PitcherNet: Powering the Moneyball Evolution in Baseball Video Analytics

Jerrin Bright, Bavesh Balaji, Yuhao Chen, David Clausi and John Zelek

Vision and Image Processing Lab

Department of Systems Design Engineering

University of Waterloo, Waterloo, ON, Canada

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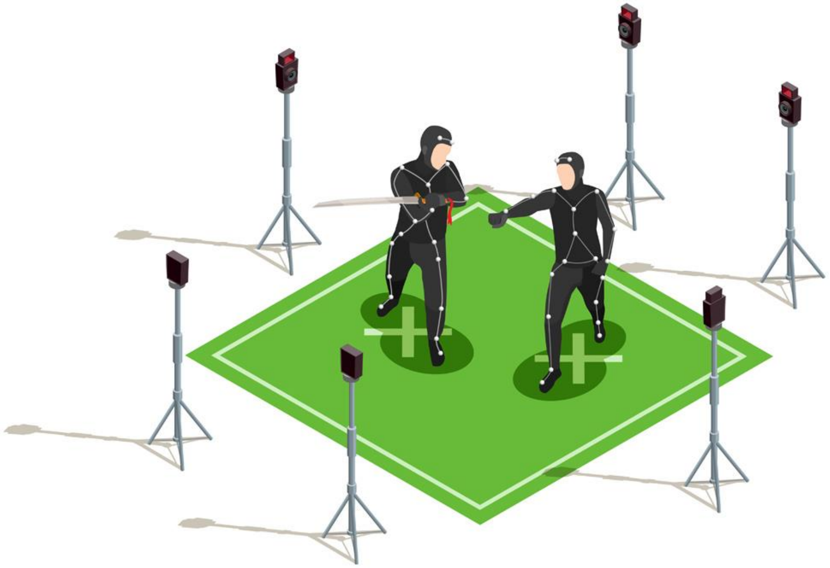
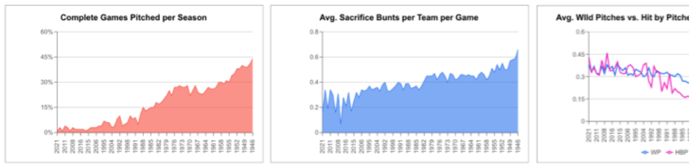
Prior Research on Baseball Analysis



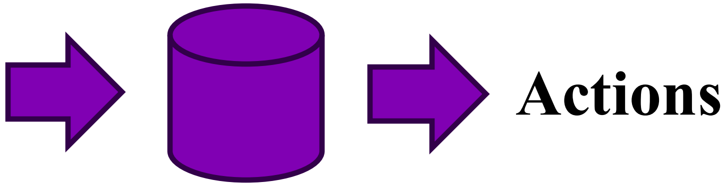
- Pre-recorded baseball databases (Pitch f/x).

- Controlled environments (MoCap Systems).



