

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING: A CONVERSATIONAL APPROACH

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August 2026 · Revision 1.0

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The engineering workflow you will use throughout this book

CHAPTER - 7

PART 1 · ≈ 12 MIN

The Shot Becomes Data

One real basketball shot, a 120-fps camera, and two columns of numbers with no gaps in them. Chapter 6 asked what we could say BETWEEN measurements. Chapter 7 asks what ONE model can say about ALL of them.



Problem

›

Model

›

Compute

›

Analyze

›

Validate

›

Improve

We have measured data. What model should represent it — and how would we know it deserves to be trusted?

Commit to a first answer before we look at anything: what would it take for YOU to trust a model of a basketball shot? **It looks right · it matches the data · it matches the physics · something else?**

Problem

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CONTENTS OF CHAPTER 7:

Chapter 6 asked: what can we responsibly say about the holes between measurements? **Chapter 7 asks:** when every point was measured, what one model should speak for all of them — and does it deserve trust?

1

The shot becomes data

One real shot · Tracker turns a flight into t , x , y · sketch before you look · what ideal physics proposes



2

The best line

$x(t)$ · predictions and residuals · why "make them sum to zero" fails · least squares, made visible in Excel



3

The curve knows gravity

$y(t)$ · a straight line leaves an arch · the quadratic fit · coefficients that carry physics · a health check



4

Fits ≠ validated

R^2 as evidence, not a certificate · what R^2 cannot see · BREAK THE AI: the higher- R^2 polynomial



5

Three models, one shot · in lab

Python · gravity, drag, spin as hypotheses · question the MODEL, the DATA and the COMPARISON · decide



Course spiral: Ch 3 — how much can a number be trusted · Ch 4–5 — trap a root, check its residual · Ch 6 — reason between measured points · Ch 7 — infer one model from all of them. Prediction before computation, as always.

One shot, one camera — what moves, and what could we measure?

VIDEO



THE SHOT

One real human basketball shot, filmed from the side. One flight: the ball leaves the hand, rises, peaks, and descends into the hoop.

THE CAMERA

Fixed camera, side view, slow motion at 120 fps: one frame every $1/120 \text{ s} \approx 0.00833 \text{ s}$ — the same clock as the bicycle wheel.

THE SHOOTER

Jennifer Henegar

ME345 Engineering Dynamics

University of Michigan–Dearborn

Special thanks to Jennifer for volunteering her basketball shot which provided the experimental data used throughout this chapter.

Play it once in silence. Watch the ball, not the shooter. When does the BALL's own motion begin?

Problem

›

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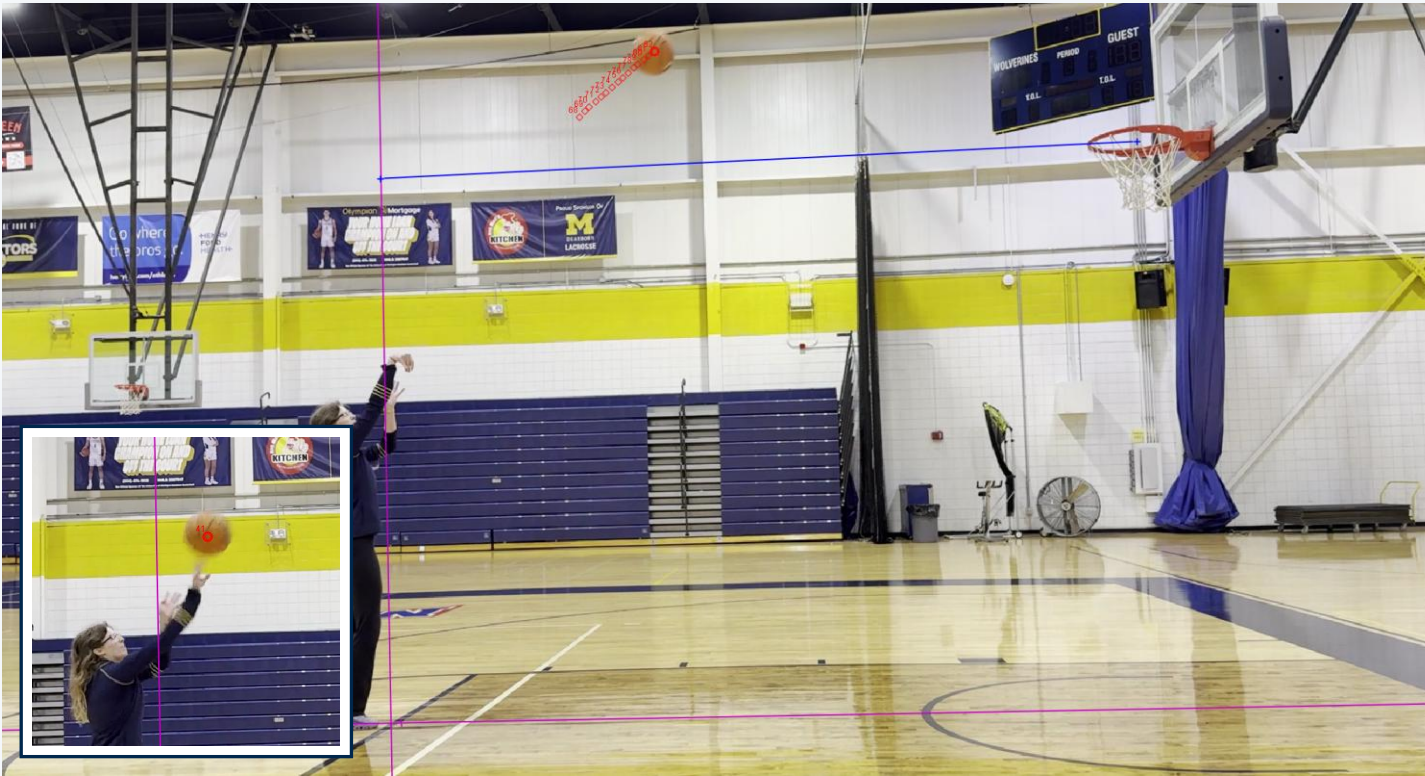
Validate

