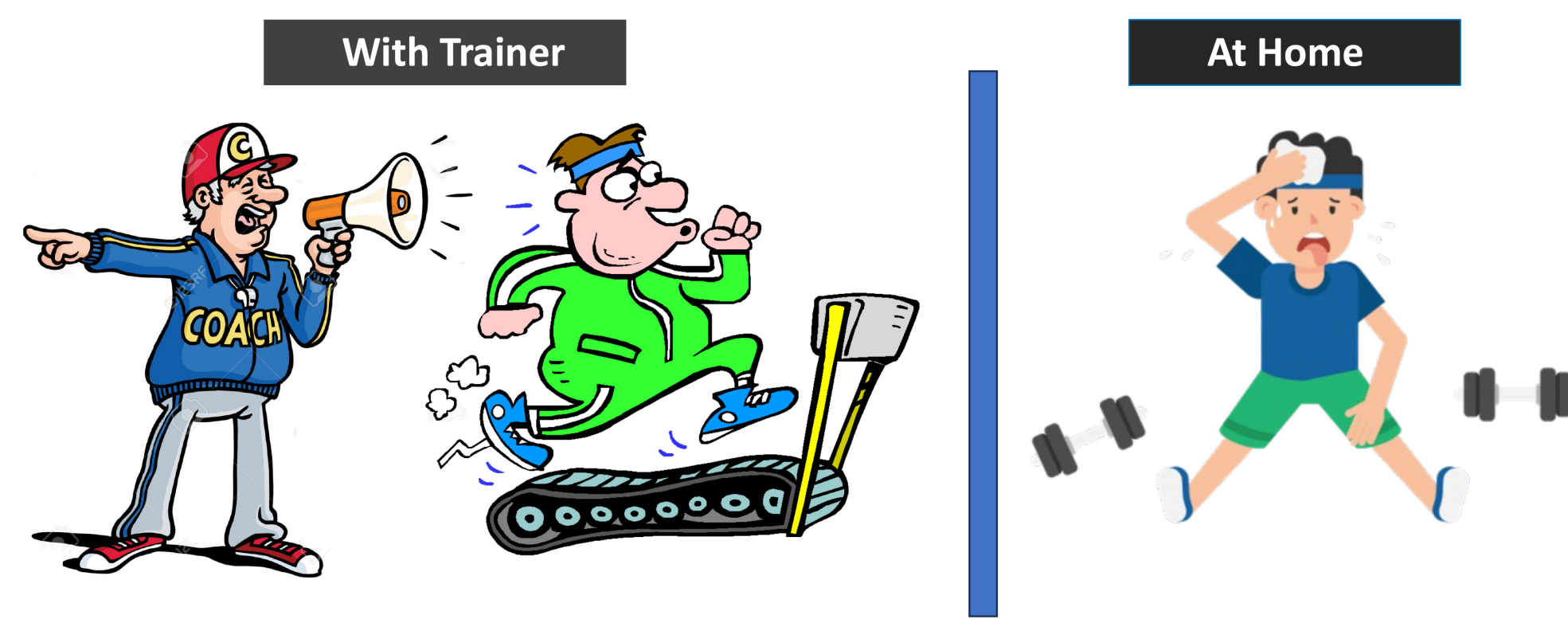
Do I need a Trainer?

Figure 1. Workout with Trainer vs Self-Practice at Home

- Home Settings lack proper exercise evaluation
- Personal trainers are an out of budget rarity
- Rehabilitation therapies and fitness workouts need real-time feedback.