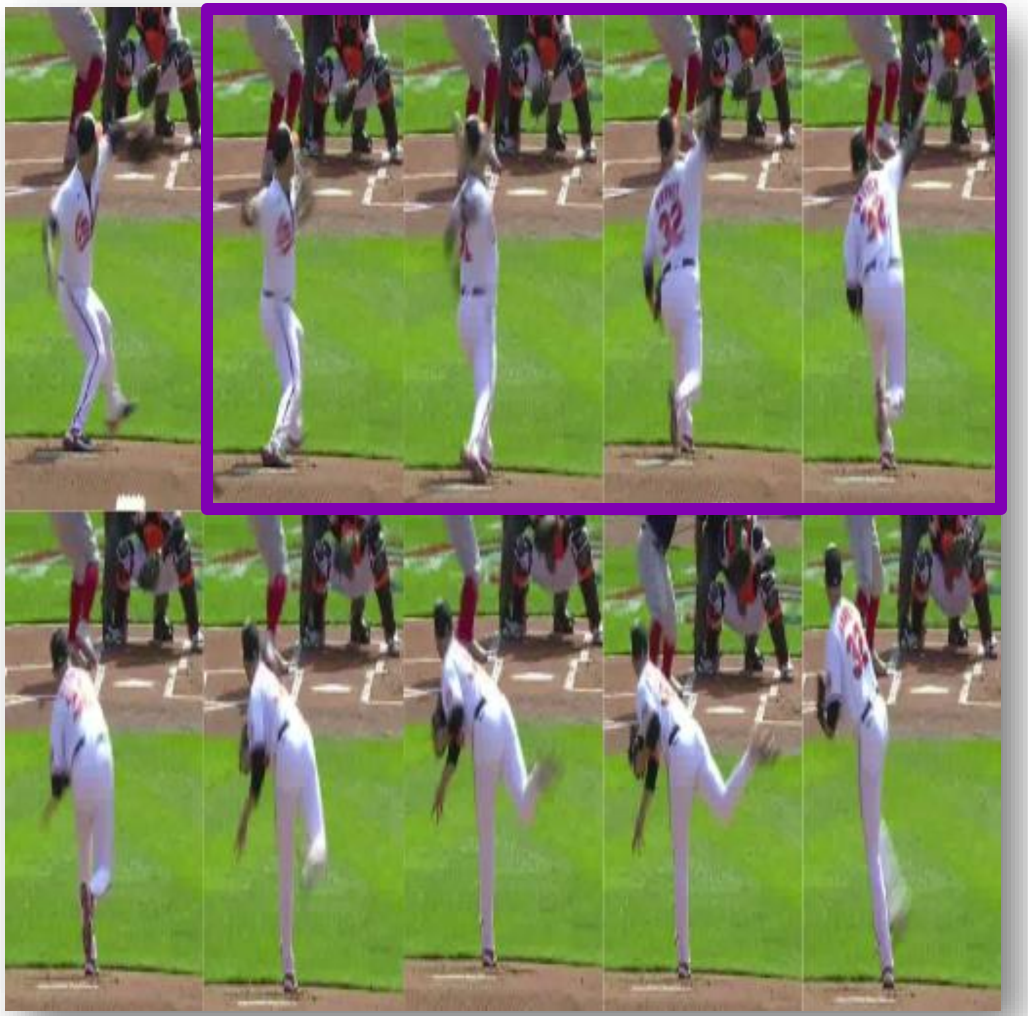
MLB Modern Era Statistics (1946–2021)

	Defensive Statistics													Offensive Statistics				
Year	ERA	CG	SHO	BB	IBB	SO	HBP	BK	WP	BF	WHIP	BAbip	E	PG	R	H	2B	3B	HR
2021	4.26	1%	1%	3.25	0.14	8.68	0.43	0.03	0.38	37.43	1.297	0.292	0.54	0	4.53	8.13	1.62	0.14	1.22
2009	4.31	3%	1%	3.42	0.24	6.91	0.33	0.03	0.33	38.49	1.39	0.299	0.59	1	4.61	8.96	1.8	0.2	1.04
2017	4.35	1%	1%	3.26	0.2	8.25	0.36	0.03	0.37	38.13	1.342	0.3	0.58	0	4.65	8.69	1.73	0.16	1.26
2011	3.94	4%	2%	3.09	0.25	7.1	0.32	0.03	0.32	38.13	1.316	0.295	0.63	0	4.28	8.7	1.73	0.18	0.94
2012	4.01	3%	1%	3.03	0.22	7.5	0.31	0.03	0.32	37.9	1.309	0.297	0.62	3	4.32	8.65	1.7	0.19	1.02
2019	4.49	1%	1%	3.27	0.16	8.81	0.41	0.03	0.37	38.39	1.334	0.298	0.6	0	4.83	8.65	1.76	0.16	1.39
2008	4.32	3%	1%	3.36	0.27	6.77	0.34	0.03	0.32	38.64	1.391	0.3	0.61	0	4.65	9.06	1.86	0.18	1
2020	4.44	2%	1%	3.39	0.11	8.68	0.46	0.04	0.38	37.03	1.327	0.292	0.58	0	4.65	8.04	1.57	0.13	1.28
2014	3.74	2%	1%	2.88	0.2	7.7	0.34	0.03	0.35	37.85	1.275	0.298	0.6	0	4.07	8.56	1.67	0.17	0.86
2016	4.18	2%	1%	3.11	0.19	8.03	0.34	0.03	0.37	38.01	1.325	0.3	0.58	0	4.48	8.71	1.7	0.18	1.16
2007	4.46	2%	1%	3.31	0.27	6.62	0.36	0.03	0.31	38.8	1.406	0.302	0.61	0	4.8	9.25	1.89	0.19	1.02
2018	4.14	1%	0%	3.23	0.19	8.48	0.4	0.03	0.38	38.08	1.304	0.295	0.57	0	4.45	8.44	1.7	0.17	1.15
2015	3.95	2%	1%	2.9	0.2	7.71	0.33	0.03	0.36	37.8	1.294	0.299	0.58	0	4.25	8.67	1.7	0.19	1.01
2010	4.07	3%	1%	3.25	0.25	7.06	0.32	0.04	0.34	38.18	1.347	0.297	0.62	2	4.38	8.76	1.75	0.18	0.95
2013	3.86	3%	1%	3.01	0.21	7.55	0.32	0.03	0.36	38.02	1.3	0.297	0.56	0	4.17	8.66	1.69	0.16	0.96
2006	4.52	3%	1%	3.26	0.29	6.52	0.37	0.03	0.31	38.71	1.408	0.301	0.63	0	4.86	9.28	1.88	0.2	1.11
2003	4.39	4%	1%	3.27	0.27	6.34	0.38	0.03	0.32	38.57	1.383	0.294	0.65	0	4.73	9.07	1.82	0.19	1.07