›

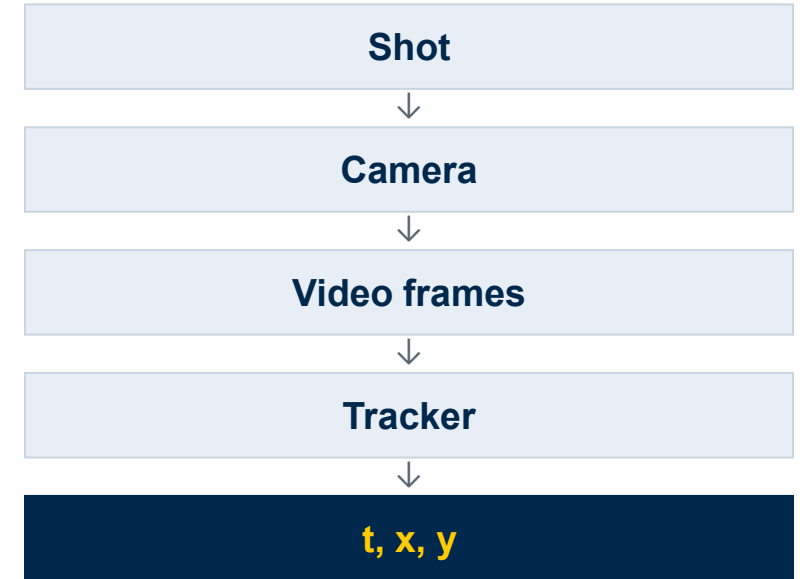
Improve



A flight becomes a table of numbers



Tracker, frame 82: manually selected ball centres so far. Inset: frame 41, the release frame.



RELEASE = frame 41: the first frame in which the ball has completely left the fingertips. Tracker's clock started with the video, so release sits at **$t = 0.342$ s**.

Tracker does not give us a trajectory. It gives us measurements of one — a position, at an instant, with a clock.