Challenges in Home Settings

Sensors
Obtrusive
More Accurate
Difficult to Calibrate

Vision
No Hindrance
Less accurate
Easy to Use

- Sensors only good for High Performance
- But Cameras better for moderate settings
- Vision methods use generic thresholds
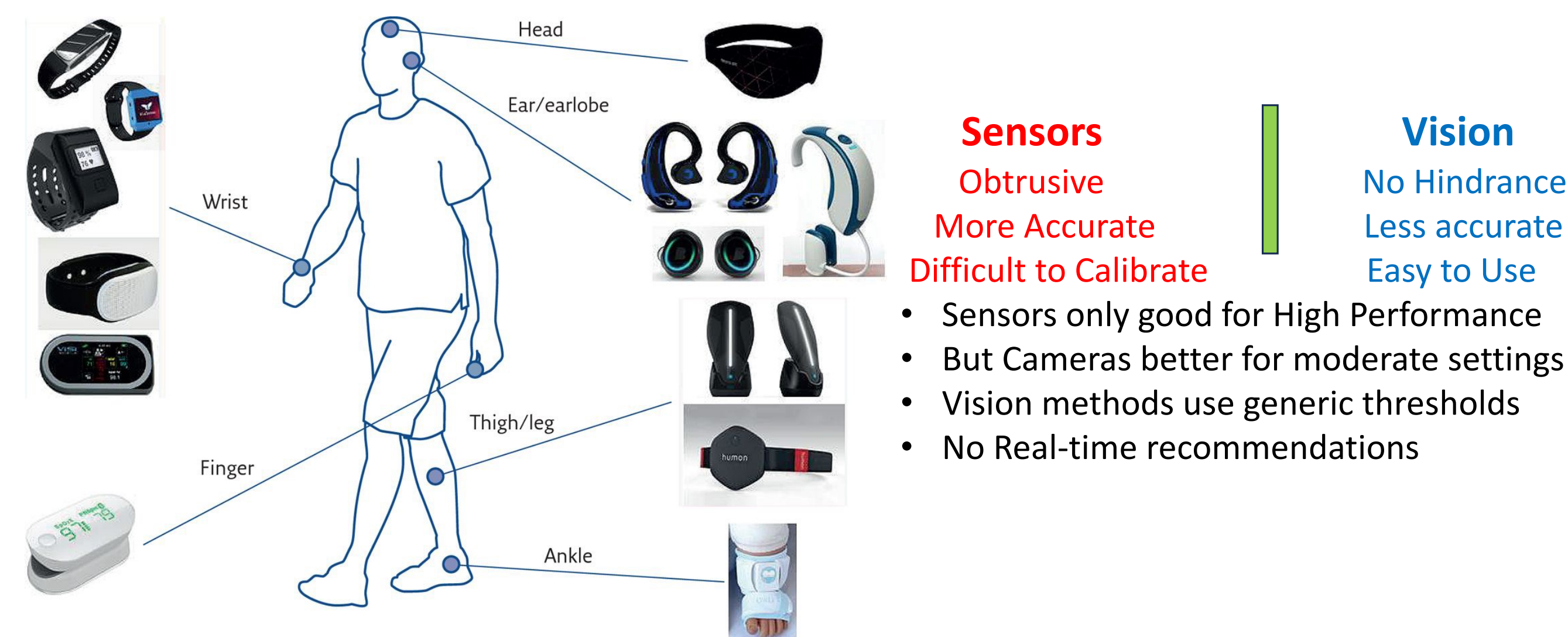- No Real-time recommendations

Figure 2. Example of Body worn sensors and comparison with vision based methods

Let's Learn the Physics of an Exercise

- Generic Solutions don't work well
- Interaction Networks(IN) [1] is one such physics-learning inference engine
- Offer Real-time Exercise form recommendations

