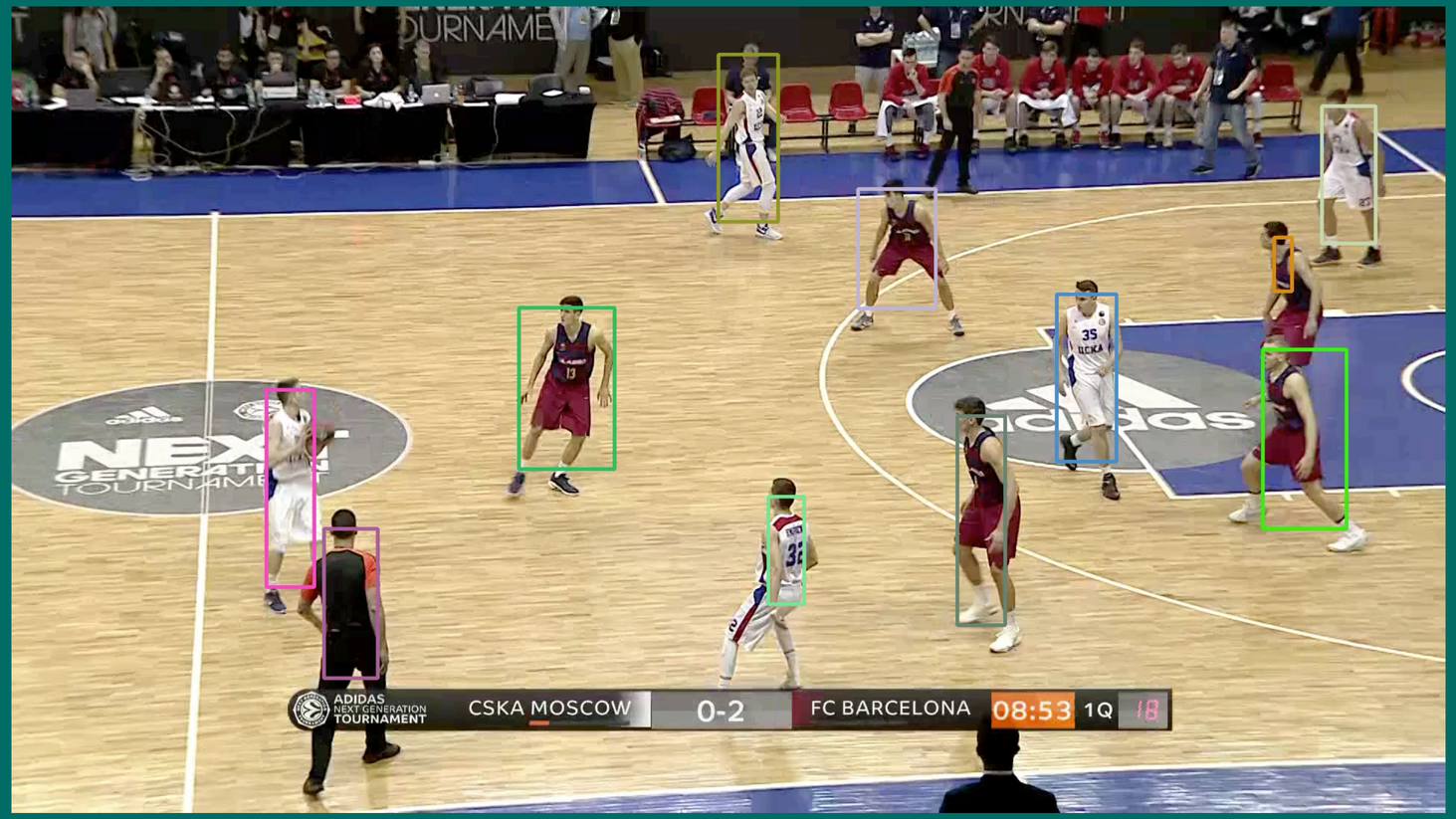
Bringing Computer Vision to the Court

Adrià Arbués-Sangüesa
Universitat Pompeu Fabra
Invited talk at CVSports 2021

Brief CV *(Curriculum Vitae, not Computer Vision)*

- PhD Fellow at Universitat Pompeu Fabra (Barcelona), defense in September 2021 (hopefully!).
- Academical contributions: tracking & body-orientation & applications



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[1] Single-Camera Basketball Tracker through Pose and Semantic Feature Fusion
[2] Multi-Person Tracking by Multi-Scale Detection in Basketball Scenarios
[3] Always Look on the Bright Side of the Field: Merging Pose and Contextual Data to Estimate Orientation of Soccer Players
[4] Using Player's Body-Orientation to Model Pass Feasibility in Soccer
+ paper extension under review!
[5] Learning Football Body-Orientation as a Matter of Classification

Research team: Adrián Martín (postdoc), Coloma Ballester and Gloria Haro (supervisors)

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C.B. Cornellà (1st team - 3rd division)

F.C. Barcelona (u15)

@arbues6

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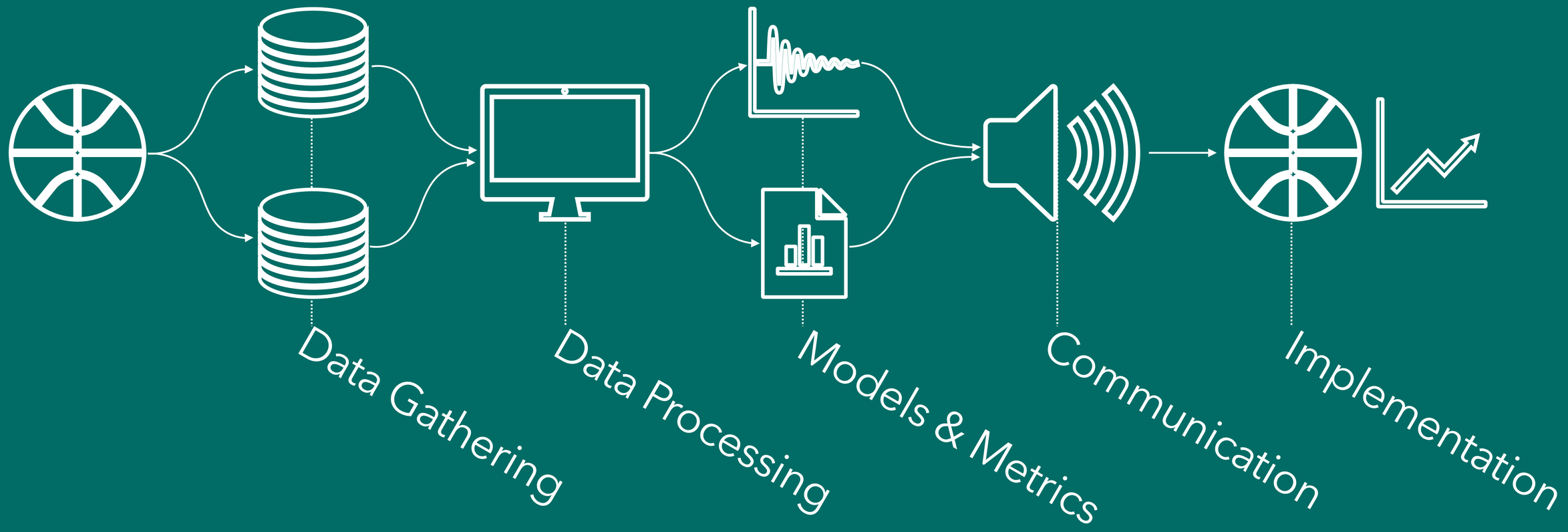
- Academical contributions: tracking & body-orientation & applications
- When models are training… I am **coaching & disseminating**!

ImproveSports Stats Course

Beyond the 4 Factors

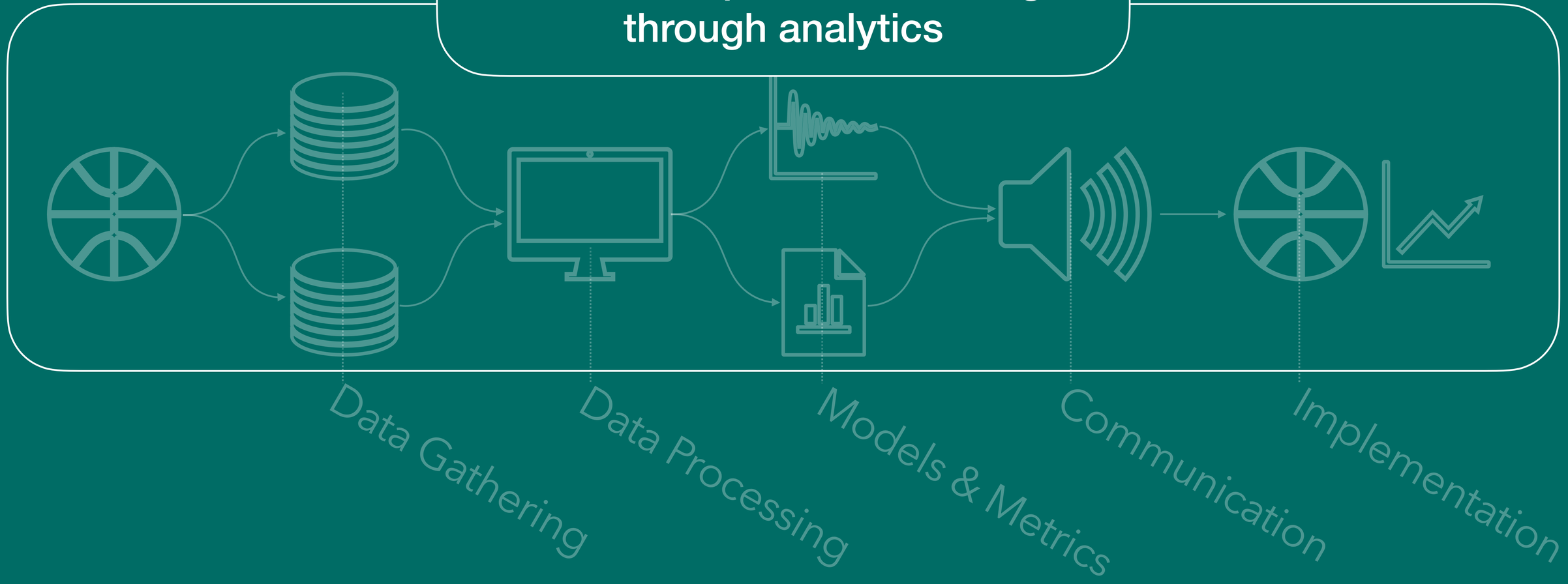
@arbues6

In this talk…


Data Gathering
Data Processing
Models & Metrics
Communication
Implementation

But first… Why?

Build a competitive advantage through analytics



Competitive Advantage

GM's / Board of directors

Hire the best possible
players / coaches

Coaching Staff

Build team chemistry
Design a playbook
Exhaustive scouting

Players

Stay healthy
Work hard & listen

Shared Goal:
Winning as many
games as possible

Data-driven processes

Competitive Advantage

GM's / Board of directors

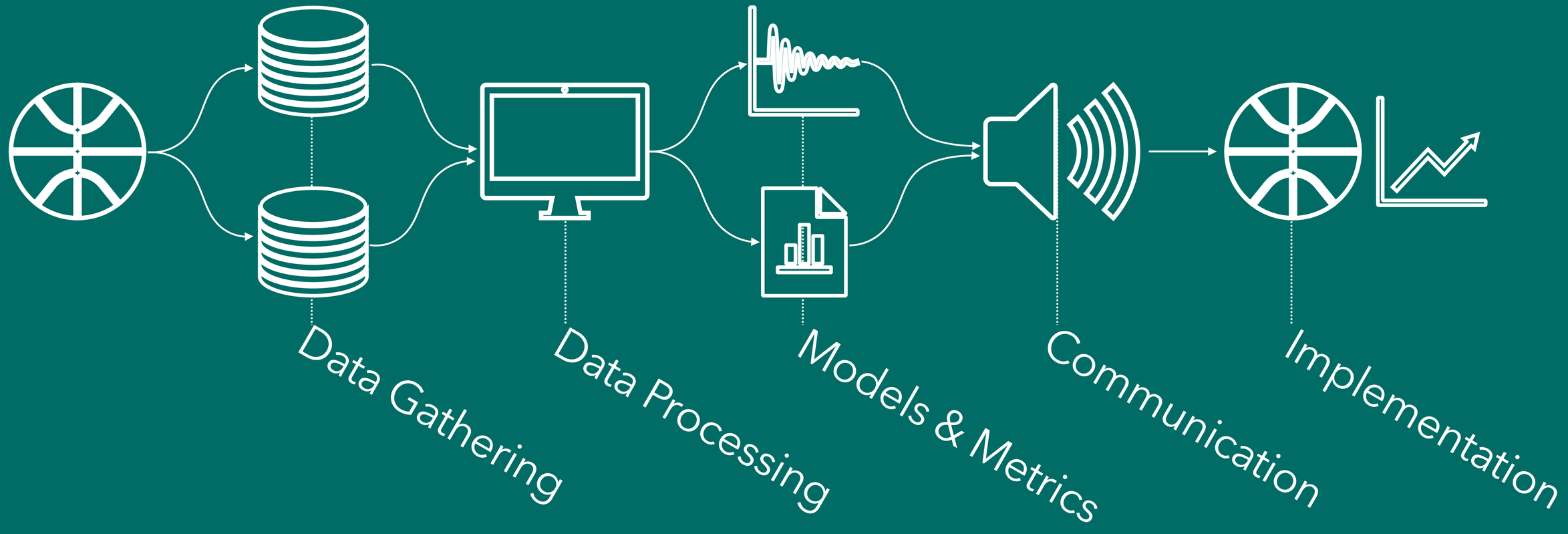
Hire the best possible
players / coaches

Coaching Staff

Design a playbook
Exhaustive scouting

How? Endless hours of film sessions.
Automated tasks through data-driven processes.

In this talk…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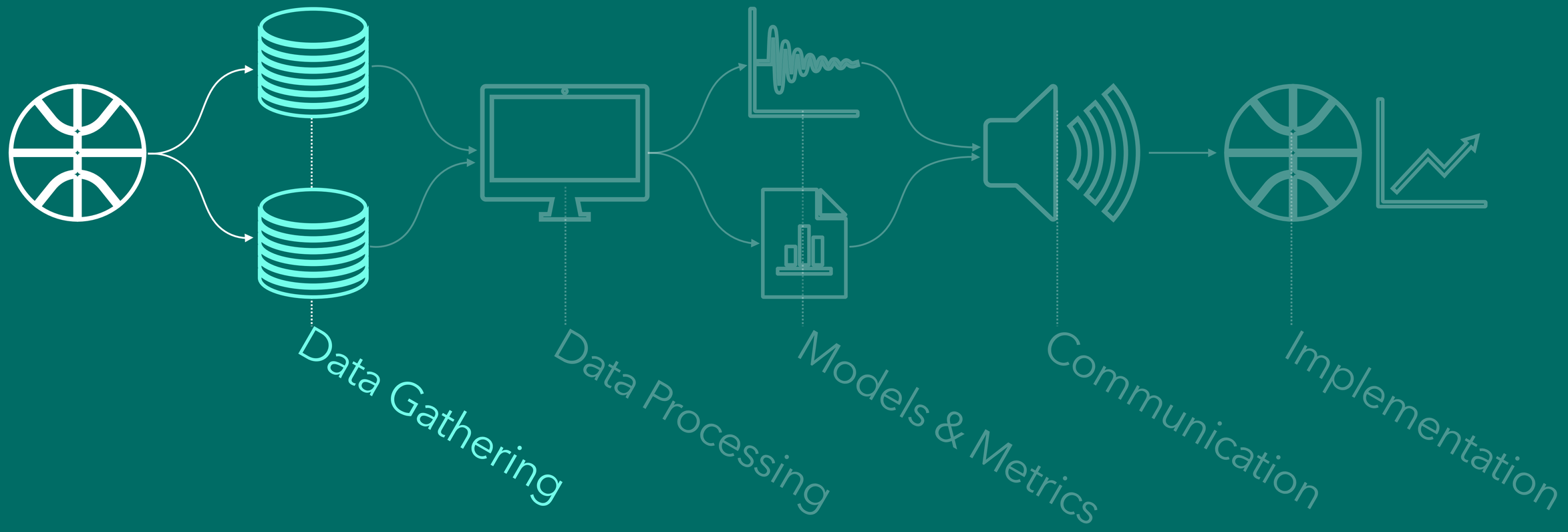
What kind of stats do we have?



Basketball analytics: coarse-to-fine approach

Who produce data?