Problem

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Model

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Compute

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Analyze

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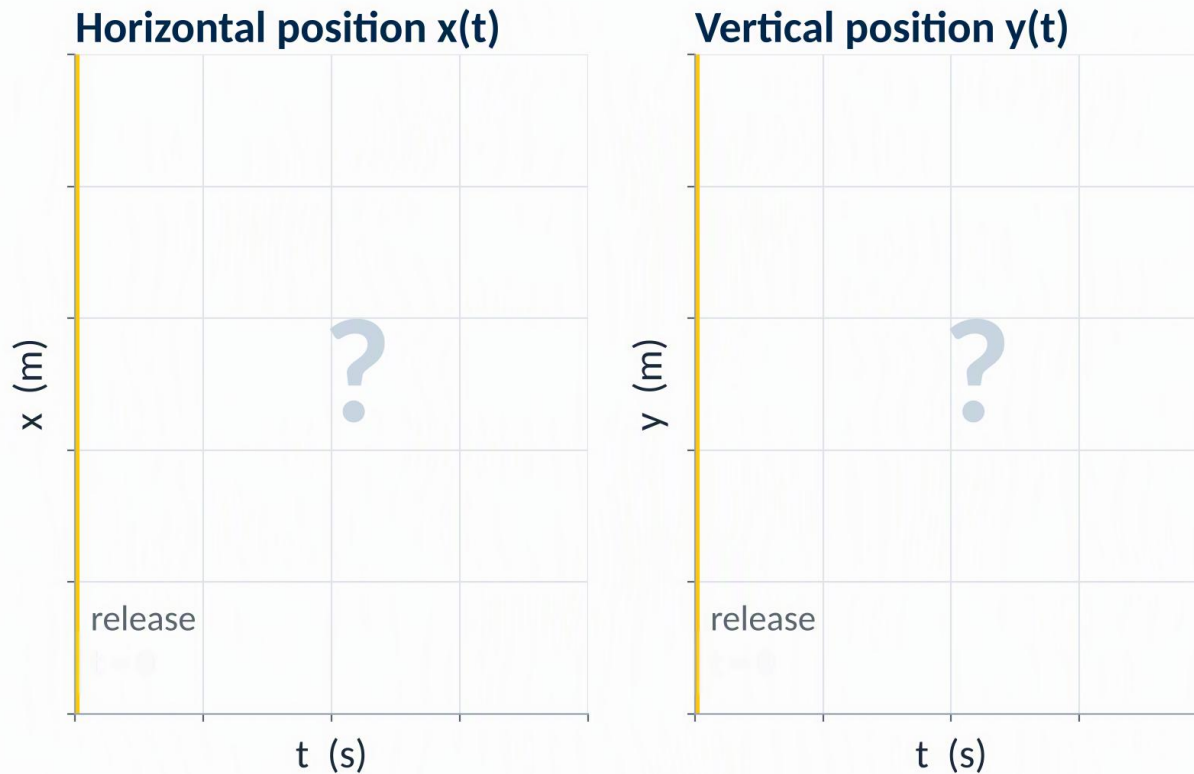
Validate

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Improve



PREDICT



Sketch $x(t)$ and $y(t)$ for the whole flight on your own paper. Do not calculate anything.

Then, for EACH sketch: what SHAPE did you draw — and what physical reason makes you expect it?

Straight line? Parabola? Something that bends a little? Commit before we look at the data.

Whatever you drew, you just proposed a model — two of them. The next slide shows what the camera actually recorded.