Challenges with Video Inputs

Motion Blur



Self-Occlusion

Out-of-distribution

Vision and Image Processing Research Group
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vip.uwaterloo.ca
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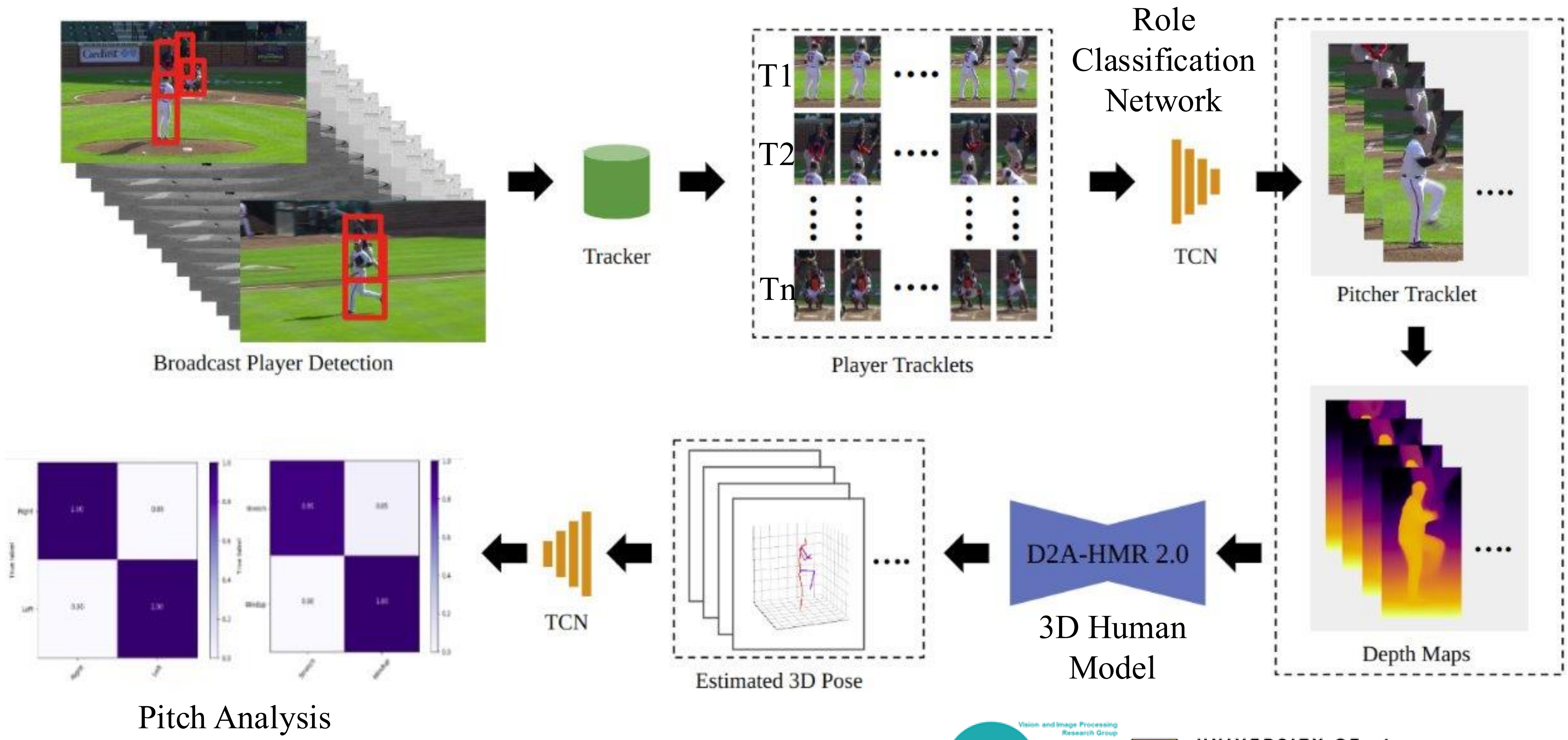
Objective