Source: Basketball England

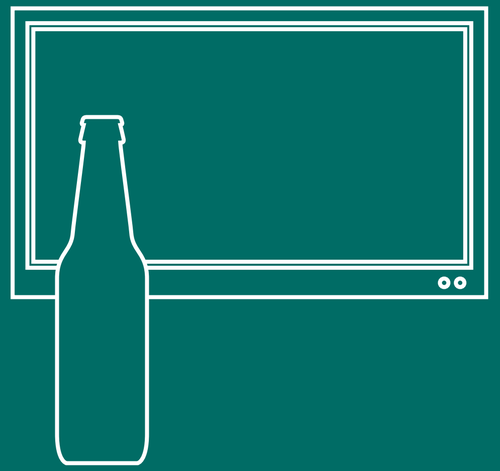
Basketball analytics: box score

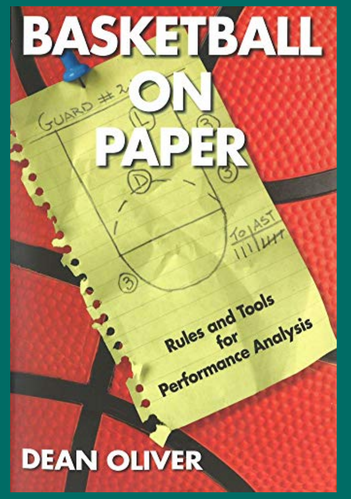
March 28th 1990
Chicago Bulls 117 - Cleveland Cavaliers 113

	Minutes	Points	2FGM	2FGA	3FGM	3FGA	FTM	FTA	OReb	DReb	AST	STL	TOV	PF
Michael Jordan	50	69	21	31	2	6	21	23	7	11	6	4	2	5
Scottie Pippen	41	7	3	10	0	0	1	2	2	6	7	5	8	5
Horace Grant	40	16	7	14	0	0	2	4	2	3	4	1	2	4
Bill Cartwright	39	9	3	7	0	0	3	4	1	4	1	0	3	5
John Paxon	23	2	1	4	0	0	0	0	0	0	1	0	2	6
B.J. Armstrong	29	6	2	7	0	0	2	2	0	1	3	2	1	5
Stacey King	17	1	0	4	0	0	1	2	1	0	1	2	0	2
Will Perdue	12	0	0	0	0	0	0	0	0	4	0	0	0	3
Charles Davis	11	5	1	2	1	1	0	0	1	1	1	0	1	2
Clifford Lett	3	2	1	1	0	0	0	0	0	0	0	0	0	2
TEAM	265	117	39	80	3	7	30	37	14	30	24	14	19	39

Basketball analytics: box score

March 28th 1990
Chicago Bulls 117 - Cleveland Cavaliers 113

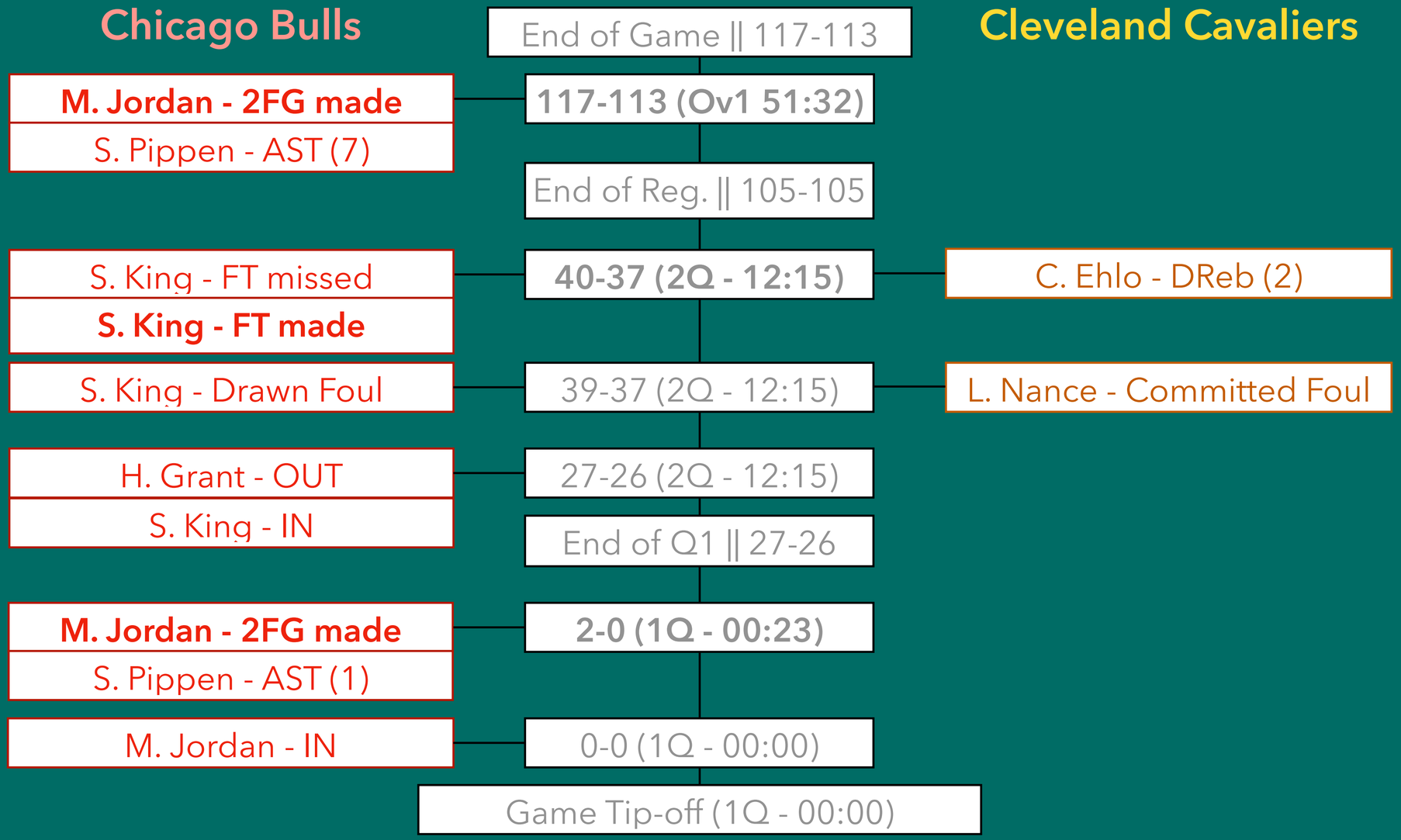




Other data sources have to be exploited!

Basketball analytics: play-by-play

Temporal domain



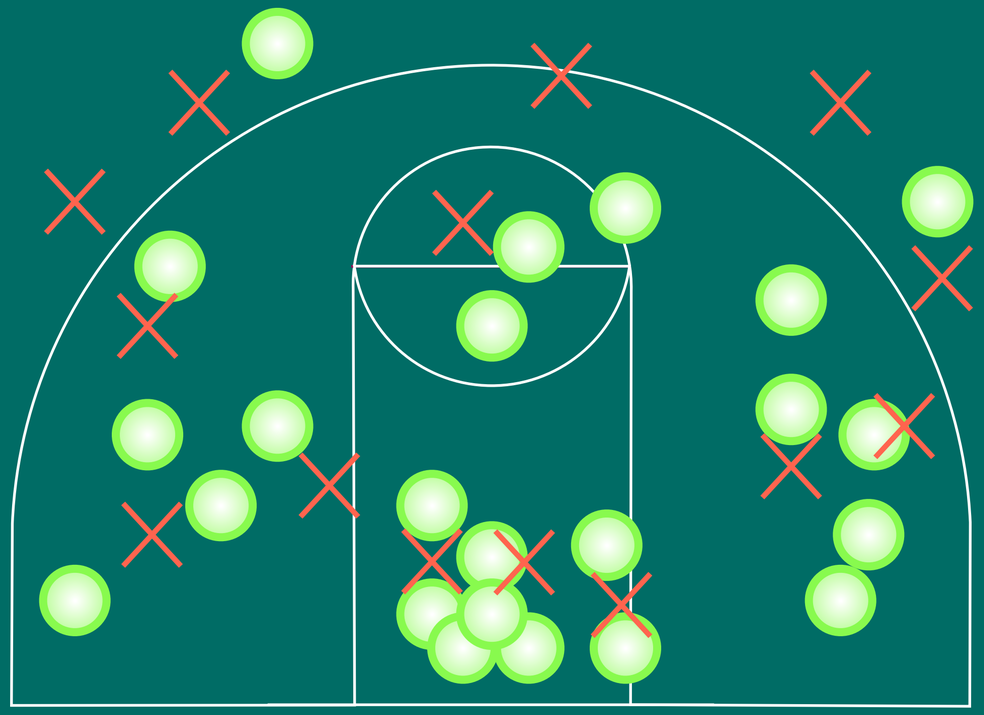
Basketball analytics: shot charts

Spatial domain

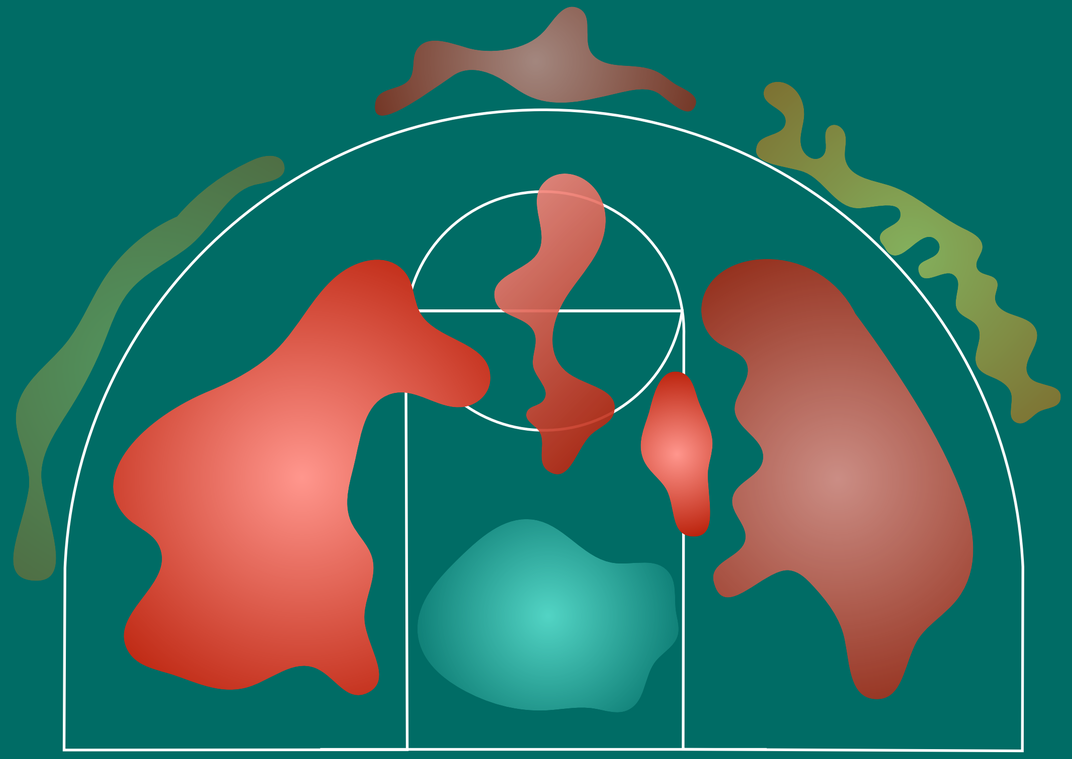
Single Game
69 points - (21/31 FG2, 2/6 FG3)

Michael Jordan

Whole Career
30.1 points - (10.9/21.2 FG2, 0.5/1.7 FG3)



Made shot Missed shot



Accuracy (percentage)

Below Average — Above Average

Basketball analytics: coarse-to-fine approach

Box score + play-by-play + shot charts… Is it enough?

[Utah] Cross-screen between Hornacek and Malone

[Chicago] No defensive switch

[Utah] Low-post play for Malone

[Chicago] Double team from weak side (baseline)

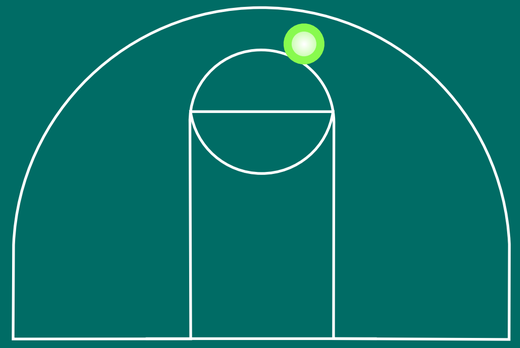
Jordan steals the ball – Malone loses it

[Chicago] Jordan calls an isolation play

[Chicago] Jordan dribbles to his right, crosses over, and scores a 2-point-open shot pull-up step-back with 5 seconds left.

[Utah] Byron Russell was the assigned defender, and could not handle Jordan's crossover.

Malone - turnover
Jordan - steal
Jordan - 2 FG made



Basketball analytics: coarse-to-fine approach

Box score + play-by-play + shot charts… Is it enough, Zeljko?

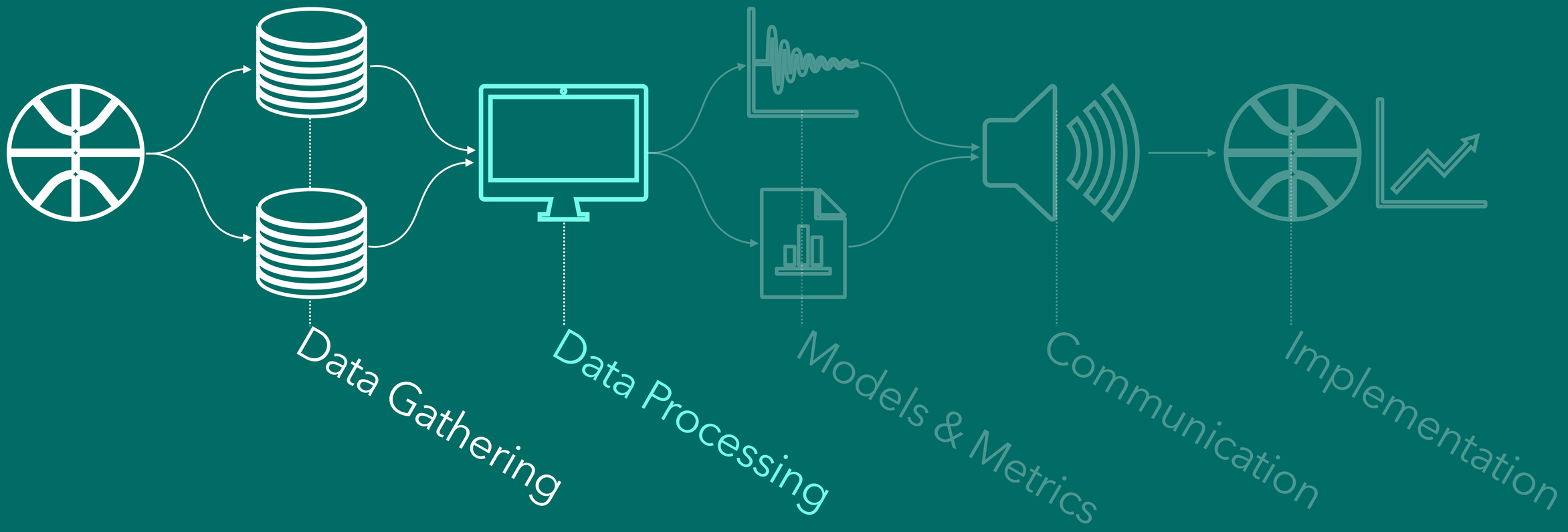
We are missing:

- Types of shots (playtype)
- Types of shots (difficulty)
- Team strategy
- Defensive metrics
- Defensive assignments