Problem



Model



Compute



Analyze



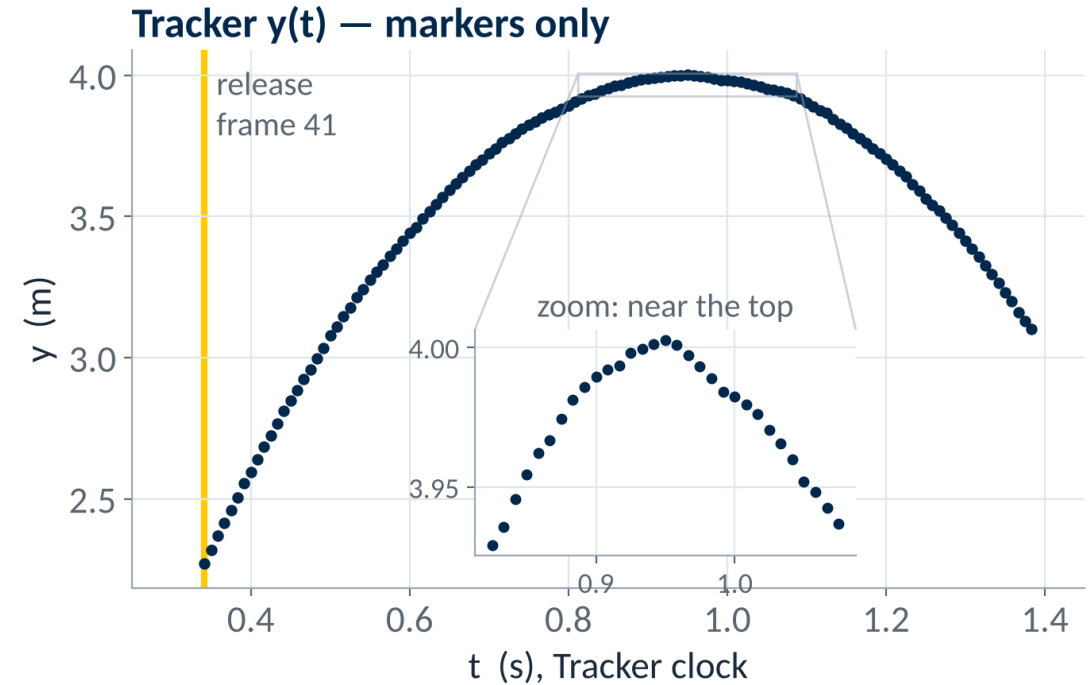
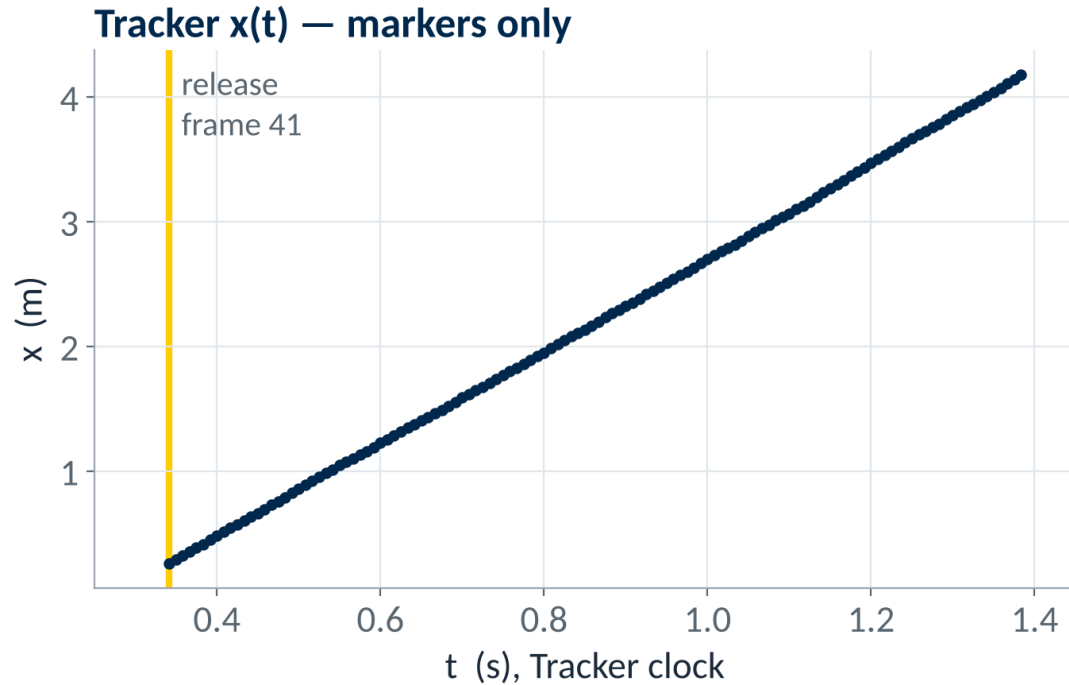
Validate



Improve



Now compare with your sketch. What do you notice?



Every frame from release to the rim: $N = 126$ measurements over 1.04 s (frames 41–166), one every $1/120$ s. **No gaps this time — and zoomed in, no smooth curve passes exactly through every point.**

Problem



Model



Compute



Analyze



Validate



Improve



The AIFE Virtual Engineering Lab makes the same prediction you did



AFTER RELEASE

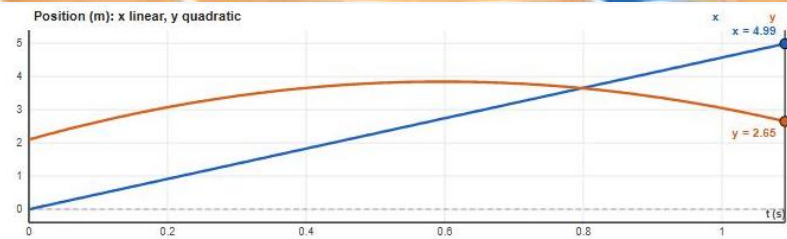
No horizontal force: $a_x = 0 \rightarrow x(t)$ is a straight line.