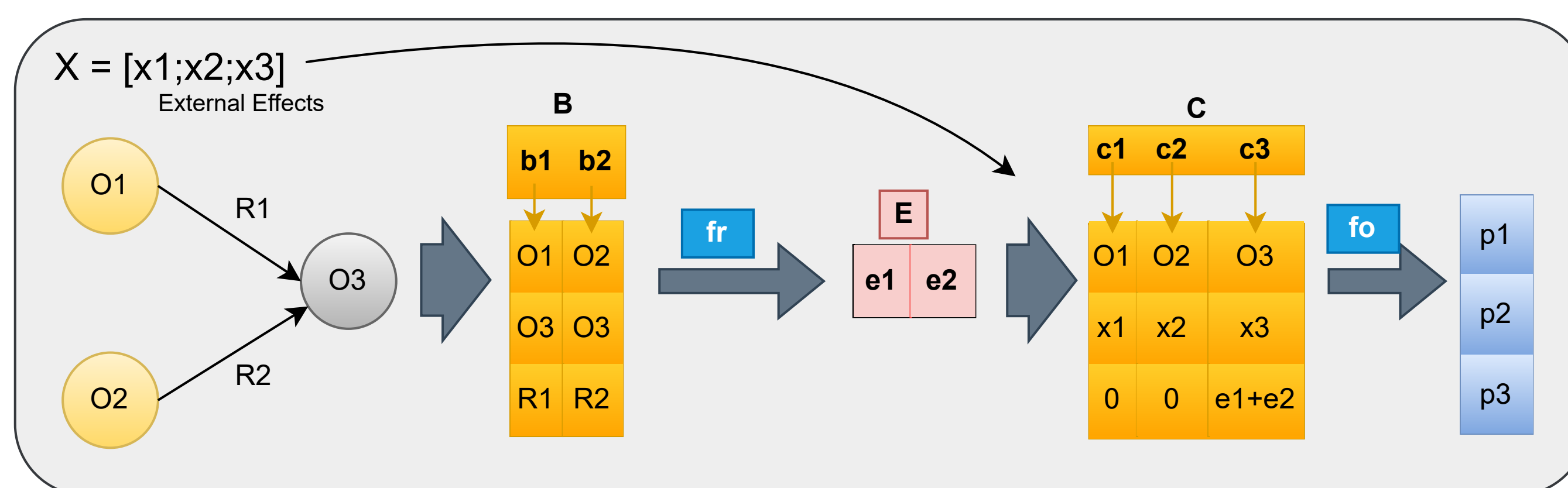## Background - Interaction Network(IN) and its input

Figure 3. Example showing working of Interaction Network

	O1	O2	O3
R1	1	0	0
R2	0	1	0

	O1	O2	O3
R1	0	0	1
R2	0	0	1

Figure 4. Sender and Receiver Matrix Graphs.