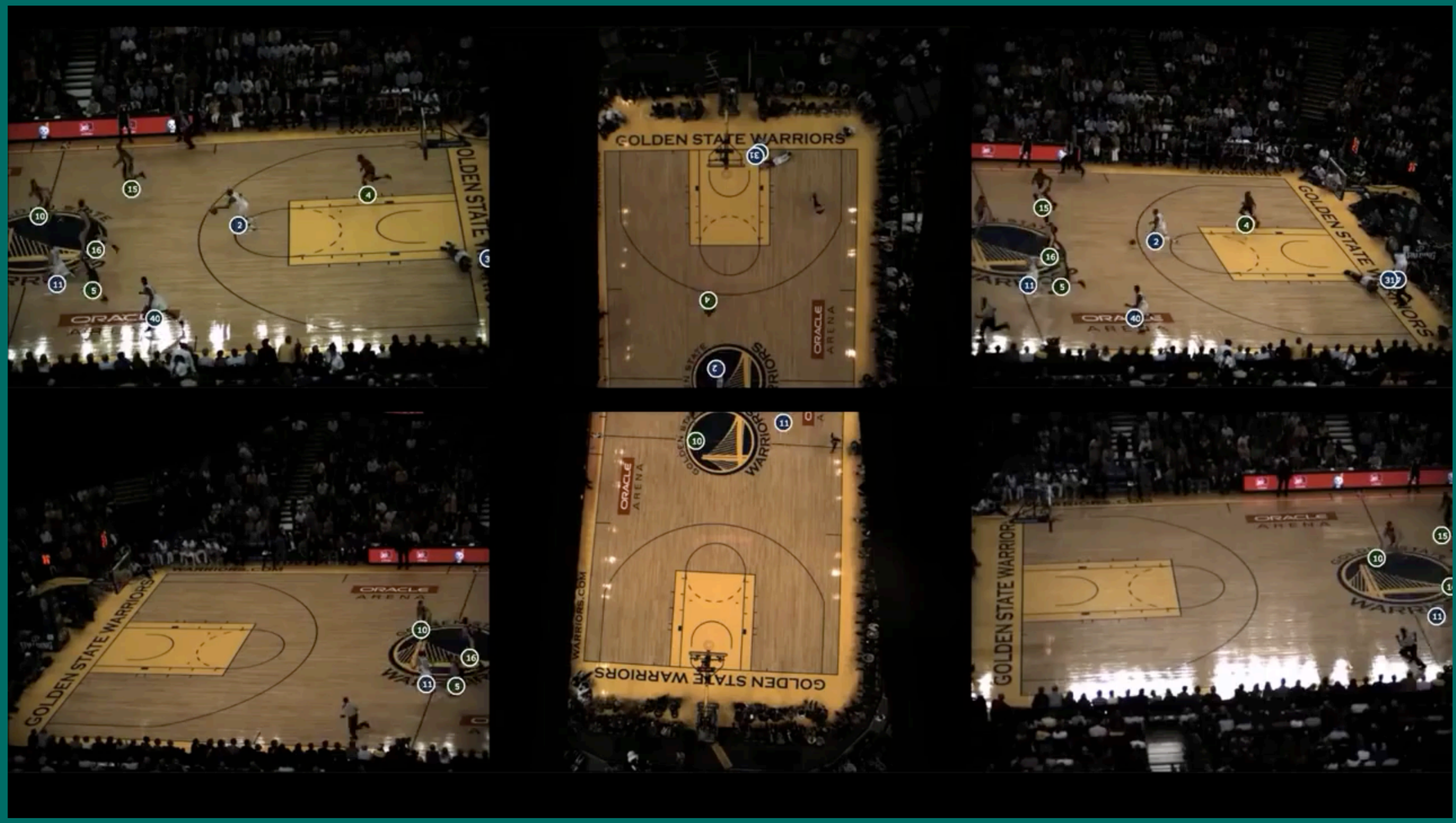
Source: GettyImages

Solution? Time-consuming video-analysis shifts, or… **Tracking**!

Where does Computer Vision fall in this context?



Computer Vision in Sports - 2D Tracking



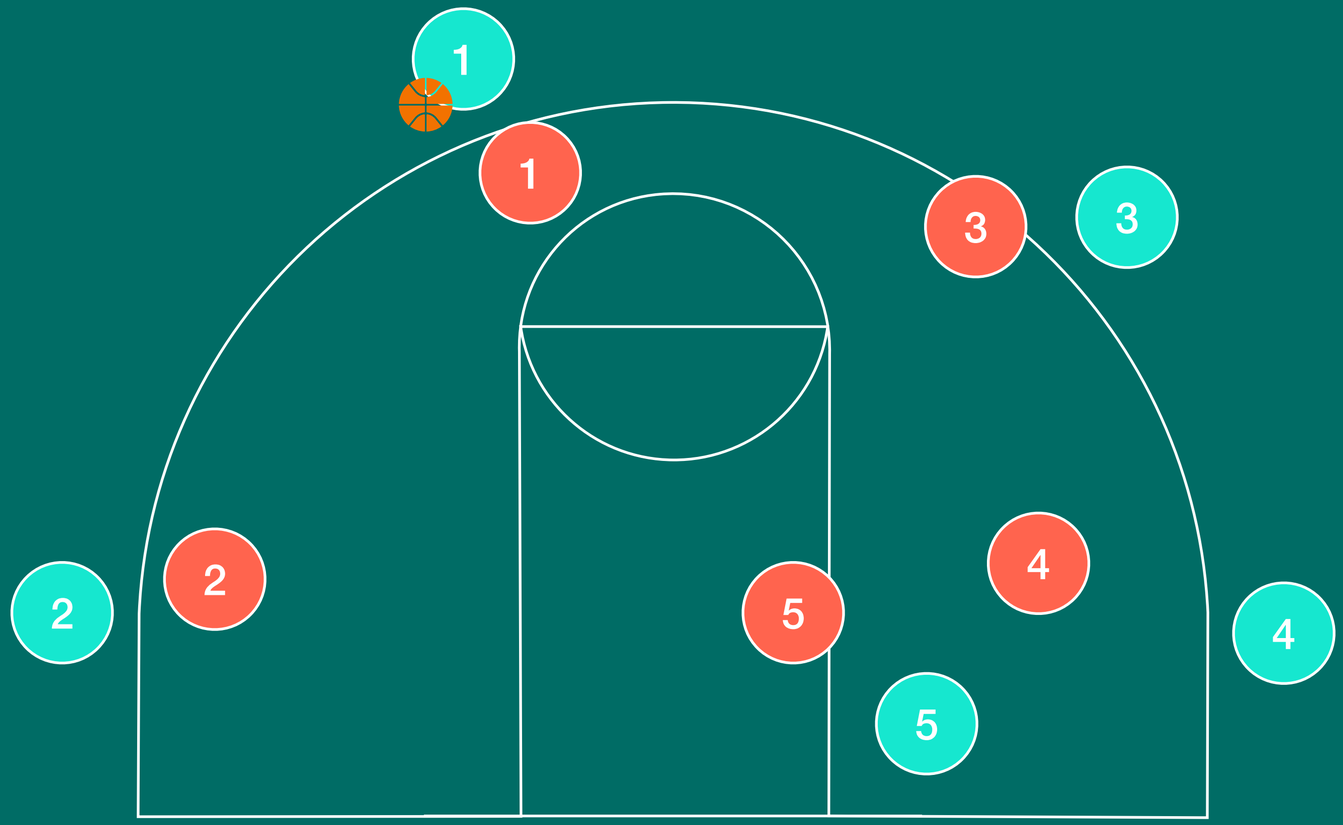
Source: STATS

Second Spectrum

STATS PERFORM

Computer Vision in Sports - 2D Tracking

Challenge - ball-screen play



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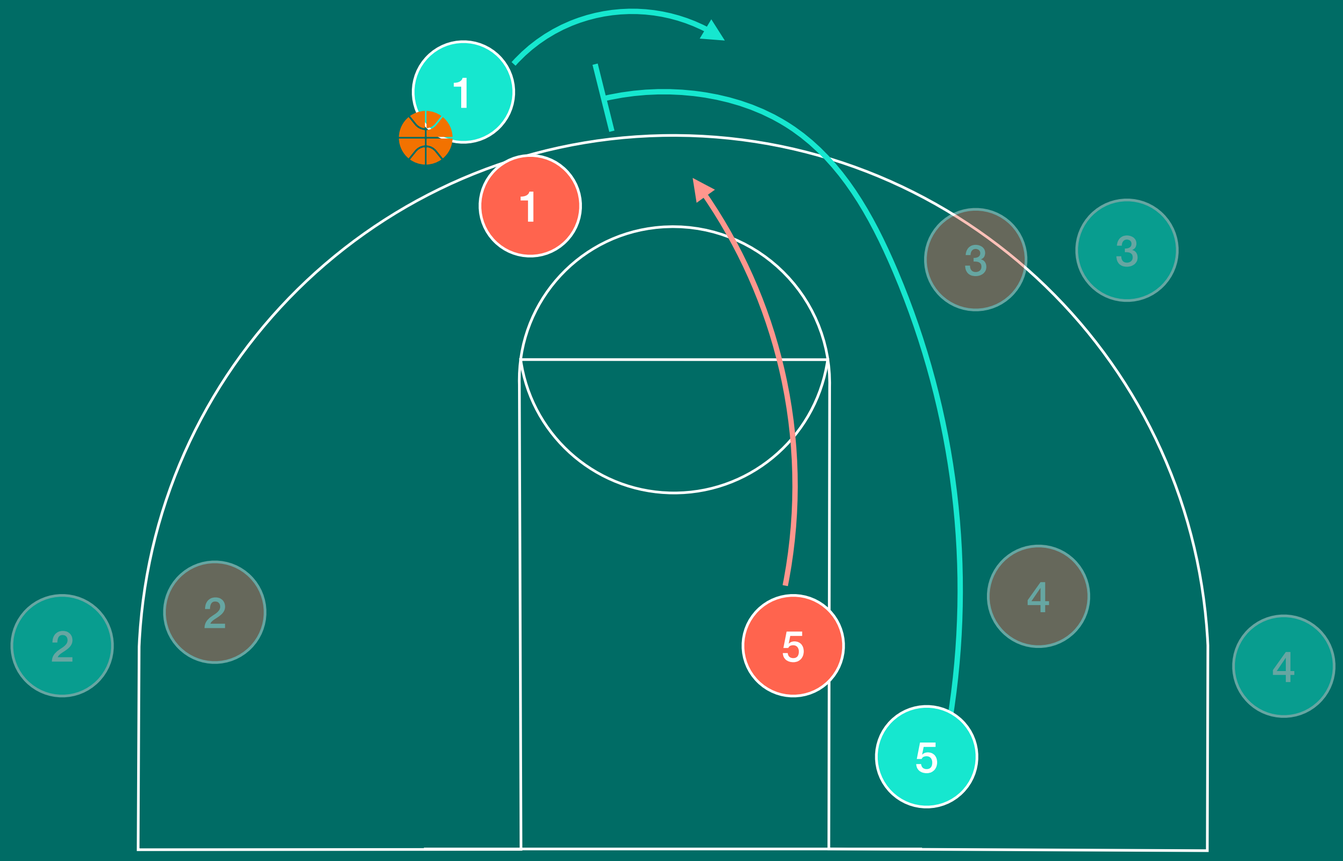
Challenge - ball-screen play



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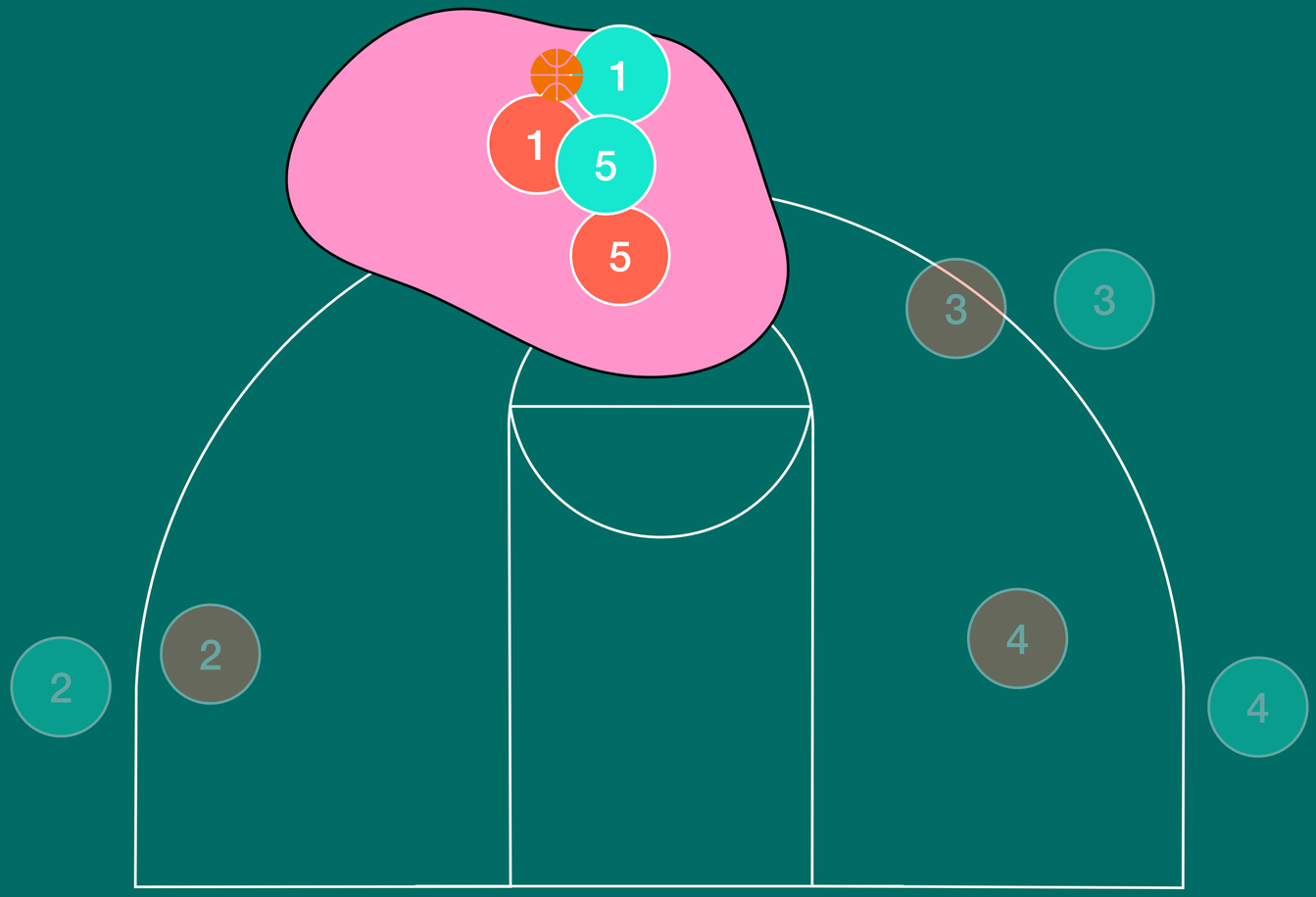
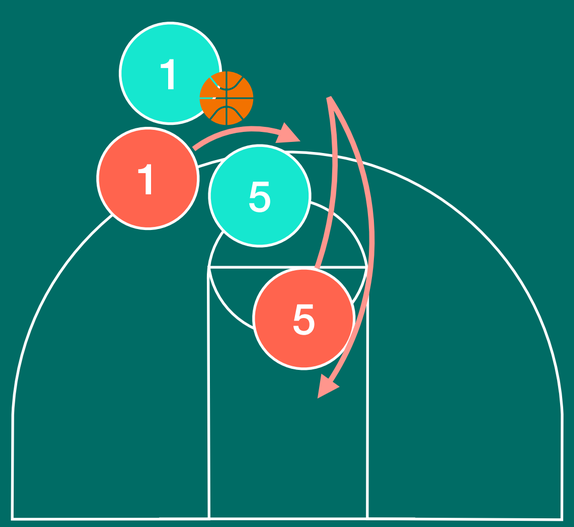
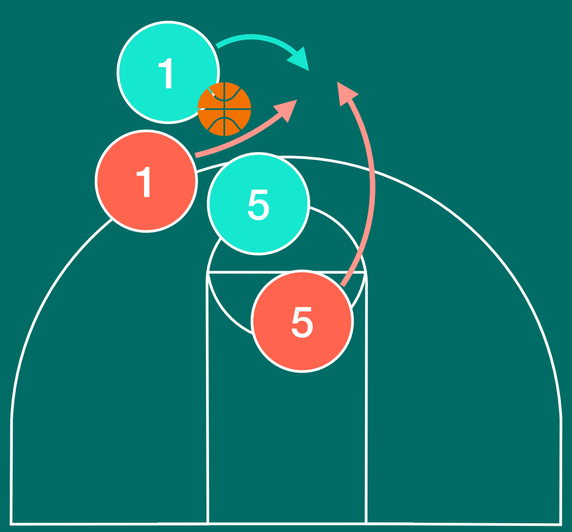