"Enable detailed analysis of pitcher dynamics from human models in 3D extracted solely from monocular broadcast feeds"

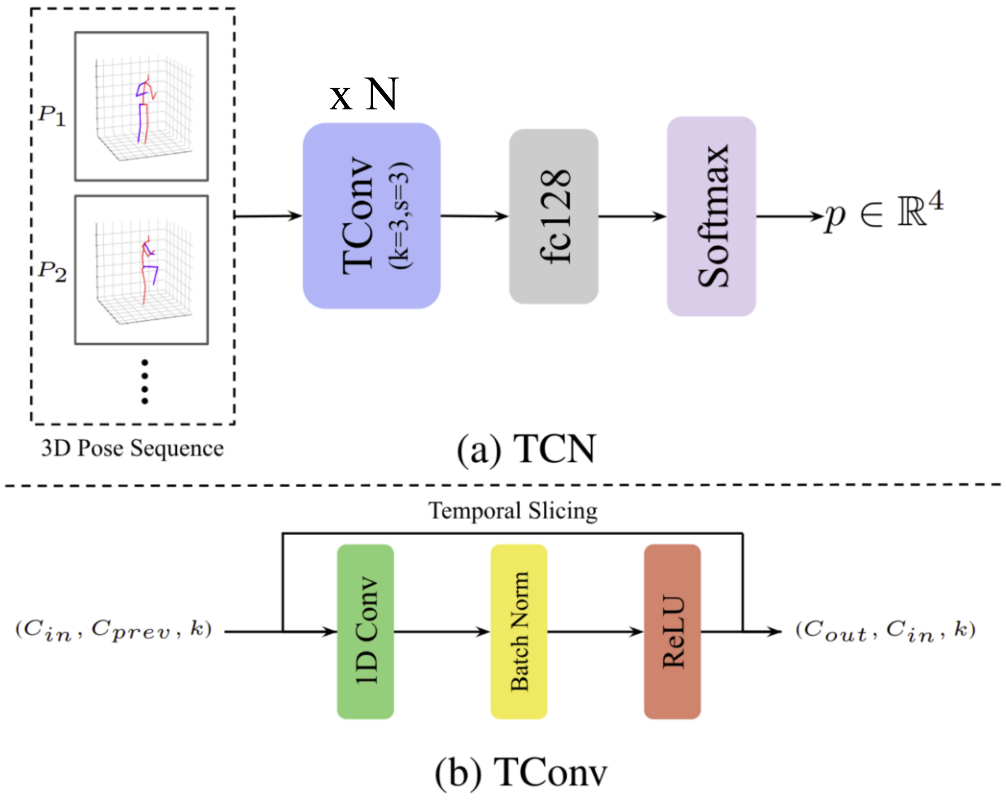
PitcherNet System



Role Classification

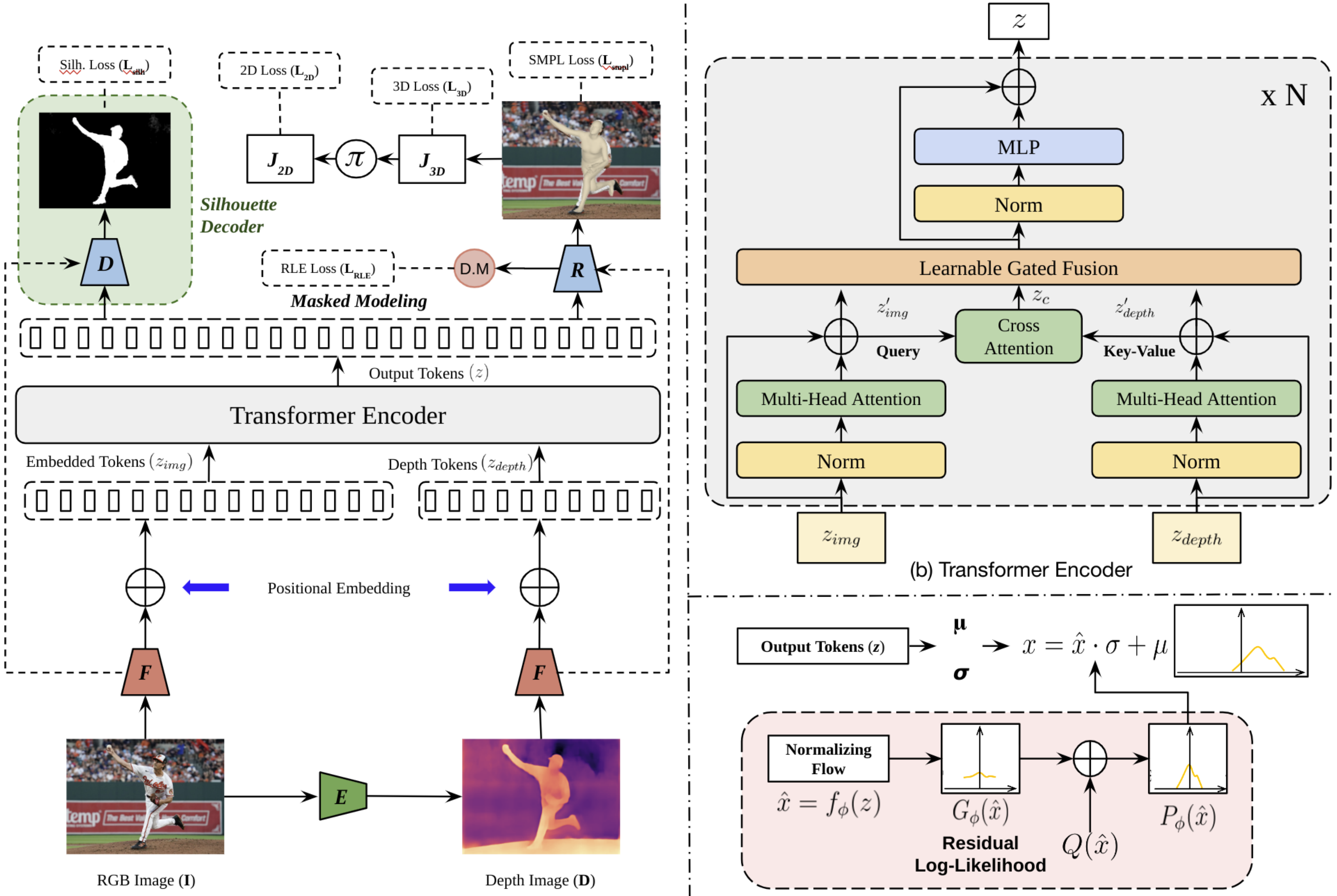
- Decouples action from player kinematics.
  - Input: Pseudo-pose from estimated tracklets.
  - Output: Player role.

