

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING: A CONVERSATIONAL APPROACH

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The engineering workflow you will use throughout this book

CHAPTER - 6

PART 3 · ≈ 17 MIN

Check It With Physics

The spreadsheet knows ten rows of numbers. You know something it does not: the bead is bolted to a wheel. Use that as evidence — not as a shortcut — and reach a verdict on each coordinate.

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Problem

›

Model

›

Compute

›

Analyze

›

Validate

›

Improve



What do we know that the spreadsheet does not?



the bead, one frame of the slow-motion video

Ten rows of numbers went into Excel. Nothing about a wheel did.

Name one physical fact about this bead that the spreadsheet has no way of knowing — and that every reconstructed point must obey.



THE ANSWER THE CLASS WILL GIVE

The bead is attached to the wheel. Wherever it is between frames, it is still on the rim — the same distance from the spindle as the measured points on either side. Not "exactly 0.3048 m": whatever the measured neighbours say that distance is.

That is independent evidence. The straight-line model did not produce it, so it can test the model. Turn it into a number the spreadsheet can compute.

Problem



Model



Compute



Analyze



Validate



Improve

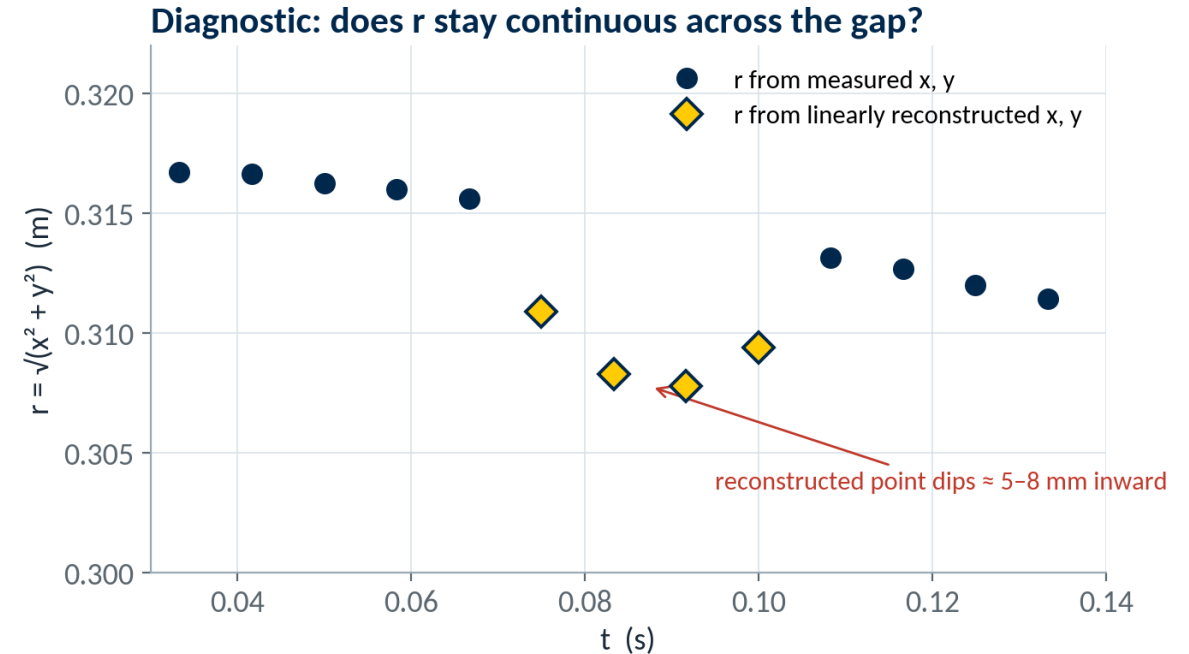


Add an independent check: does r stay continuous across the gap?

t (s)	x (m)	y (m)	Data Type	r (m)
0.050000	-0.117594	-0.293563	MEASURED	0.3162
0.058333	-0.093531	-0.301857	MEASURED	0.3160
0.066667	-0.068832	-0.308022	MEASURED	0.3156
0.075000	-0.04315	-0.30790	INTERPOLATED	0.3109
0.083333	-0.01747	-0.30778	INTERPOLATED	0.3083
0.091667	0.00821	-0.30766	INTERPOLATED	0.3078
0.100000	0.03389	-0.30754	INTERPOLATED	0.3094
0.108333	0.059576	-0.307425	MEASURED	0.3131
0.116667	0.082395	-0.301627	MEASURED	0.3127
0.125000	0.106590	-0.293238	MEASURED	0.3120

$$r = \sqrt{x^2 + y^2}$$

Column E: =SQRT(B5^2 + C5^2) copied down. A diagnostic — a quantity we compute only to test the reconstruction.