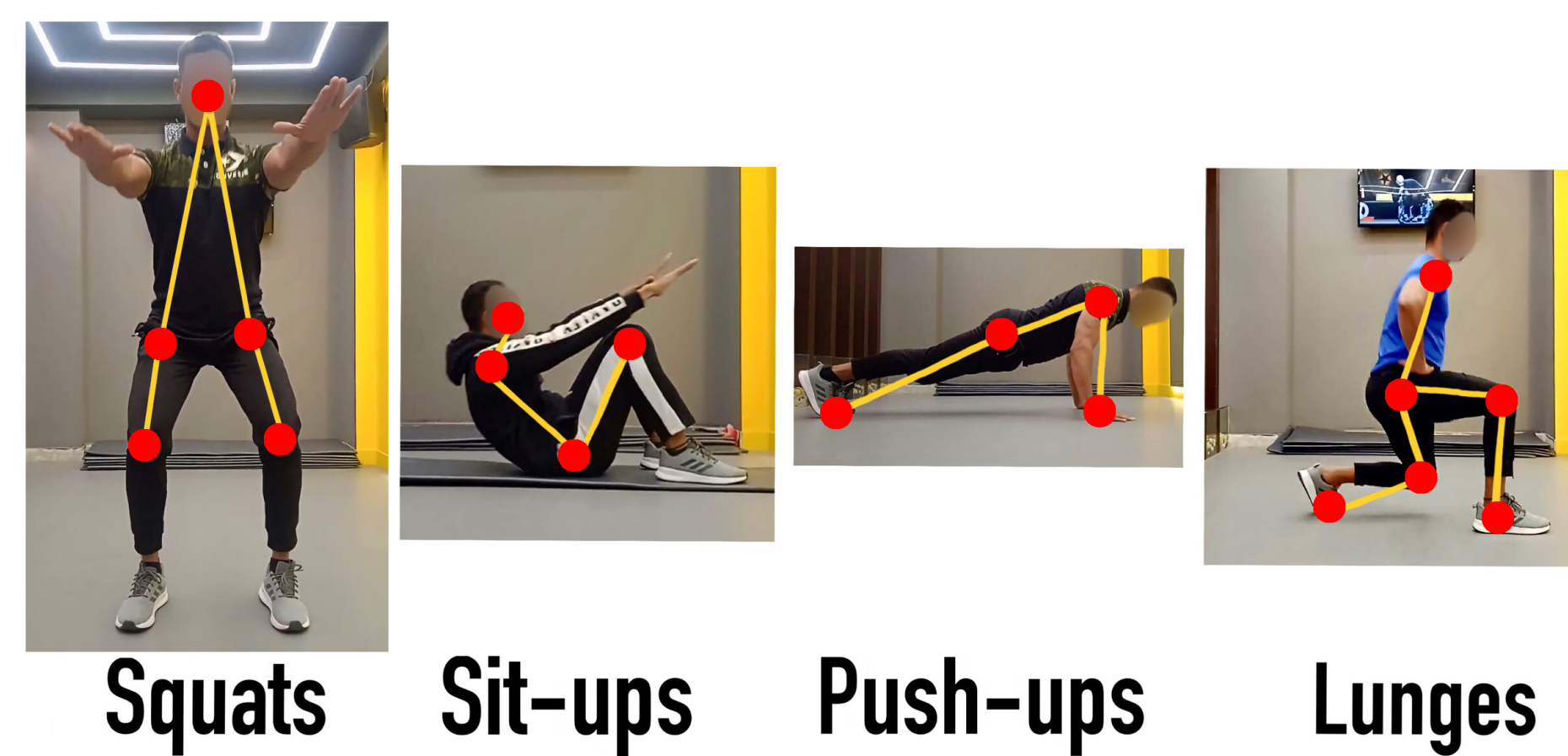## The Big Picture

Squats   Sit-ups   Push-ups   Lunges

Figure 5. Stick Figure for four full-body exercises. Selected landmarks for each exercise are marked in red.
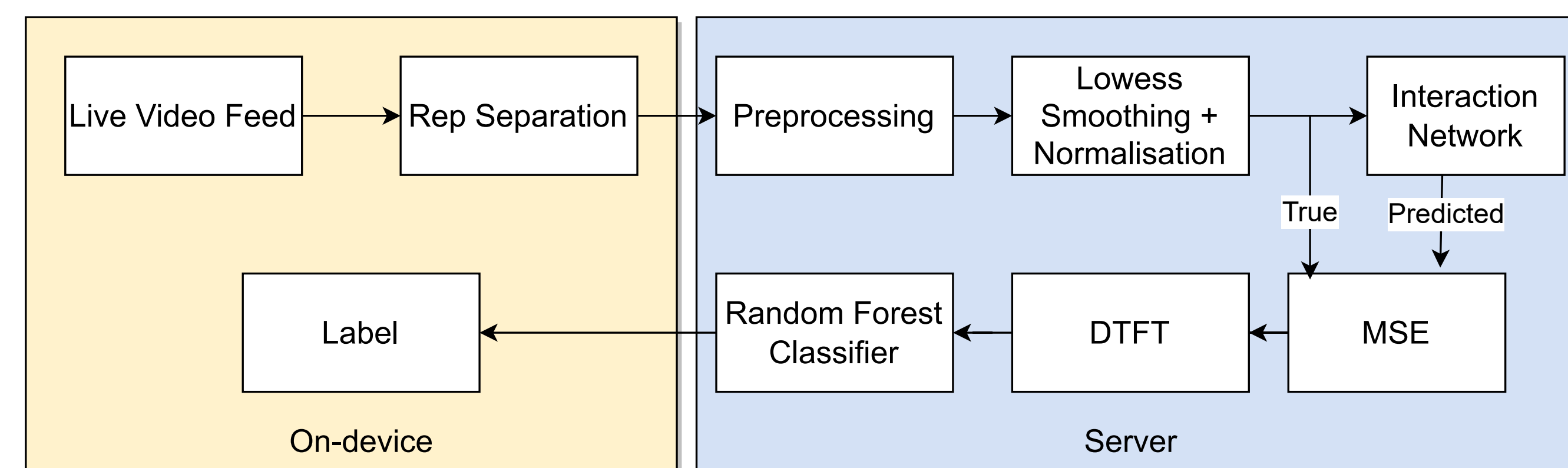