- Invariant to viewpoint/ facial features/ player jersey numbers.



3D Human Model

- Distribution and depth aware 3D modeling [2].
- Motion blur and in-the-wild data augmentation.
- Generalizable, reliable 3D human models.



(a) Proposed D2A-HMR framework

(b) Transformer Encoder

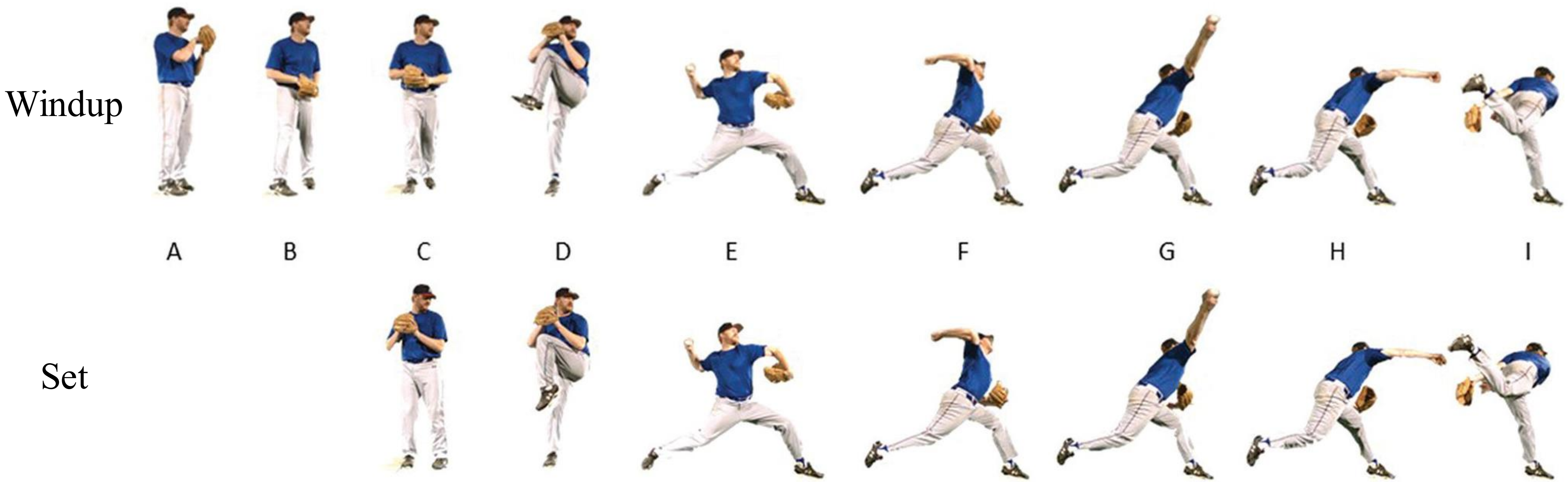
(c) Distribution Matching (D.M)