Computer Vision in Sports - 2D Tracking

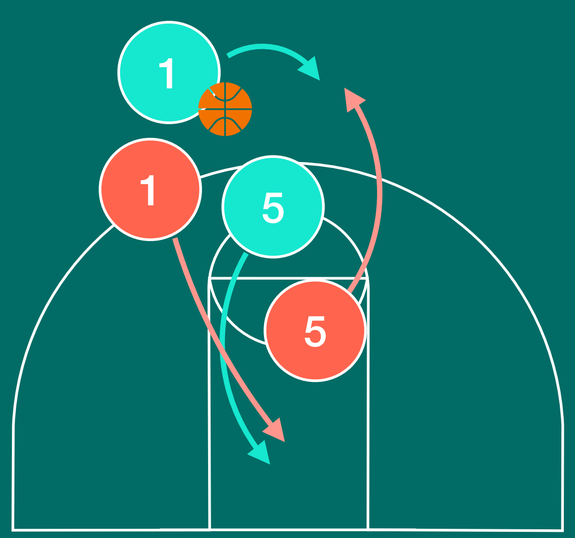
Challenge - ball-screen play



Show / Hedge



Trap

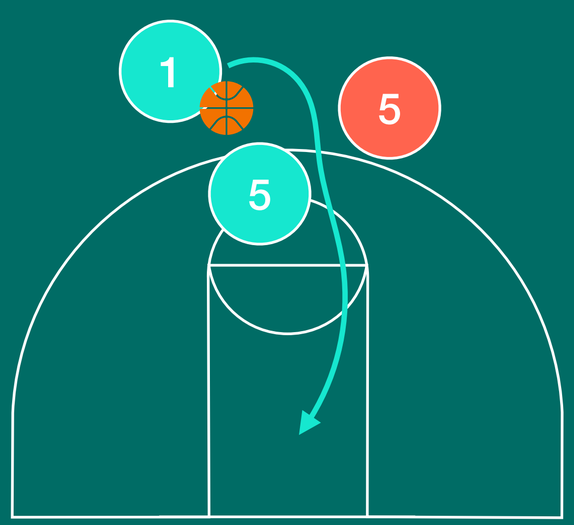


Switch

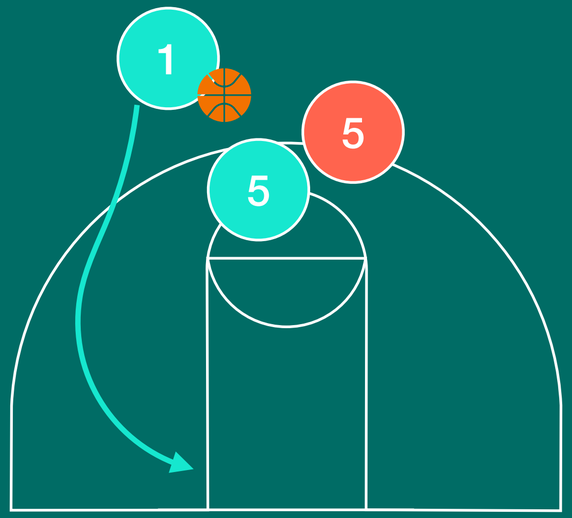
Decision-making process: defense

Computer Vision in Sports - 2D Tracking

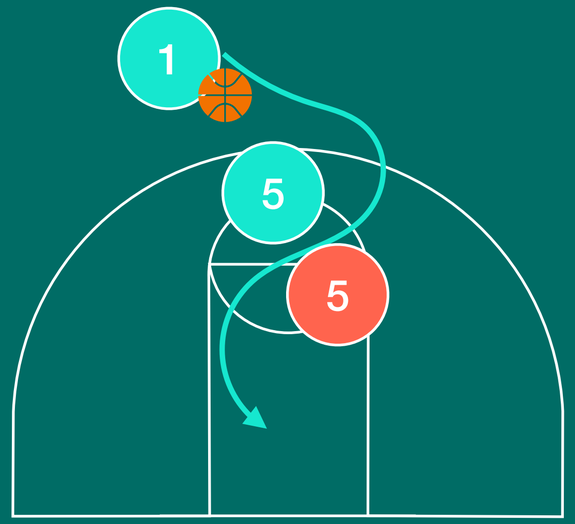
Challenge - ball-screen play



Split



Reject

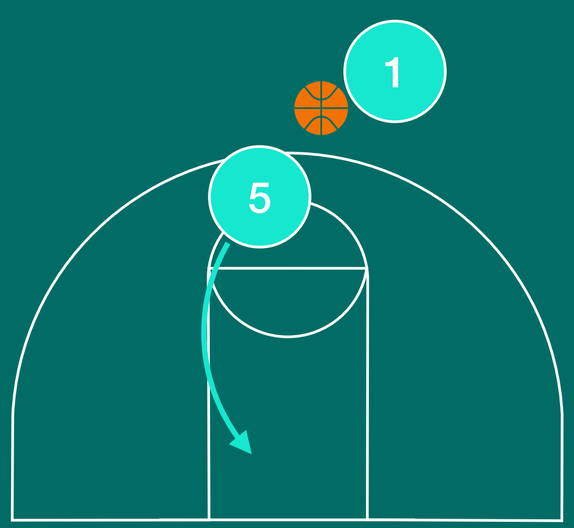


Snake

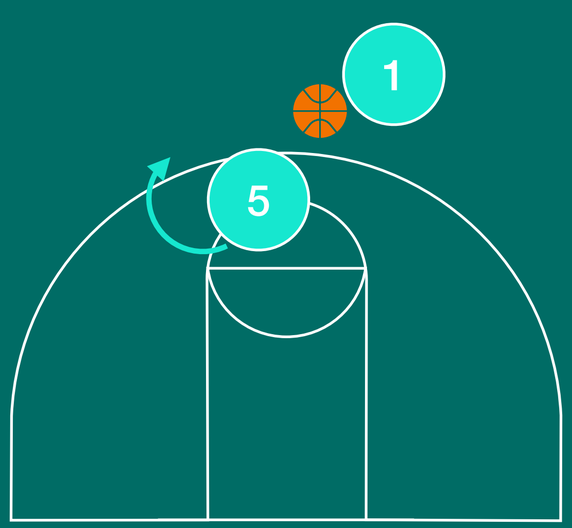
Decision-making process: ball handler

Computer Vision in Sports - 2D Tracking

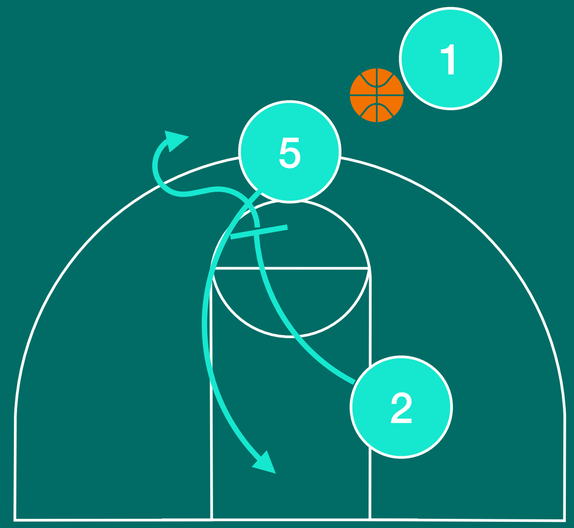
Challenge - ball-screen play



Roll / Short Roll



Pop

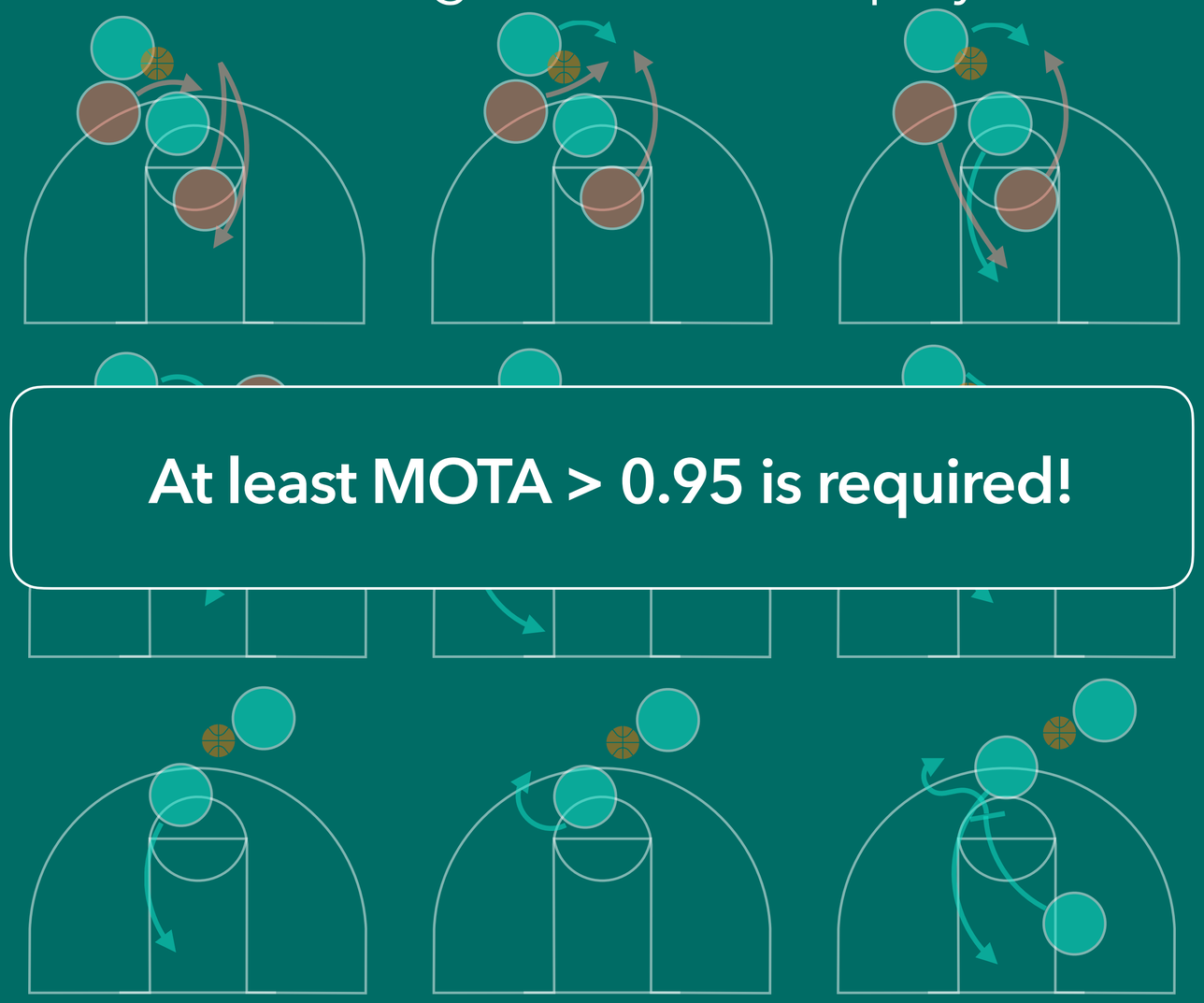


Spanish PnR

Decision-making process: screener

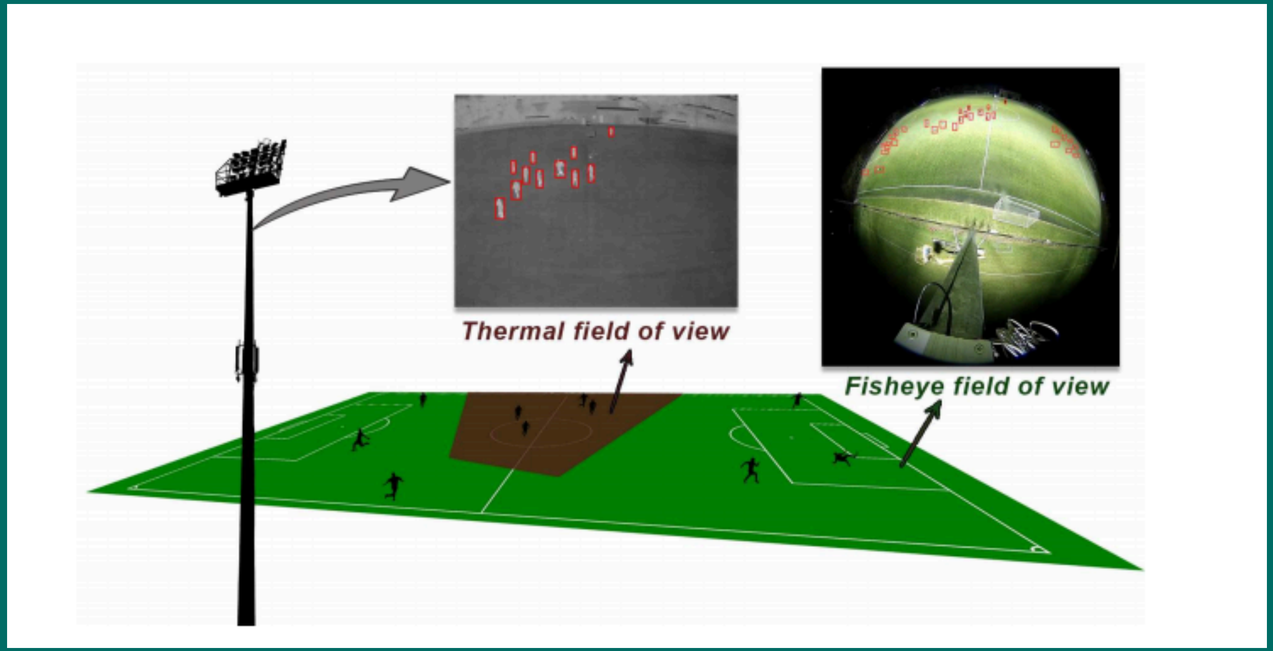
Computer Vision in Sports - 2D Tracking

Challenge - ball-screen play



Computer Vision in Sports - 2D Tracking

- Complex set-ups, or… Provide automatic CV-based tracking data through creative low-cost solutions!



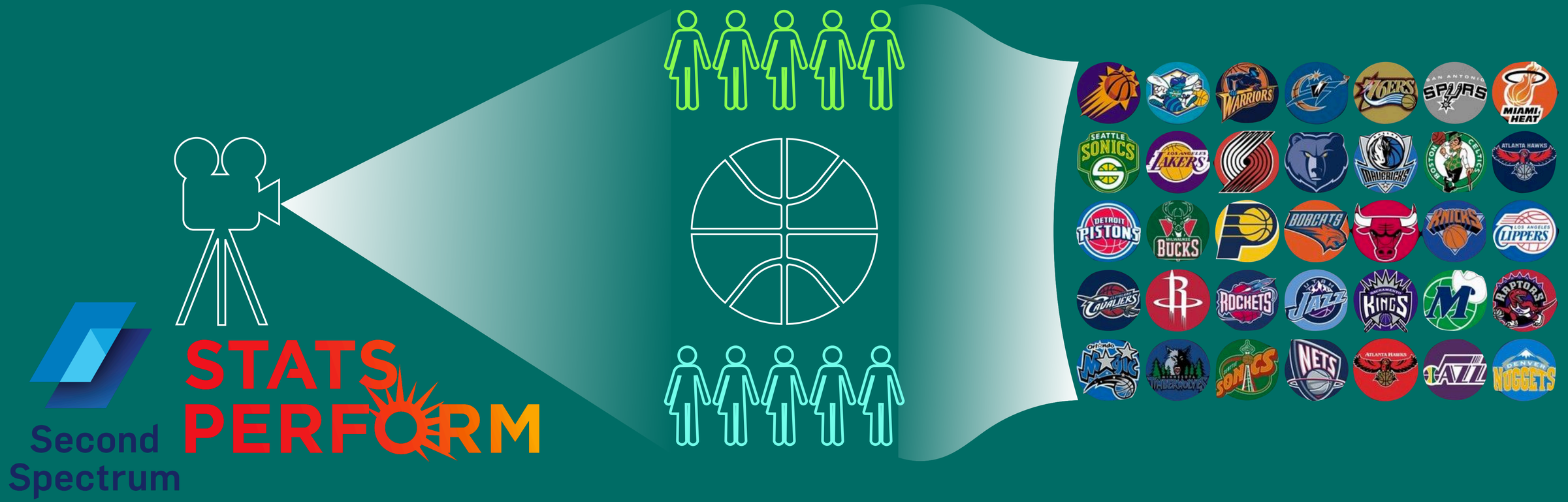
Multimodal and multiview distillation for real-time player detection on a football field [Cioppa, Deliège, *et al.*]

Computer Vision in Sports - 2D Tracking

- Complex set-ups, or… Provide automatic CV-based tracking data through creative low-cost solutions!