Figure 6. Flowchart illustrating our Interactive System's workflow.

- **Input:** Joint's position and velocity
- **Output:** Rollouts as per the learned physics
- **Classification:** The MSE between correct and performed posture
- **Recommendation:** One of the class categories

How well does it Work?

Model	Squats	Pushups	Lunges	Situps
MLP	0.91±0.02	0.98±0.03	0.95±0.03	0.99±0.01
RNN	0.85±0.04	0.98±0.01	0.94±0.01	0.98±0.02
GRU	0.87±0.03	0.98±0.01	0.93±0.02	0.94±0.04
IN	0.94±0.02	0.98±0.01	0.97±0.01	0.98±0.01

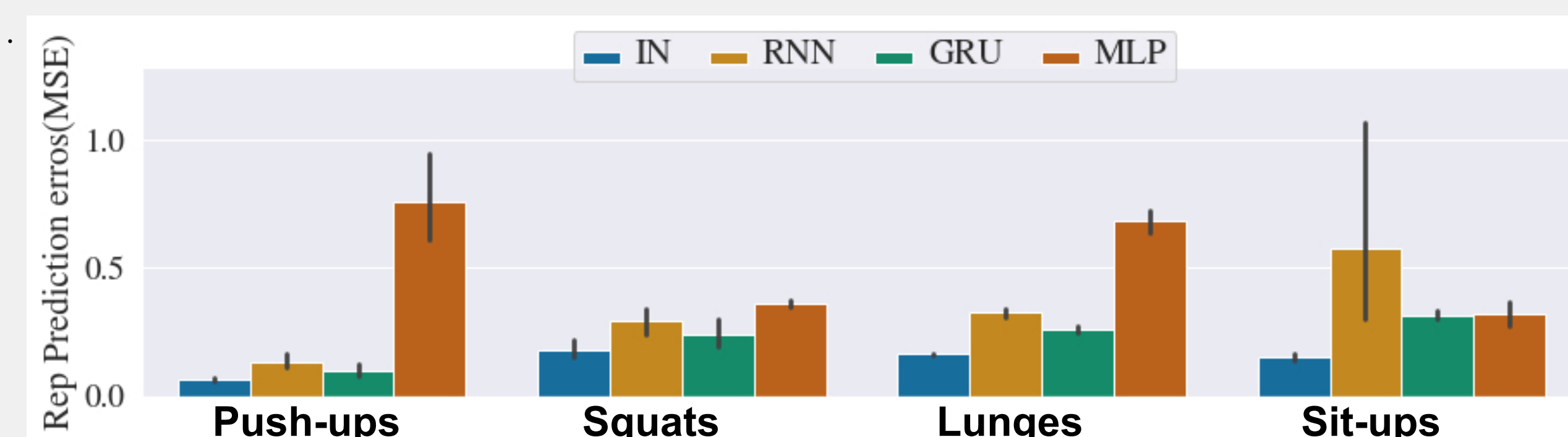Table 1. Avg. F1 **scores** for full body exercises