[2] **Jerrin Bright**, Bavesh Balaji, Harish Prakash, Yuhao Chen, David A Clausi, and John Zelek. 2024. Distribution and Depth-Aware Transformers for 3D Human Mesh Recovery. In 21st Conference on Robots and Vision - ORAL

Pitch Analysis

- Pitch Position

$$PP(windup, set) = \sigma(TCN(X))$$

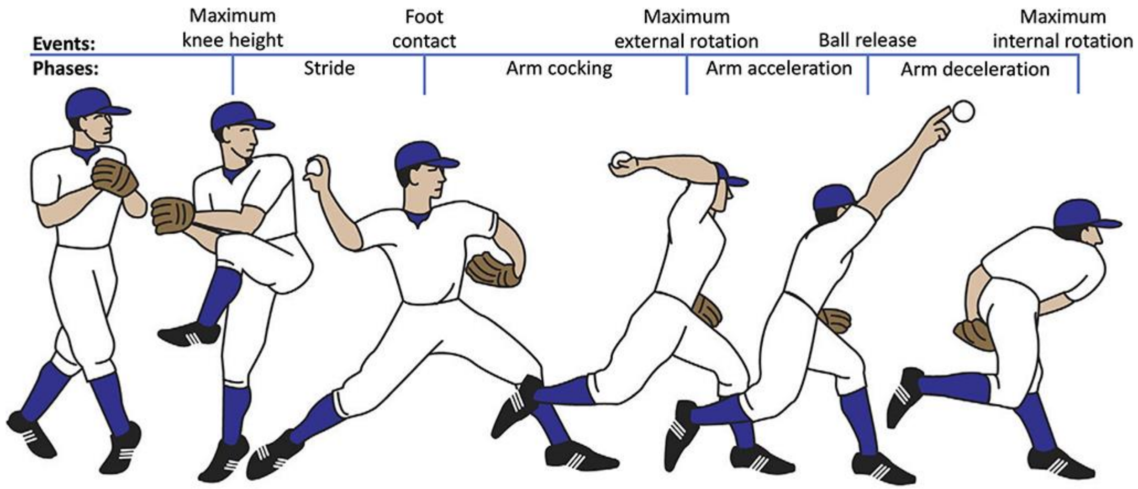


Pitch Analysis

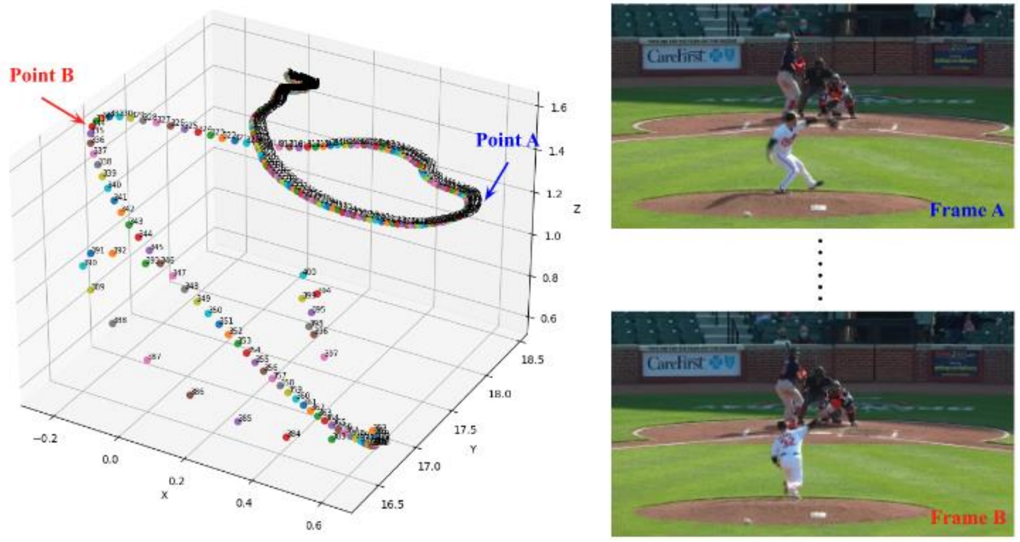
- Release Point

$$P_{rel} = argmax(v(i)|i \in [P_b - n/2, P_b + n/2])$$

Point A- Arm Cocking
Point B- Arm Deceleration



6 phases of pitching action



Trajectory of the right wrist joint in 3D space

Pitch Analysis

- Pitch Velocity

$$v_p = \omega \times l = \{(atan(w_y^r, w_x^r) - atan(w_y^{r-1}, w_x^{r-1})) \times T\} \times l$$

- Release Extension

$$E_{rel} = \sqrt{(w_x - a_x)^2 + (w_y - a_y)^2 + (w_z - a_z)^2}$$

Quantitative Results of Role Classification

Table I. Comparison with baselines

	Test Accuracy ↑
LSTM	85.55
Transformer	91.11
Ours	**96.66**

Table II. Comparison with jersey identification techniques

	Test Accuracy ↑
Gerke *et al.* [21]	64.47
Li *et al.* [30]	88.29