Self-Supervised Small Soccer Player Detection and Tracking [Hurault *et al.*]

Computer Vision in Sports - 2D Tracking



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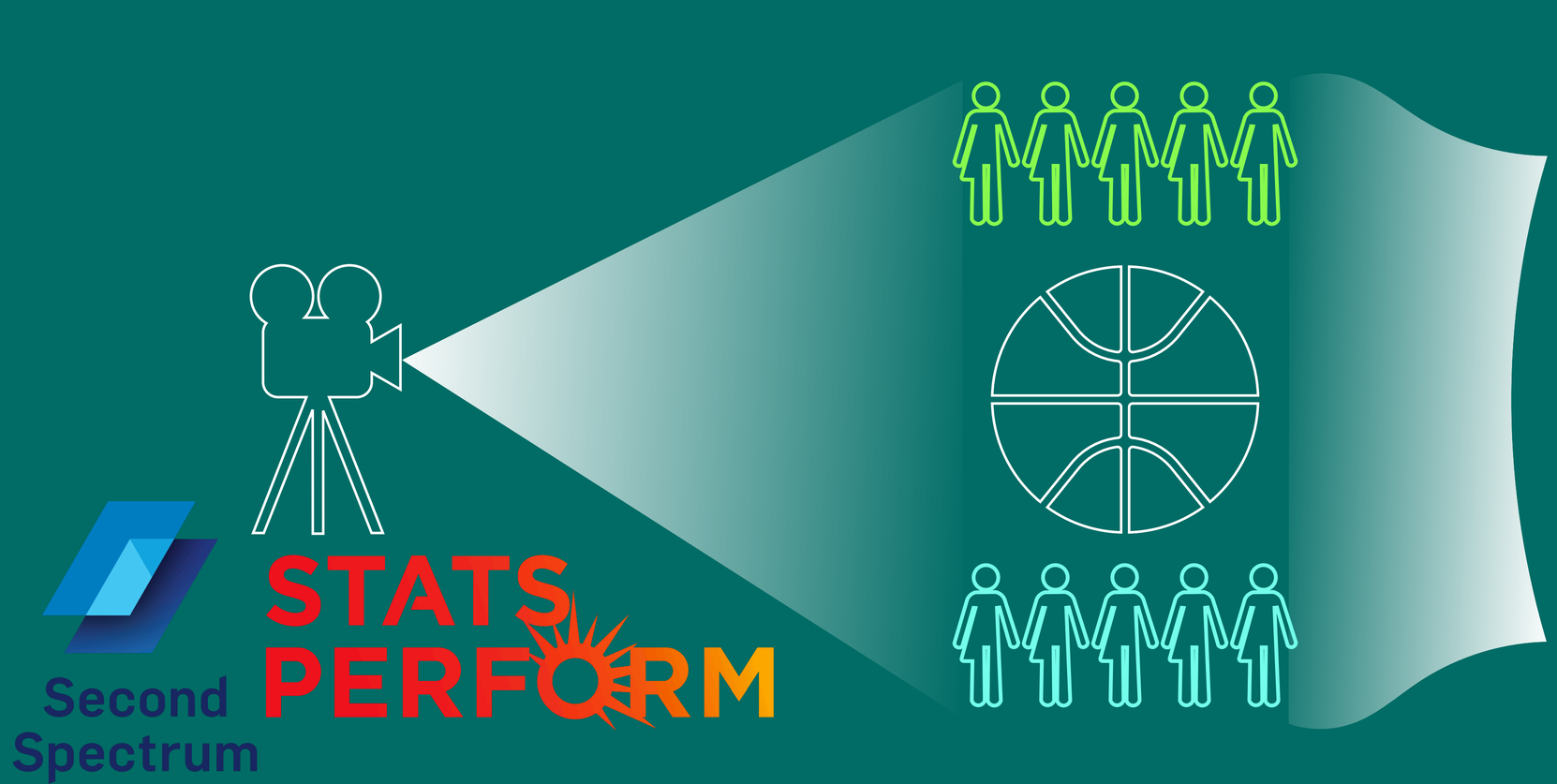


Computer Vision in Sports - 2D Tracking

NBA ANALYTICS STAFF BY TEAM

Team	Staffer	Title
	Dwight Lutz	Sr. Director, Basketball Strategy & Analytics
	Max Horowitz	Sr. Data Scientist, Basketball Strategy & Analytics
	Mike Zarren	Assistant GM and Team Counsel
	David Sparks	Director of Basketball Analytics
	Shane Fenske	Basketball Ops Technology Developer
	Drew Cannon	Basketball Ops Analyst
	Luigi Sorbara	Basketball Ops Statistician and Programmer
	David Lewin	Director of Player Personnel
	Glenn DuPaul	Director of Analytics
	Logan MacPhail	Director of Coaching Analytics
	Rami Antoun	Senior Developer
	Kevin Roark	Basketball Systems Developer
	Rohan Jaitley	Basketball Video and Analytics Assistant
	George Rodman	Director of Basketball Analytics & Strategy
	Alexander Powell	Head of Quantitative Analysis & Development
	Michael Mirandi	Basketball Ops Software Developer
	Steve Weinmann	Assistant GM
	Miles Abbett	Manager, Minor League Scouting & Analytics
	Faizan Hasnany	Coordinator of Basketball Analytics
	Jon Nichols	Sr Director of Analytics and Personnel
	Brad Havens	Basketball Systems Developer
	Jeremy Sabath	Frontend Web Developer
	Haralabos Voulgaris	Director of Qualitative Research and Development
	James Brocato	Director of Basketball Analytics
	Jeremias Englemann	Senior Analyst
	Chris Newell	Basketball Analytics Associate
	Mondrick Jones	Player Analytics Manager
	Nikhil Roy	Quantatitve Research Analyst/Developer
	Zach Chu	Basketball Analytics Liason
	Tommy Balcetis	VP of Strategy and Analytics
	Layne Vashro	Senior Analyst
	Aaron Blackshear	Director of Research
	Dan Rosenbaum	Sr Director of Basketball Strategy
	Sammy Gelfand	Director of Coaching Analytics
	Doug Harding	Data Scientist
	Peter Nygaard	Basketball Systems Developer
	Pabail Sidhu	Director of Basketball Analytics & Innovation
	Matt Holbrook	Data Scientist
	Kevin Steele	Data Engineer
	Eli Witus	Assistant GM
	Monte McNair	Assistant GM
	Fan-Hal Koung	Director of Basketball Analytics
	Jason Roman	Basketball Operations Analyst
	Ed Kupfer	Basketball Analyst

Team	Staffer	Title
	Spencer Anderson	Director Basketball Analytics
	Ryan Renteria	Basketball Analytics Advisor
	Nick Fleder	Basketball Data Analyst
	Jud Winton	VP of Research and Analytics
	Gregory Peim	Director of Research and Analytics
	Marshall Smith	Basketball Data Analyst
	Ben Starks	Basketball Data Analyst
	Matt Elijah	Manager of Strategic Planning
	Chethan Reddy	Full Stack Developer
	Philip Chang	Sr. Manager of Basketball Analytics
	Diana Ma	Data Scientist
	Harry Heffernan	Basketball Analyst and Developer
	Rich Cho	VP of Basketball Strategy
	JT Campbell	Basketball Analyst
	Daniel Marcus	Personnel Evaluator - Grizzlies / GM - Hustle
	Shane Battier	VP Basketball Development & Analytics
	Brian Hecker	Dir of Basketball Analytics and Perfomance Tech
	Zac Robertson	Manager of Basketball Analytics
	Tyler Brandt	Basketball Researcher
	Liam Doyle	Basketball Analyst
	T.J. Barra	Director of Basketball Research
	Ashley Brio	Manager of Basketball Analytics
	Sachin Gupta	EVP of Basketball Ops
	Nick Restifo	Sr. Basketball Ops Analyst
	Cole Fisher	Basketball Ops Analyst
	Somak Sarkar	Analytics Manager
	Mike Smith	Director, Data Analytics & Pro Scout
	Warren Spencer	Basketball Operations Analyst
	Kelsey Roberts	Database/Basketball Analyst
	Jesse Gould	Director of Pro Evaluation
	Wynn Sullivan	Director of Strategic Planning
	Tom Perry	Director of Data Science & Solutions
	Greg Flood	Data Science & Solutions Scientist
	Ryan Shea	Data Science & Solutions Scientist
	William Burger	Data Science & Solutions Software Developer
	Thomas Van de Houten	Data Science & Solutions Software Developer
	James Kopanidis	Strategic Planning Analyst
	Ezra Van Negri	Strategic Planning Analyst
	Bailey Joseph	Strategic Planning Analyst
	David Bencs	Director of Basketball Analytics
	Ryan Chen	Data Scientist
	David Corbett	Data Scientist
	Matthew Devita	Basketball Data Analyst
	Soumya Kambhampati	Data Scientist
	Dylan Murphy	Basketball Operations Analyst
	Anna Zhao	Data Scientist/Developer

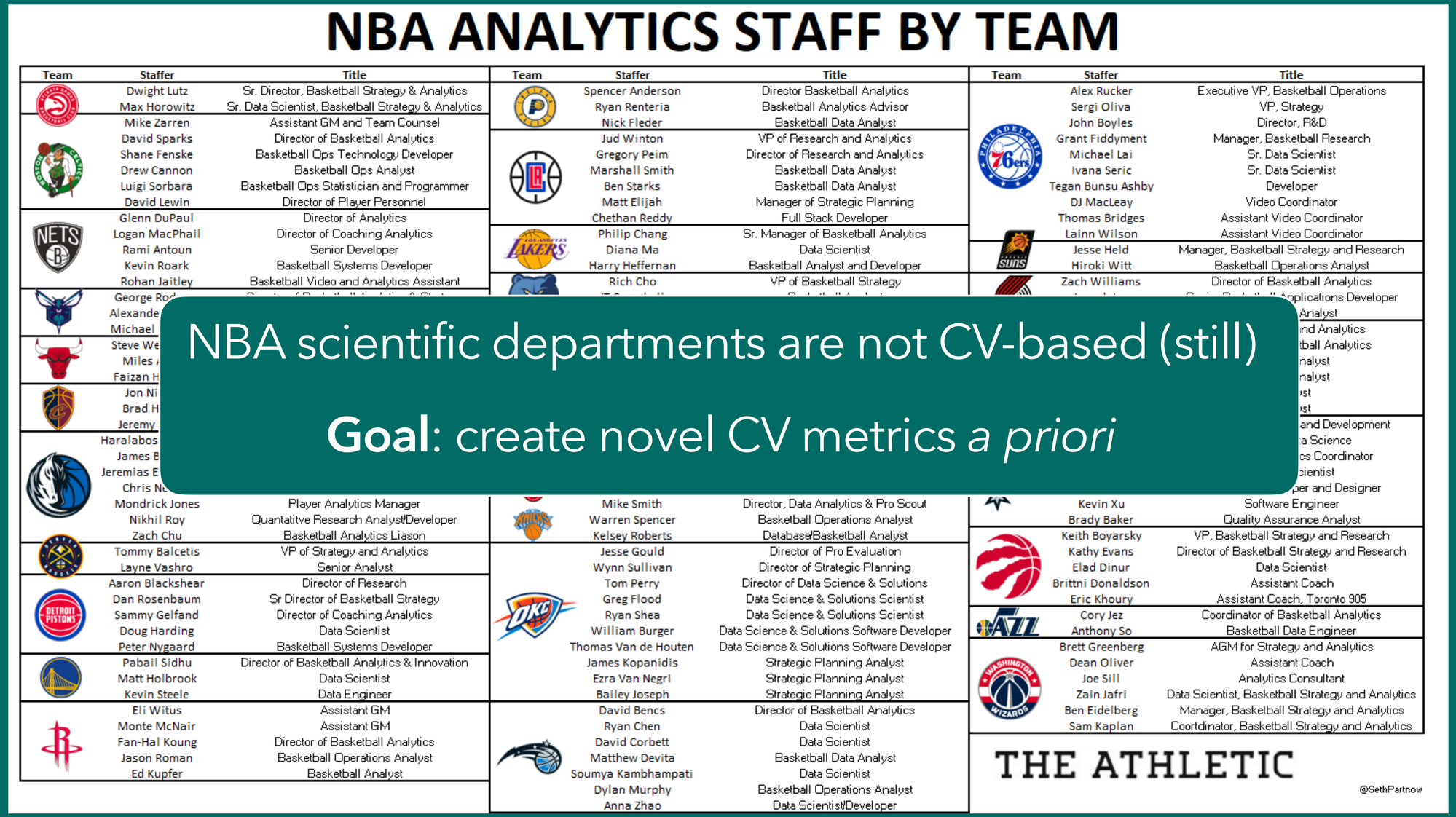
Team	Staffer	Title
	Alex Rucker	Executive VP, Basketball Operations
	Sergi Oliva	VP, Strategy
	John Boyles	Director, R&D
	Grant Fiddyment	Manager, Basketball Research
	Michael Lai	Sr. Data Scientist
	Ivana Seric	Sr. Data Scientist
	Tegan Bunsu Ashby	Developer
	DJ MacLeay	Video Coordinator
	Thomas Bridges	Assistant Video Coordinator
	Lainn Wilson	Assistant Video Coordinator
	Jesse Held	Manager, Basketball Strategy and Research
	Hiroki Witt	Basketball Operations Analyst
	Zach Williams	Director of Basketball Analytics
	Joseph Lee	Senior Basketball Applications Developer
	Ryan Parker	Statistical Analyst
	Luke Bornn	VP of Strategy and Analytics
	Colin Montague	Director of Basketball Analytics
	Matt van Bommel	Senior Analyst
	Chris Pickard	Senior Analyst
	Calvin Floyd	Analyst
	Marshall Payne	Analyst
	Nick Repole	Director of Research and Development
	Josh Fink	Director of Data Science
	AJ Meyer	Coaching Analytics Coordinator
	David Kaplan	Sr Data Scientist
	Joshua Ryan	Bball Ops Developer and Designer
	Kevin Xu	Software Engineer
	Brady Baker	Quality Assurance Analyst
	Keith Boyarsky	VP, Basketball Strategy and Research
	Kathy Evans	Director of Basketball Strategy and Research
	Elad Dinur	Data Scientist
	Brittni Donaldson	Assistant Coach
	Eric Khoury	Assistant Coach, Toronto 905
	Cory Jez	Coordinator of Basketball Analytics
	Anthony So	Basketball Data Engineer
	Brett Greenberg	AGM for Strategy and Analytics
	Dean Oliver	Assistant Coach
	Joe Sill	Analytics Consultant
	Zain Jafri	Data Scientist, Basketball Strategy and Analytics
	Ben Eidelberg	Manager, Basketball Strategy and Analytics
	Sam Kaplan	Coortdinator, Basketball Strategy and Analytics

THE ATHLETIC

@SethPartnow

Source: Seth Partnow

Computer Vision in Sports - 2D Tracking

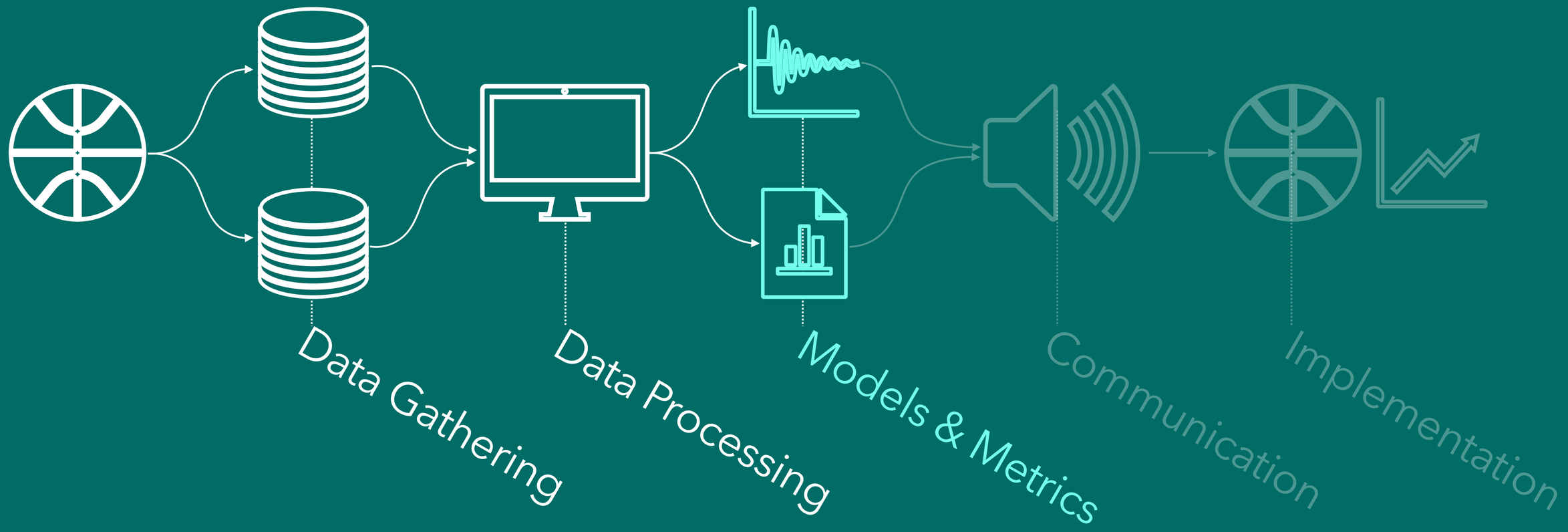


NBA scientific departments are not CV-based (still)

Goal: create novel CV metrics *a priori*

Source: Seth Partnow

What metrics are we supposed to extract?