Figure 7. Avg. rollout pred. **errors** over exercise reps(MSE) for Baselines and IN.
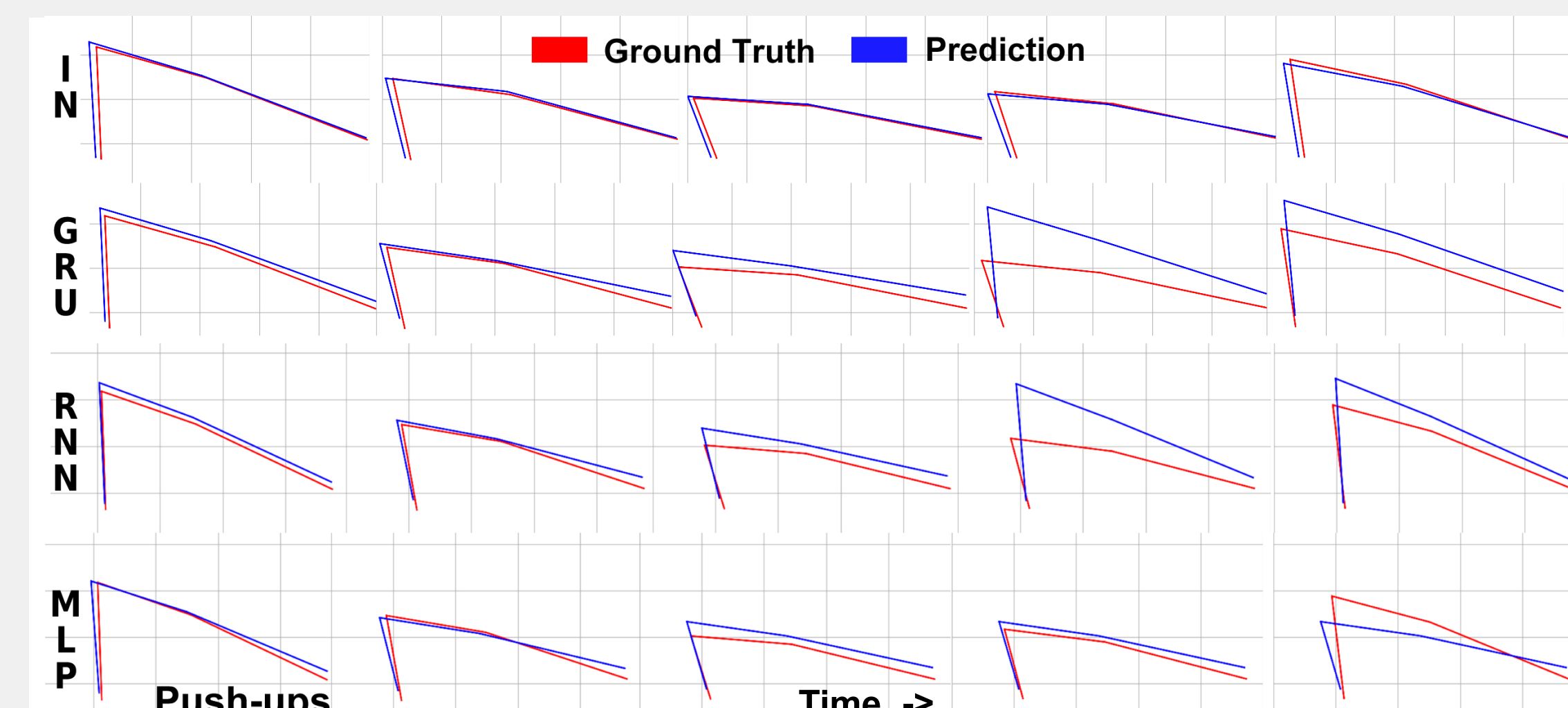