Vats *et al.* [48]	89.46
Balaji *et al.* [2]	93.68
Balaji *et al.* [3]	94.70
Ours	**96.82**

Quantitative Results of Pitch Analysis

Table III. Performance of our pitch statistics modules

(a) Handedness

	Accuracy ↑	F1 Score ↑	Precision ↑
LSTM	85.0	85.7	90.0
Ours (TCN)	**100.0**	**100.0**	**100.0**

(b) Pitch Position

	Accuracy ↑	F1 Score ↑	Precision ↑
LSTM	81.3	82.5	85.0
Ours (TCN)	**97.5**	**97.4**	**95.0**

(c) Release Point

	A_1 ↑	A_2 ↑	A_5 ↑
LSTM	31.3	46.4	63.5
TCN	43.4	51.5	77.6
Ours	**80.8**	**85.8**	**97.9**

(d) Pitch Velocity

	$A_{1\%}$ ↑	$A_{2\%}$ ↑	$A_{5\%}$ ↑
LSTM	5.1	13.1	22.2
TCN	10.1	18.1	48.4
Ours	**43.4**	**68.6**	**94.9**

(e) Release Extension

	$A_{5\%}$ ↑	$A_{8\%}$ ↑	$A_{10\%}$ ↑
LSTM	4.0	7.1	11.1
TCN	14.1	19.1	25.2
Ours	**24.2**	**31.3**	**37.3**

Qualitative Results (Pitch Analysis)

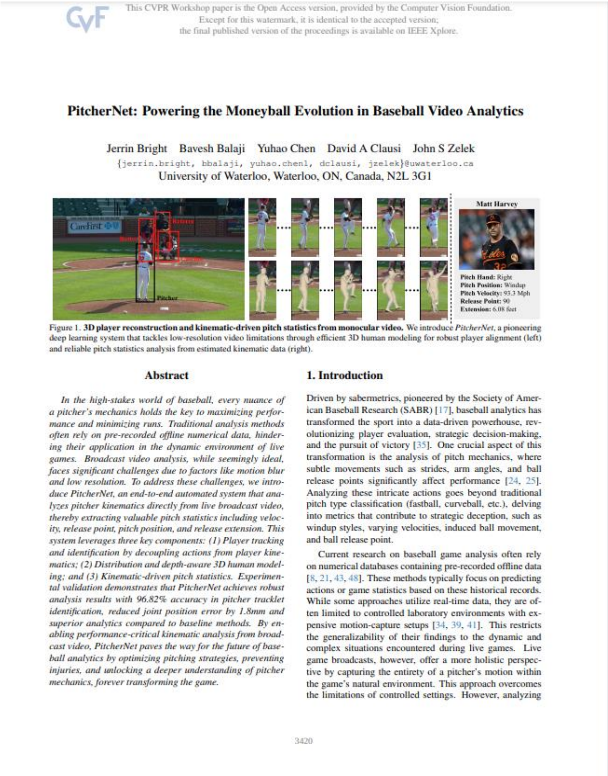
Pitch Hand	**Pred**: Left	**GT**: Left
Pitch Position	**Pred**: Stretch	**GT**: Stretch
Pitch Velocity	**Pred**: 90.48 Mph	**GT**: 87.58 Mph
Release Point	**Pred**: 90	**GT**: 90
Extension	**Pred**: 5.85 feet	**GT**: 6.13 feet