Metrics: Guidelines (not only CV)

[Credits - Justin Jacobs]

Model implicit features that cannot be estimated with the physics of the game. Learn from the output - valuable insights.

Prediction

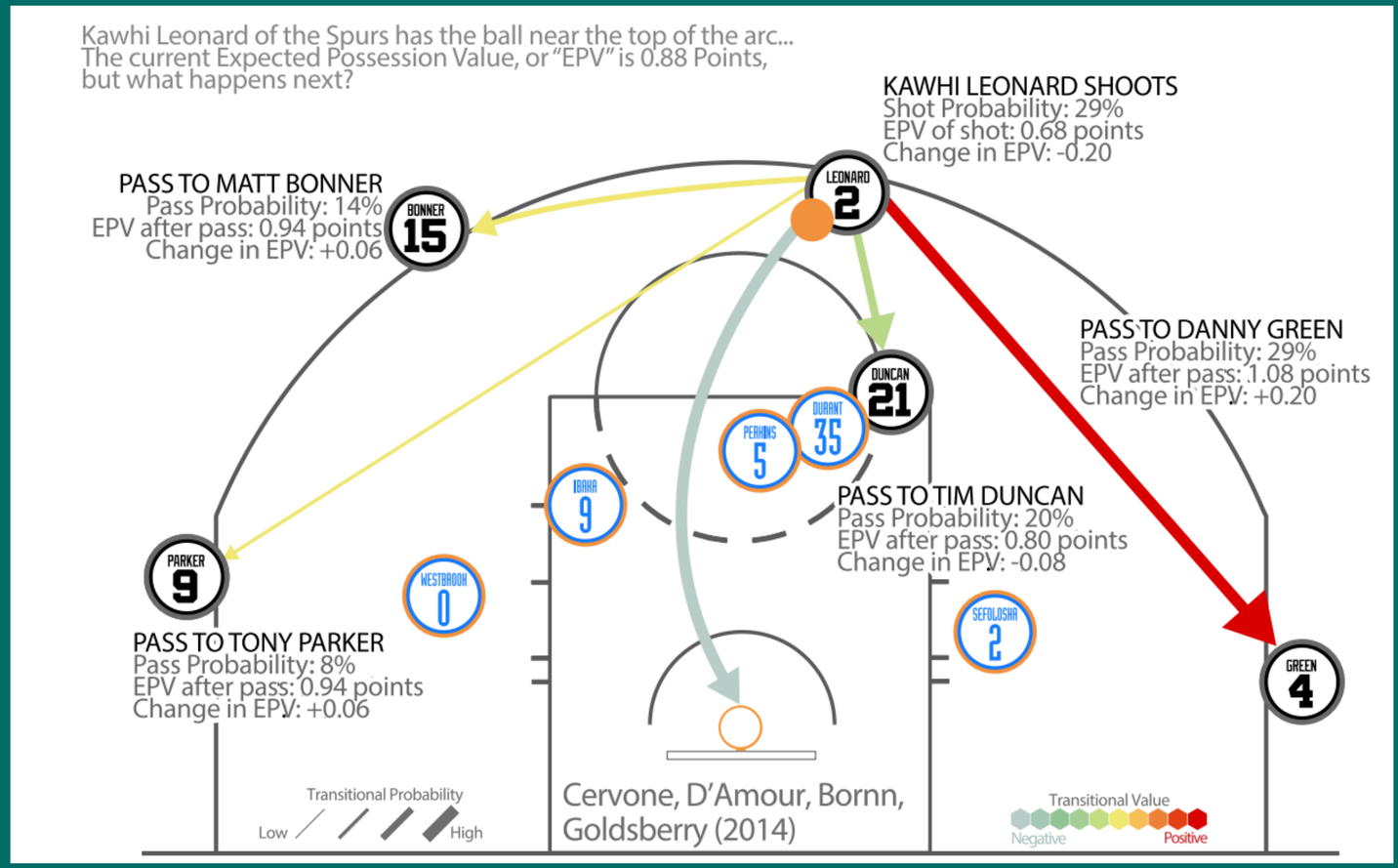
Interpretability

Actionable Intelligence

Sacrifice accuracy for interpretability.

Metrics: on top of CV - Predict

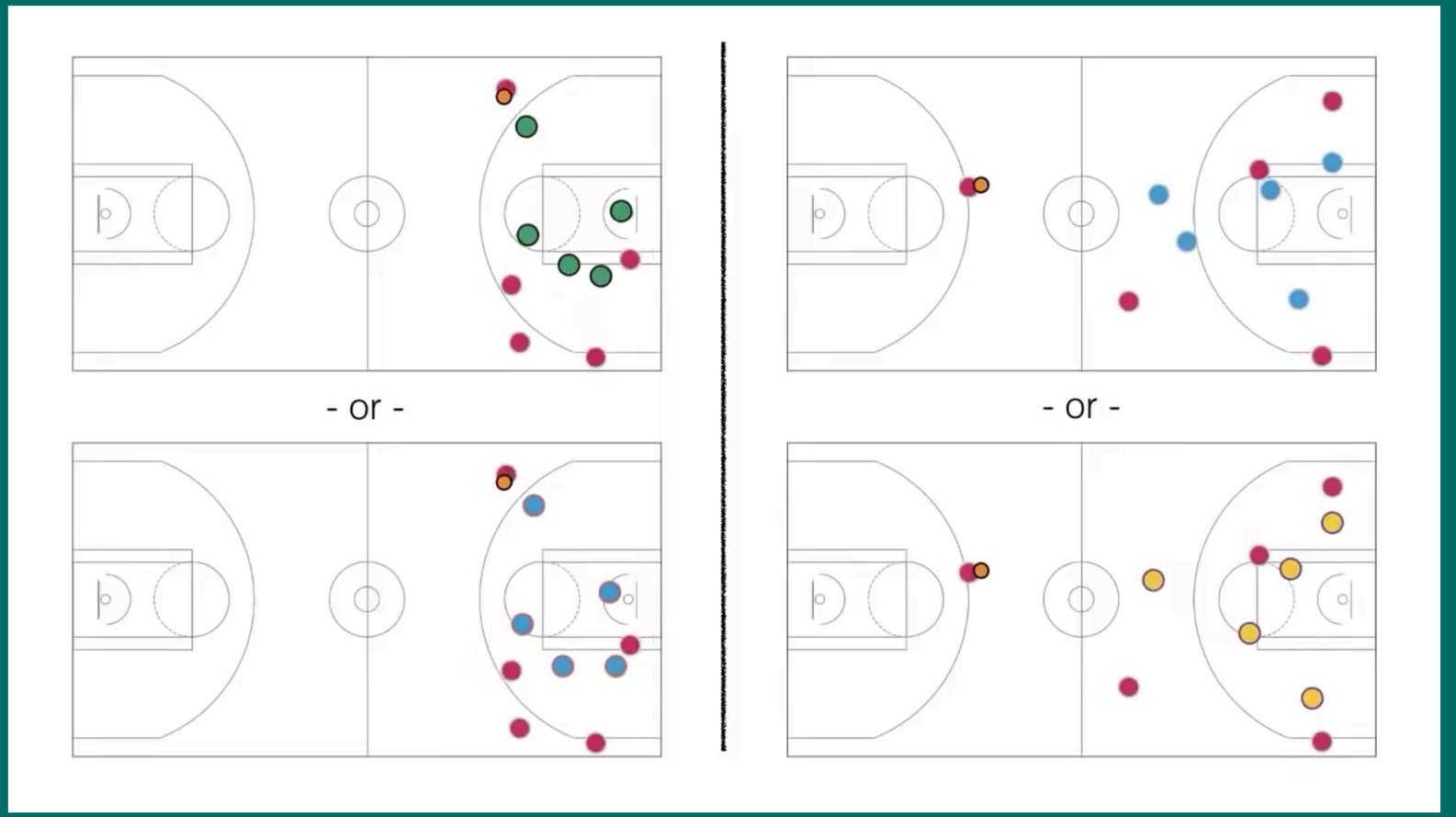
- Train models from tracking data to obtain meaningful insights



EPV Models [Cervone *et al.* 2014 - basketball, Fernández *et al.* - soccer 2019]

Metrics: on top of CV - Predict

- Train models from tracking data to obtain meaningful insights



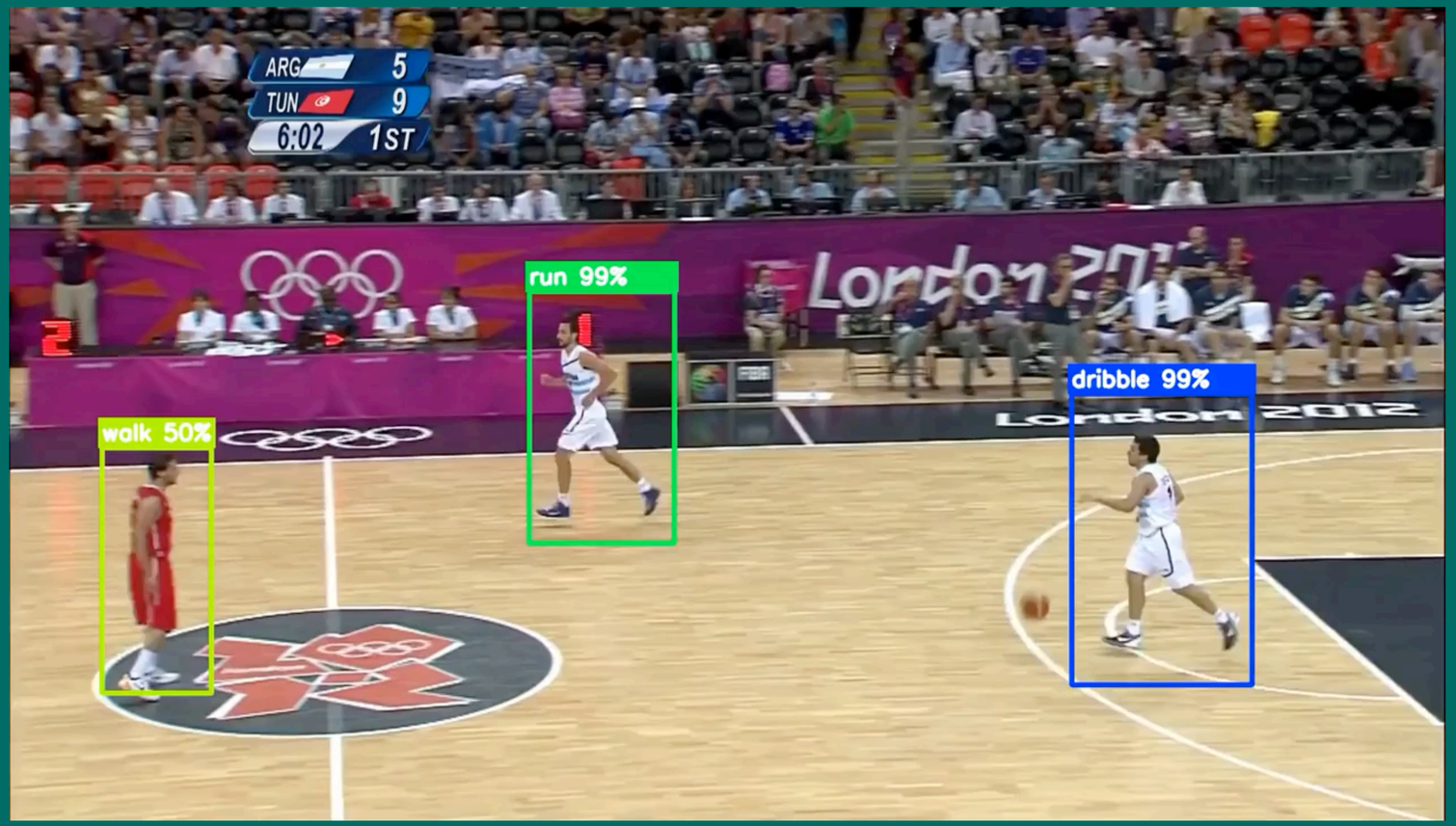
Bhostgusters - What if scenarios / Ghosting [Seidl *et al.*, 2018]

Metrics: on top of CV - Enrich & Analyze

- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she is…*

Metrics: on top of CV - Enrich & Analyze

- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she is jumping / passing / screening…*



Proper definition of open / contested shots

Body-language / Effort

Automatic playtype

Summarization

Action Recognition [Francia *et al.*, 2018]

Metrics: on top of CV - Enrich & Analyze

- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she's facing towards x° (+ pose data)*

Field-of-view estimation

Specific angle stats:
- Passing / screening

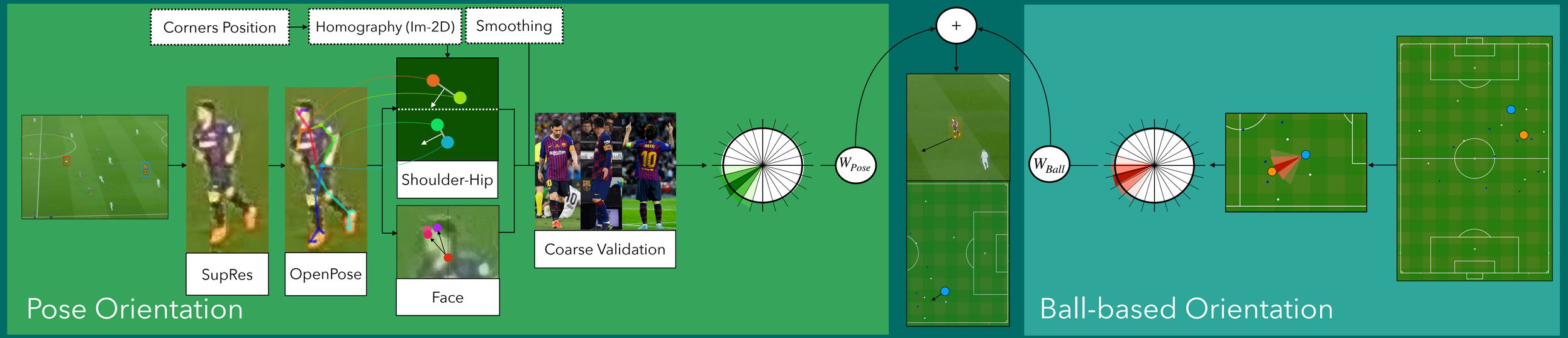
Left / right deviations

Model refinement
a posteriori

Body Orientation [Arbués-Sangüesa *et al.*, 2020-2021]