Figure 8. Pushups comparison for Baselens

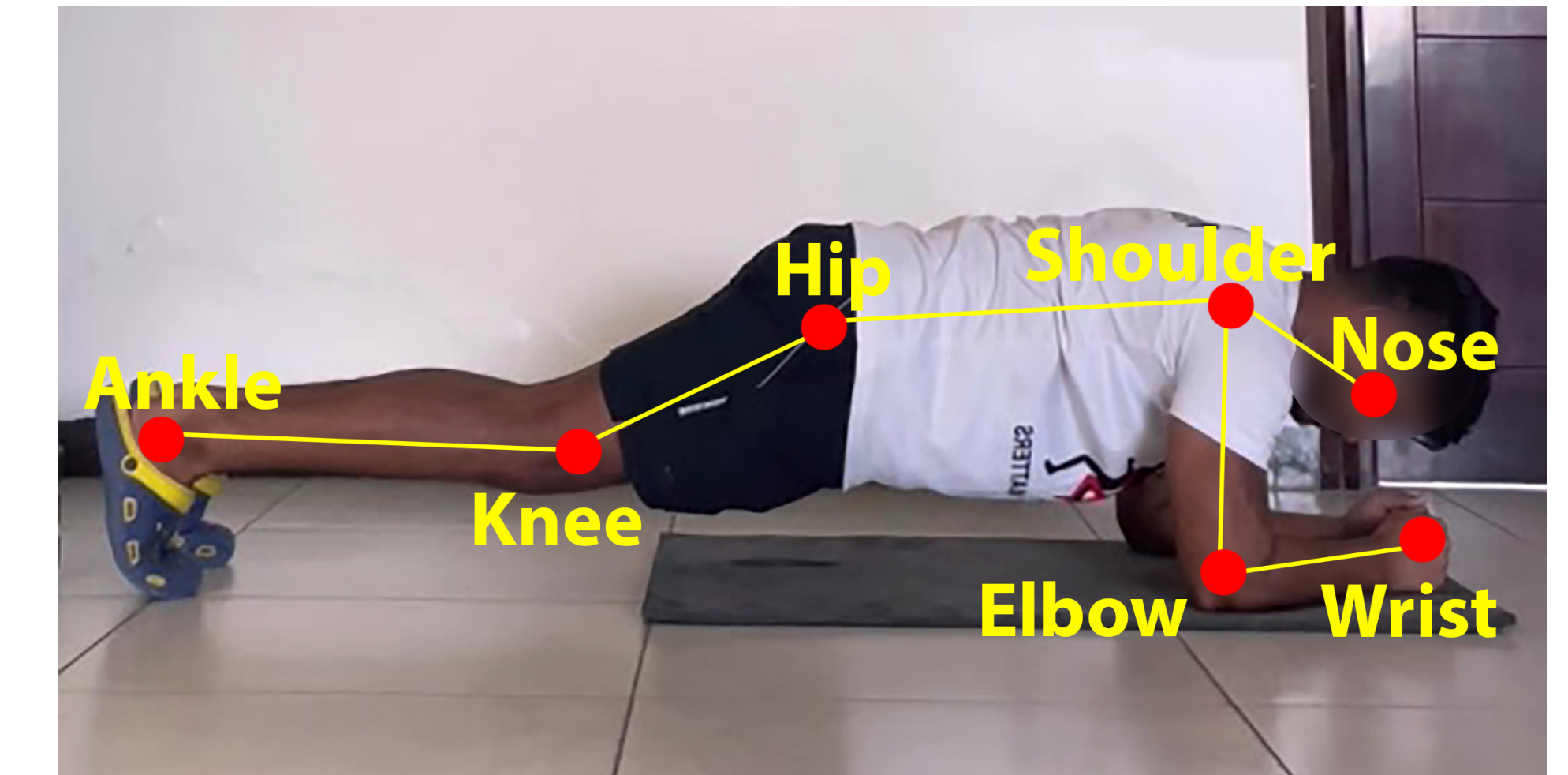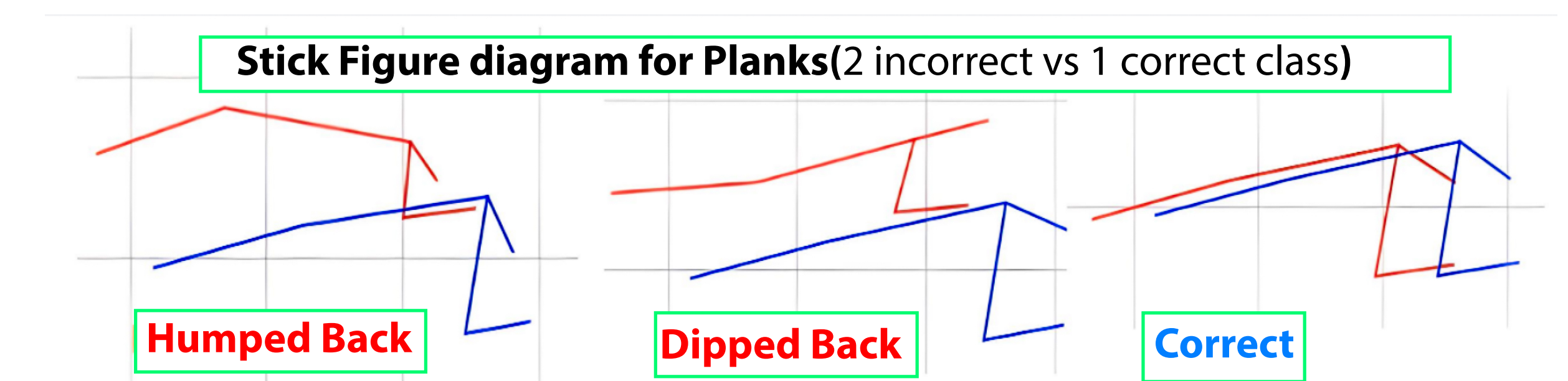## Incorrect Categories illustration - Planks