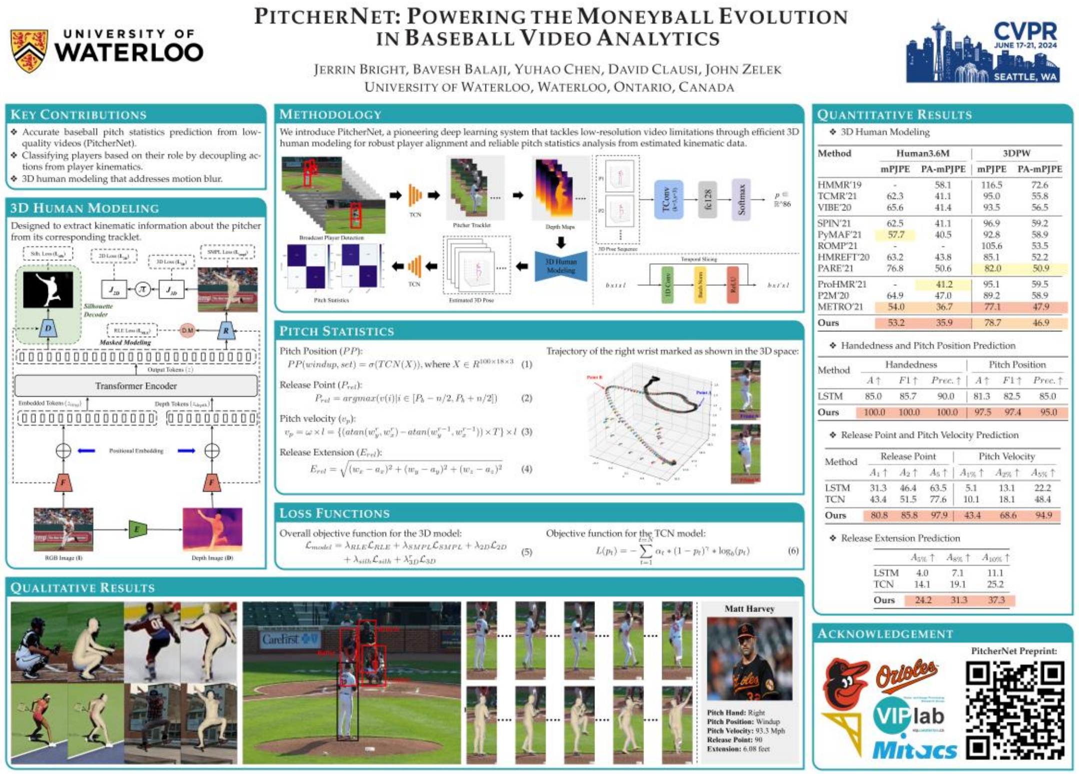
Pitch Hand	**Pred**: Left	**GT**: Left
Pitch Position	**Pred**: Windup	**GT**: Windup
Pitch Velocity	**Pred**: 85.76 Mph	**GT**: 89.17 Mph
Release Point	**Pred**: 88	**GT**: 89
Extension	**Pred**: 6.01 feet	**GT**: 6.16 feet

Pitch Hand	**Pred**: Right	**GT**: Right
Pitch Position	**Pred**: Windup	**GT**: Windup
Pitch Velocity	**Pred**: 85.46 Mph	**GT**: 85.65 Mph
Release Point	**Pred**: 87	**GT**: 87
Extension	**Pred**: 6.17 feet	**GT**: 6.11 feet

Summary

- Reliable pitch analysis driven by player kinematics and human model priors.
- Role classification aiming to classify players by decoupling actions.
- D2A-HMR v2 which improves 3D human modeling in degraded image quality.





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Thank you!

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