Gravity only: $a_y = -g \rightarrow y(t)$ is a parabola.

THE MODEL STATES ITS LIMITS

VEL prints it on screen: **"ideal planar projectile — no drag, spin, lateral error or rim rebound."**

An honest model says what it leaves out. Remember those three words: drag, spin, lateral.



VEL · Projectile Motion — Basketball, free-throw preset. An ideal-model shot, not our measured shot.

Physics proposes the form and its constraints. Data help determine the unknown coefficients. Validation asks whether they agree.

Problem



Model



Compute



Analyze



Validate

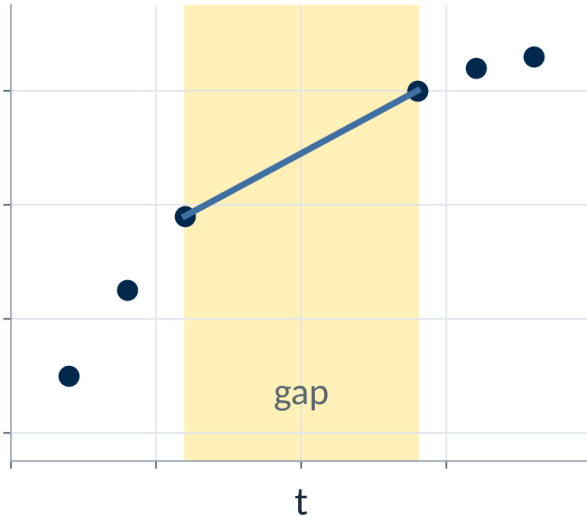


Improve

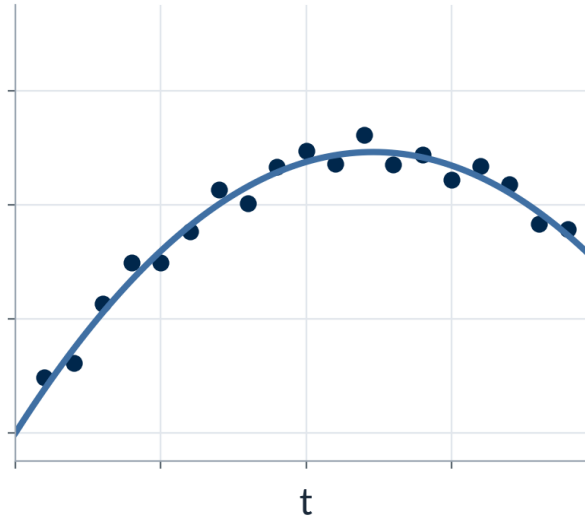


The question has changed

Ch 6 · through two neighbours



Ch 7 · one model, all points



schematic — not measured data

You have already seen one: Lab 6, Program 2 fitted $A(t) = A_0 e^{-\lambda t}$ to the |peak| envelope and printed an R^2 . It passed near the peaks, not through them. Today we open that box.

CHAPTER 6 · INTERPOLATION

A few frames missing. Estimate **between** two measured neighbours; the line passes **through** them. Local: it speaks only for the gap.

CHAPTER 7 · CURVE FITTING

Every frame measured. Propose **one model for all** the points. It may pass **near** every point and through none — because real measurements scatter.

CURVE FITTING choosing the coefficients of a proposed model so it agrees as well as possible with **ALL** the data. Not connecting the dots. Not recovering the truth.

Problem



Model



Compute



Analyze



Validate



Improve



Two candidate models. Which numbers — and should we trust them?

$$x(t) = A_x t + B_x$$

a straight line · 2 coefficients

$$y(t) = A_y t^2 + B_y t + C_y$$

a parabola · 3 coefficients

WHICH NUMBERS?

No line passes through every x point.
Who picks A_x and B_x — and by what rule?

→ **Part 2**

WHAT DO THEY MEAN?

Are A_y , B_y and C_y just numbers the software prints — or do they carry physics?

→ **Part 3**

SHOULD WE TRUST IT?

If the curve fits beautifully, is the model right? If model and data disagree, who is wrong?

→ **Parts 4–5**

FITS ≠ VALIDATED. The chapter's principle — not announced, but earned by the end of Part 4.

Problem



Model



Compute



Analyze



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