Metrics: on top of CV - Enrich & Analyze

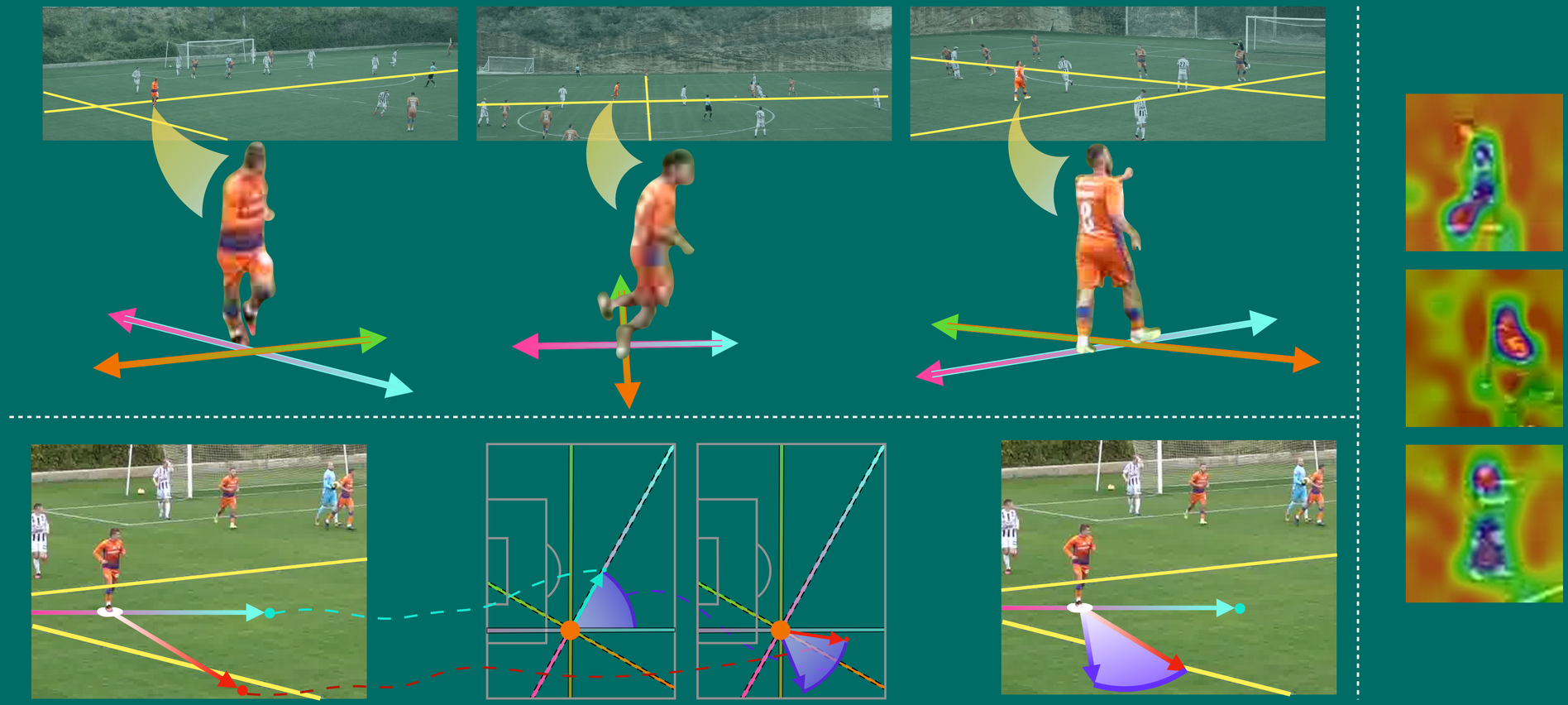
- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she's facing towards x° (+ pose data)*



Always Look on the Bright Side of the Field: Merging Pose and Contextual Data to Estimate Orientation of Soccer Players [ICIP 2021]

Metrics: on top of CV - Enrich & Analyze

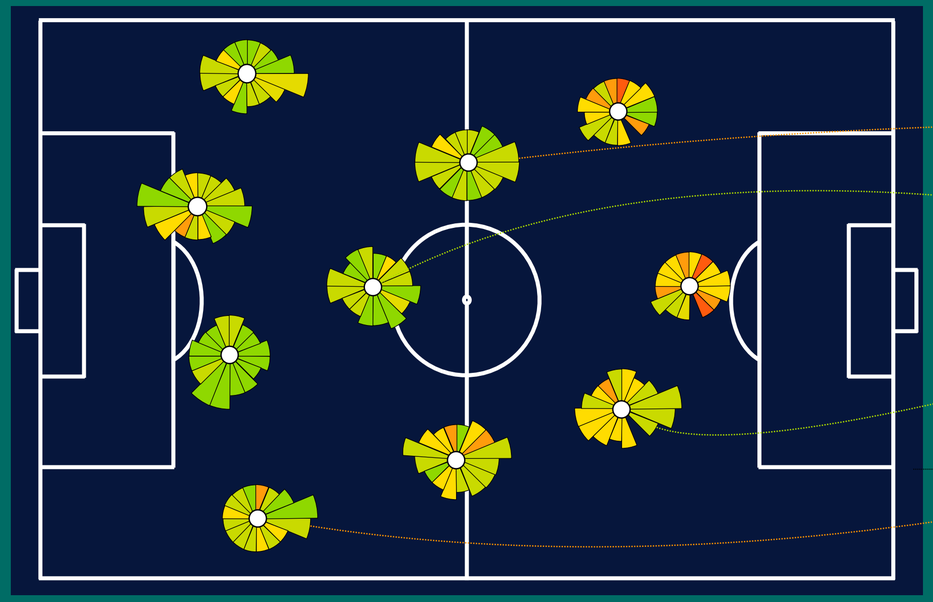
- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she's facing towards x° (+ pose data)*



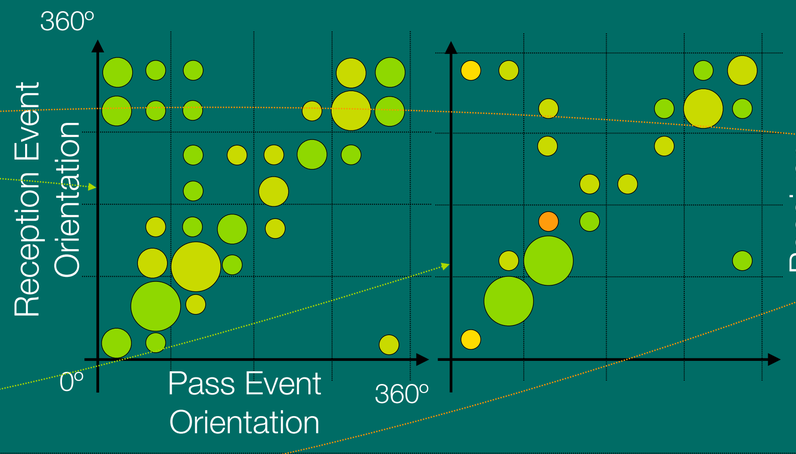
Metrics: on top of CV - Enrich & Analyze

- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she's facing towards x° (+ pose data)*

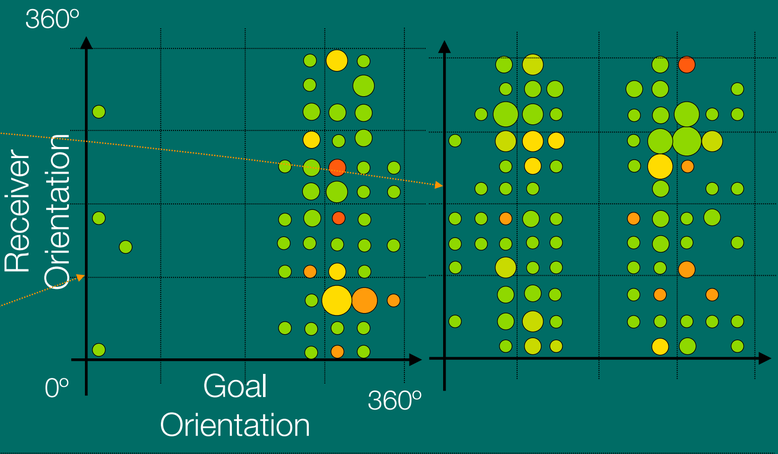
OrientSonar Maps



Reaction Maps



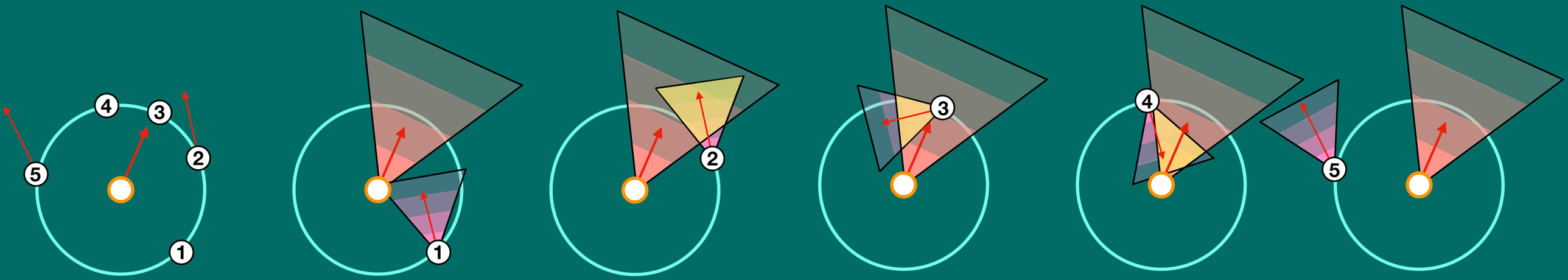
On-Field Maps



Orientation-based Maps

Metrics: on top of CV - Enrich & Analyze

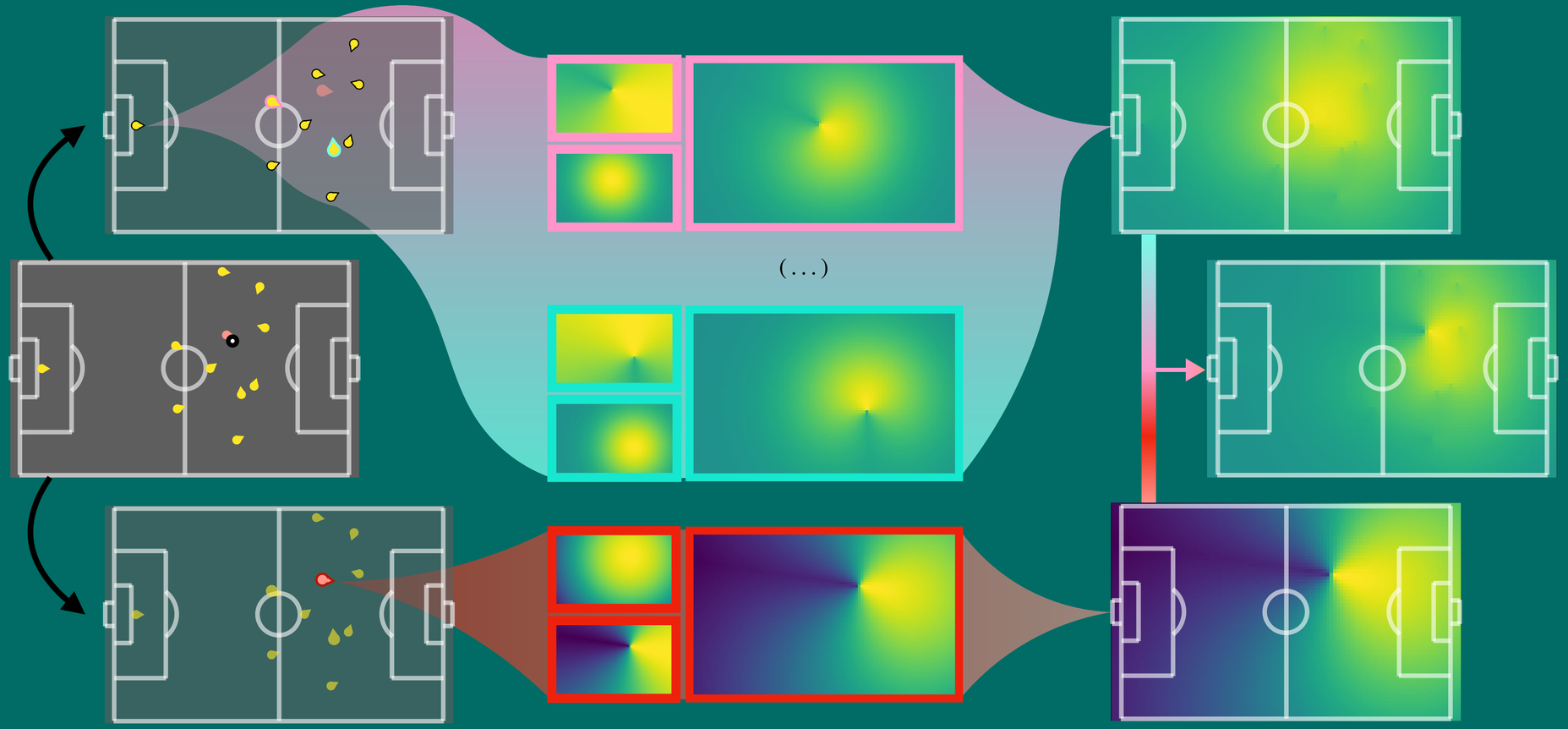
- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she's facing towards x° (+ pose data)*



Using Player's Body-Orientation to Model
Pass Feasibility in Soccer [CVSports20', 2n Place Award]

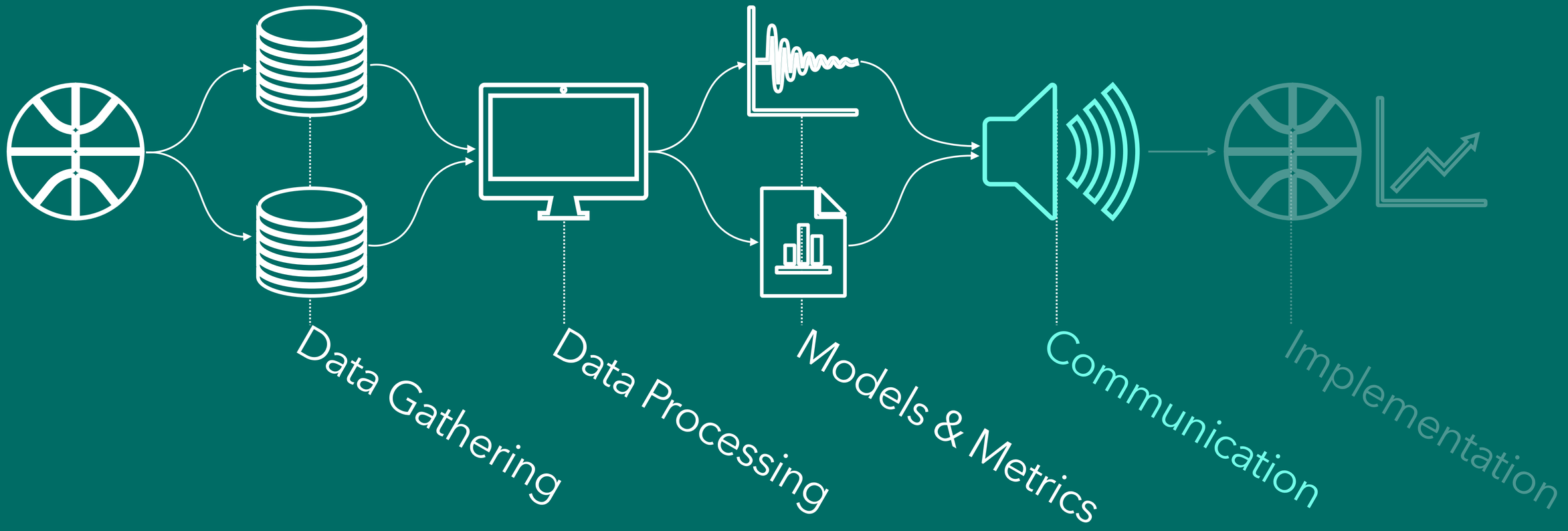
Metrics: on top of CV - Enrich & Analyze

- Add more layers the 2D information to re-define metrics:
  - *A player is at (X, Y) and he/she's facing towards x° (+ pose data)*