Figure 9. Planks - landmarks

Stick Figure diagram for Planks(2 incorrect vs 1 correct class)

Humped Back   Dipped Back   Correct

Figure 10. Planks correct incorrect classes

Real time Recommendations

- **Mobile application**
  - Captures user exercise
  - Outputs joint coordinates
  - Each exercise repetition sent to the server
- **Server**
  - Classifies rep as correct or mistake of a particular type
- **Corrective Recommendations**
  - Specific diagnosis displayed via the app
  - This feedback arrives before their next rep is halfway complete

Exercise	Mean(sec)	Standard deviation(sec)
Squats	0.55	0.13
Sit-ups	0.39	0.07
Push-ups	0.36	0.11
Lunges	0.54	0.09

Table 3. Lag time(seconds) for new rep recognition.

Conclusion and Discussion

- Physics endowed pipeline improves motion dynamics prediction
- Low latency prompts the user to quickly correct potential exercise injuries

Front Raise	MLP	RNN	GRU	IN
2 Classes	0.96±0.03	0.93±0.02	0.93±0.06	0.96±0.03
4 Classes	0.91 ±0.03	0.90±0.01	0.89±0.05	0.91±0.01
6 Classes	0.82±0.04	0.79±0.05	0.80±0.04	0.88±0.03

Table 2. Front Raise Classification Complexity with increasing incorrect classes

References

[1] Peter Battaglia, Razvan Pascanu, Matthew Lai, Danilo Jimenez Rezende, et al. Interaction networks for learning about objects, relations and physics. *Advances in neural information processing systems*, 29, 2016.

[2] Steven Chen and Richard R Yang. Pose trainer: correcting exercise posture using pose estimation. *arXiv preprint arXiv:2006.11718*, 2020.

[3] Jiunn Ng. *Posture evaluation for variants of weight-lifting workouts recognition*. PhD thesis, UTAR, 2020.