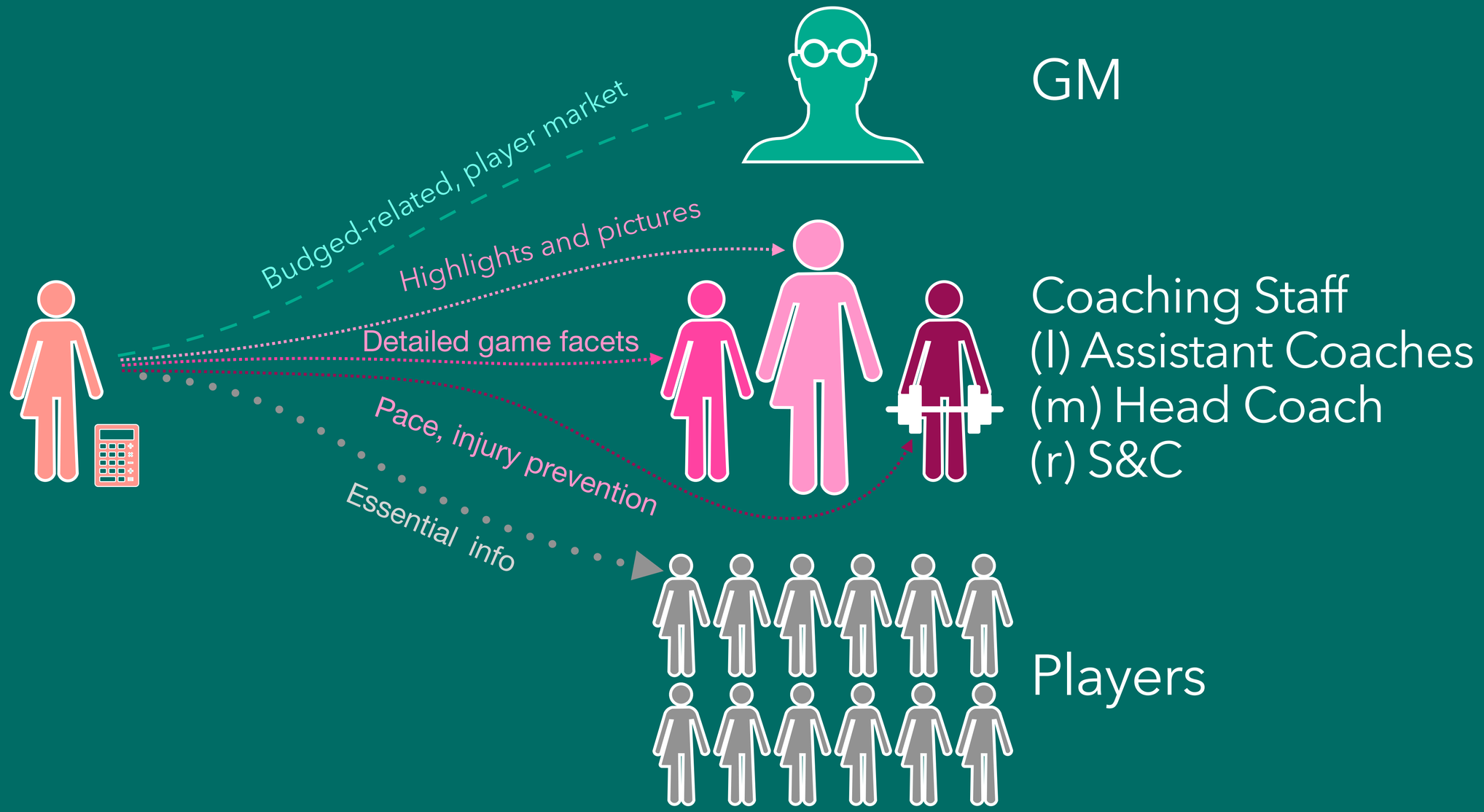
Stay tuned!

I have stats… Now what?

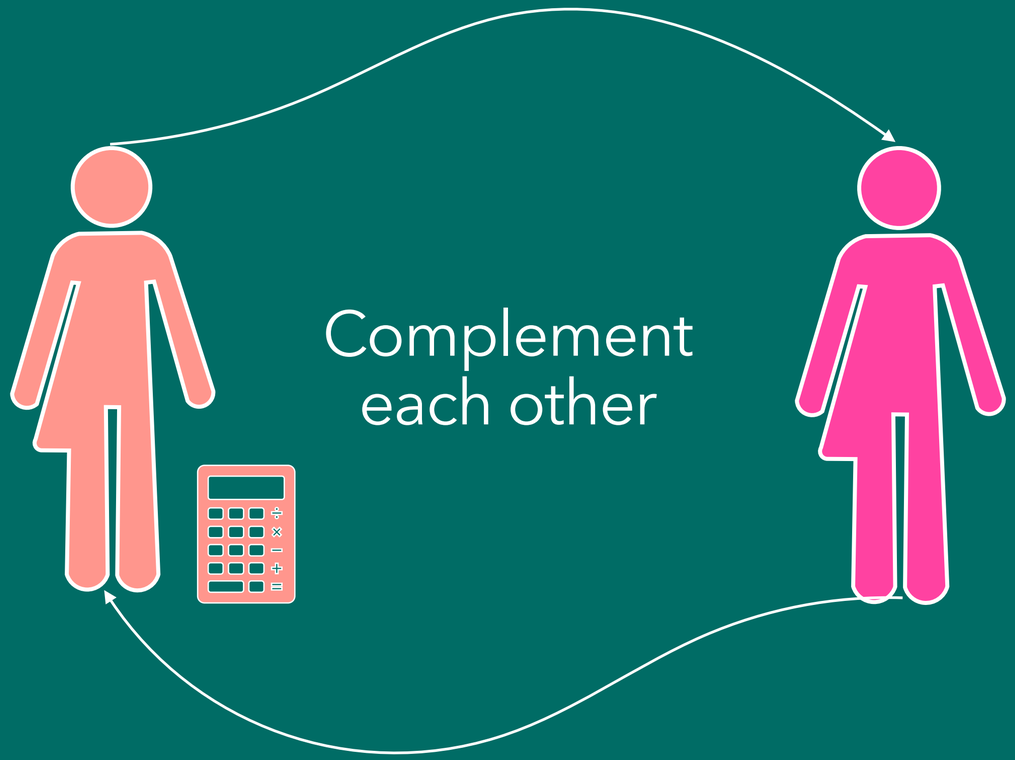


Communication

Each communication channel is unique



Communication

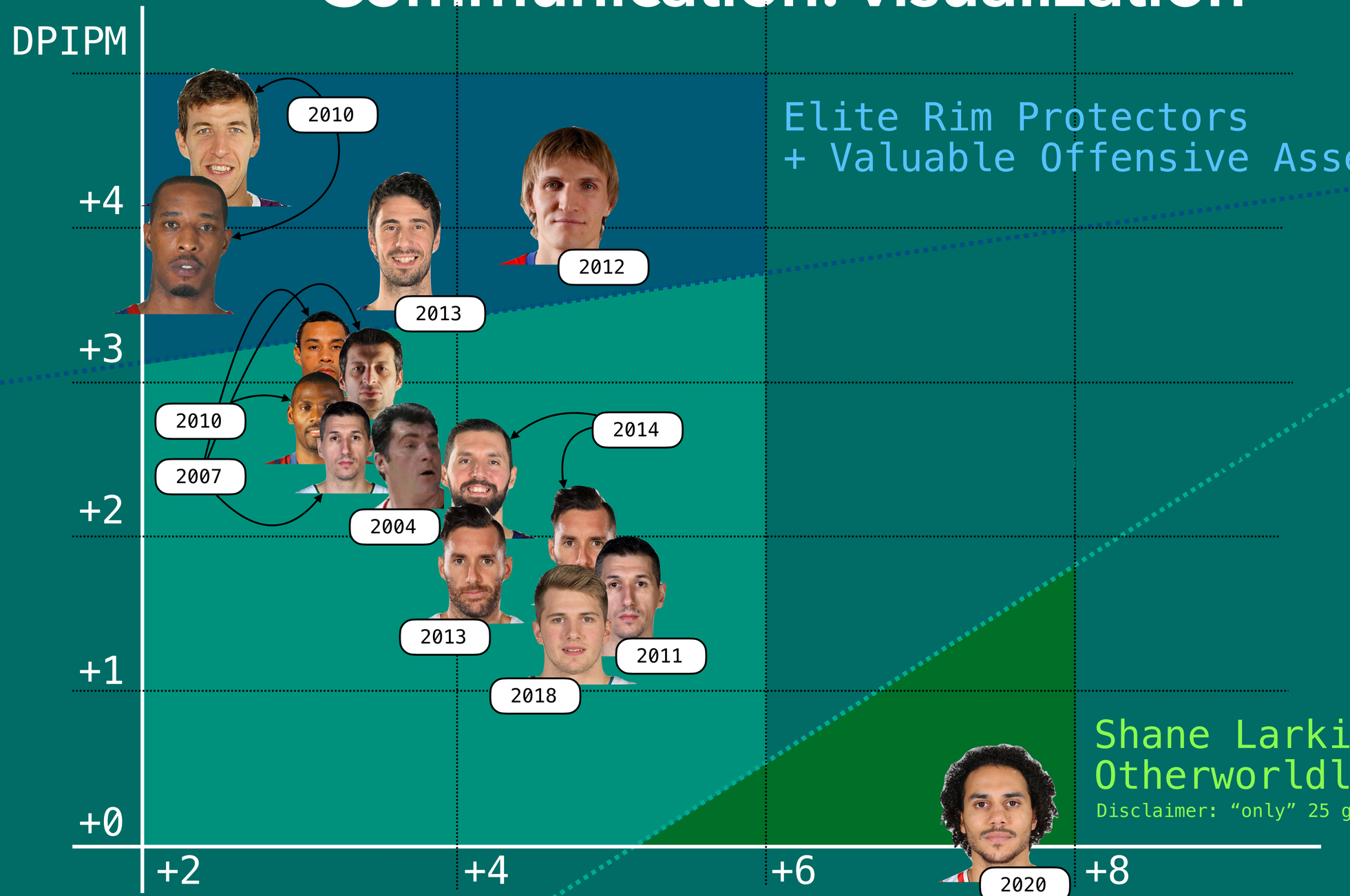


Be a valuable resource, not a coaching thread

Learn how to ask the appropriate questions

Acquire the coaching staff’s lingo

Communication: visualization



Communication

[Credits - Seth Partnow]

- Being better is not being right at everything, it is being less wrong.
- Put data in the language of sport – hybrid profiles.
- Properties of language:

Almost all statistics are arbitrary (not the scoreboard)

We use representative abstractions of game concepts (*e.g.* rebound)

Communication

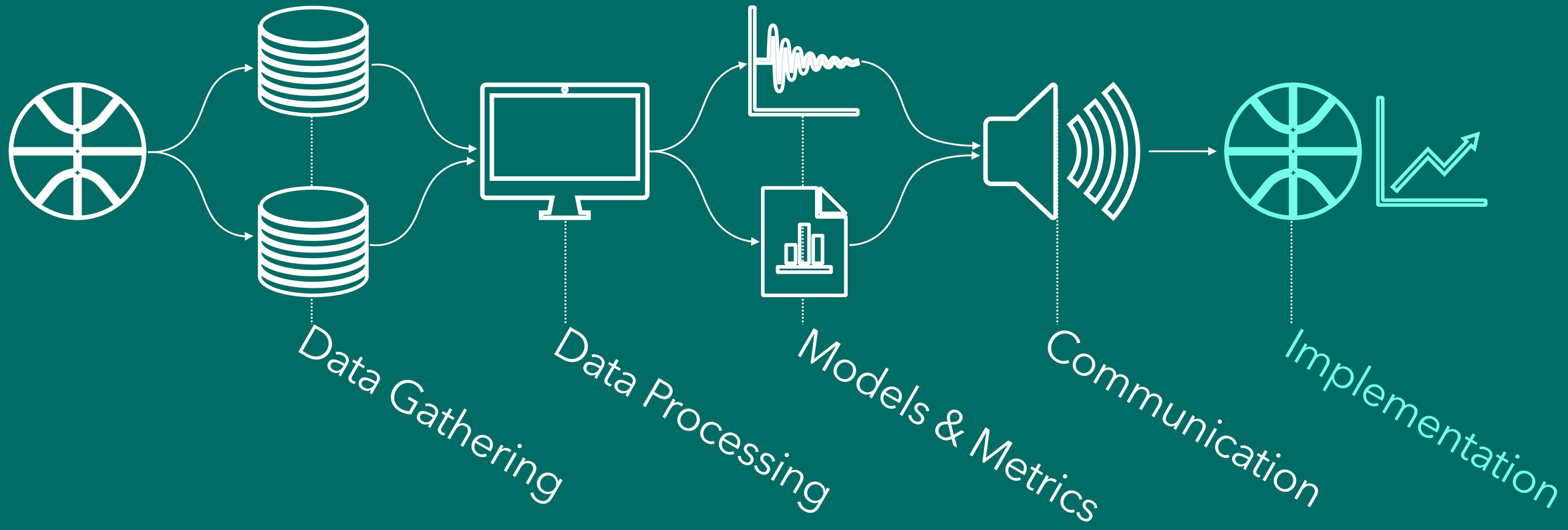
[Credits - Seth Partnow]

- Being better is not being right at everything, it is being less wrong.
- Put data in the language of sport – hybrid profiles.
- Properties of language:

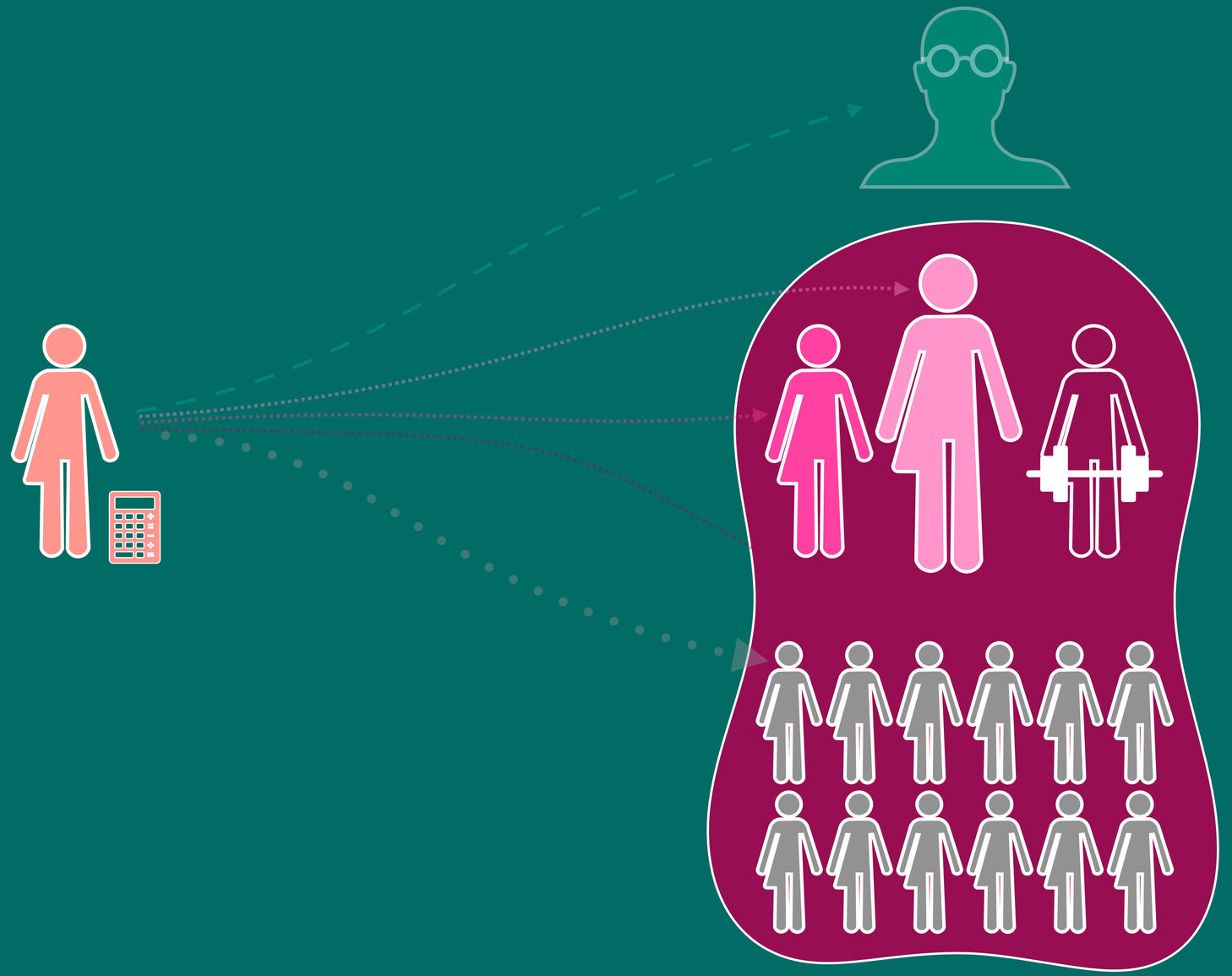
Naming stats: objective & basic, clear calculation / concepts.

Avoid: unnecessary jargon / opaque terms, snake oil.

In this talk…


Data Gathering
Data Processing
Models & Metrics
Communication
Implementation

Implementation



Acknowledgements

Gloria Haro
Coloma Ballester
Adrián Martín
Martí Casals
Seth Partnow
Todd Whitehead
Justin Jacobs
Andrew Patton
Mike Beuoy
Nathan Walker
Xavi Pardina
Juan Llaneza
Diego Ocampo
Javier Fernández
Raúl Peláez

Thanks for the attention

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Free agent from fall 2021!