Measured neighbours: $r \approx 0.3156$ m before the gap, 0.3131 m after. Linear (x, y) reconstruction: $r \approx 0.3109, 0.3083, 0.3078, 0.3094$ m — a dip of 5–8 mm toward the spindle, then back.

The reconstructed POINT does not stay on the measured trajectory. It sags inward. Something in (x, y) is wrong — and Part 2 already told us which coordinate to suspect.

Problem



Model



Compute



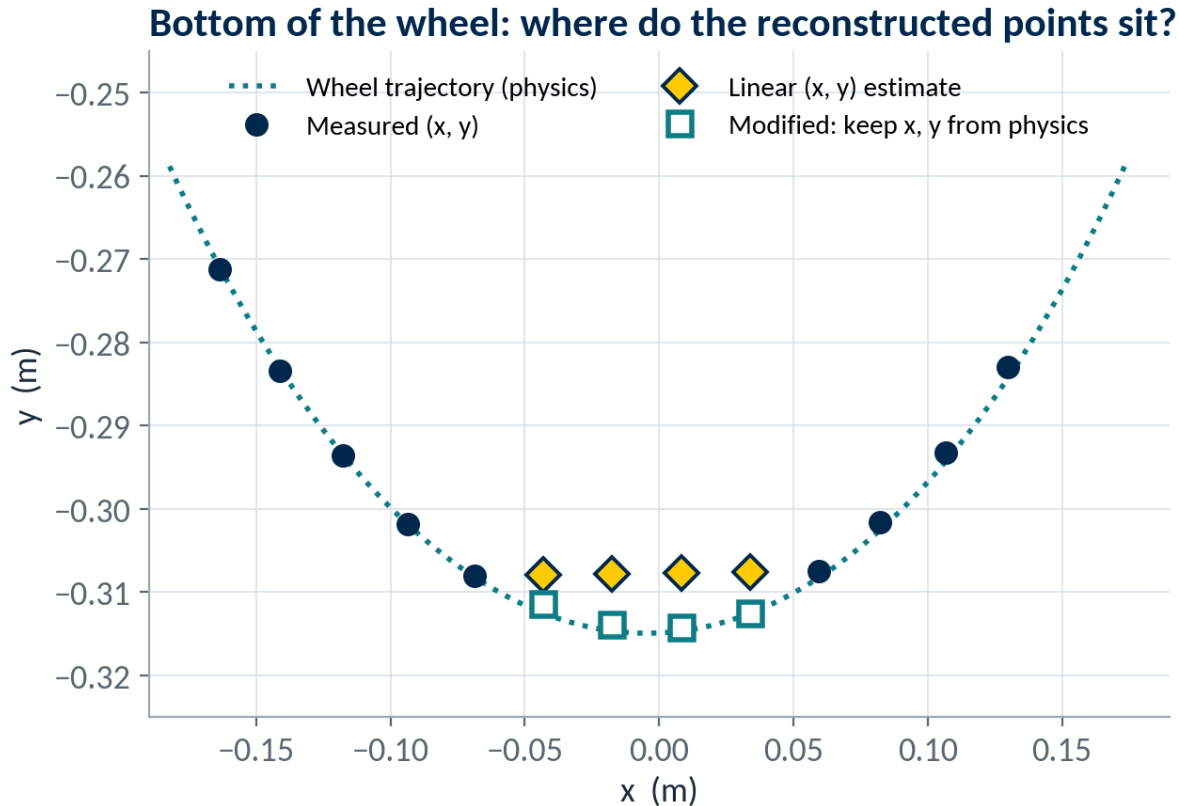
Analyze

**Validate**

Improve



The bead moves on a circle. Now that fact is allowed in.



THE PHYSICAL RELATIONSHIP

$$x = R \cos \theta(t), \quad y = R \sin \theta(t)$$

approximately circular motion; $\theta(t)$ the bead's angle as the wheel turns

WHY x WORKED AND y DID NOT

Near the bottom of the wheel x is crossing zero — the cosine is at its STRAIGHTEST there, so a chord follows it almost perfectly.

At the same instant y is at its minimum — the sine is at its most CURVED, so the chord cuts across the top of the arc and sits a few millimetres too high.

The circle was never a shortcut. Students proposed it in Part 1; the data-based estimate came first; now the physics arrives as independent evidence — and it explains exactly what the $r(t)$ check saw.

Problem



Model



Compute



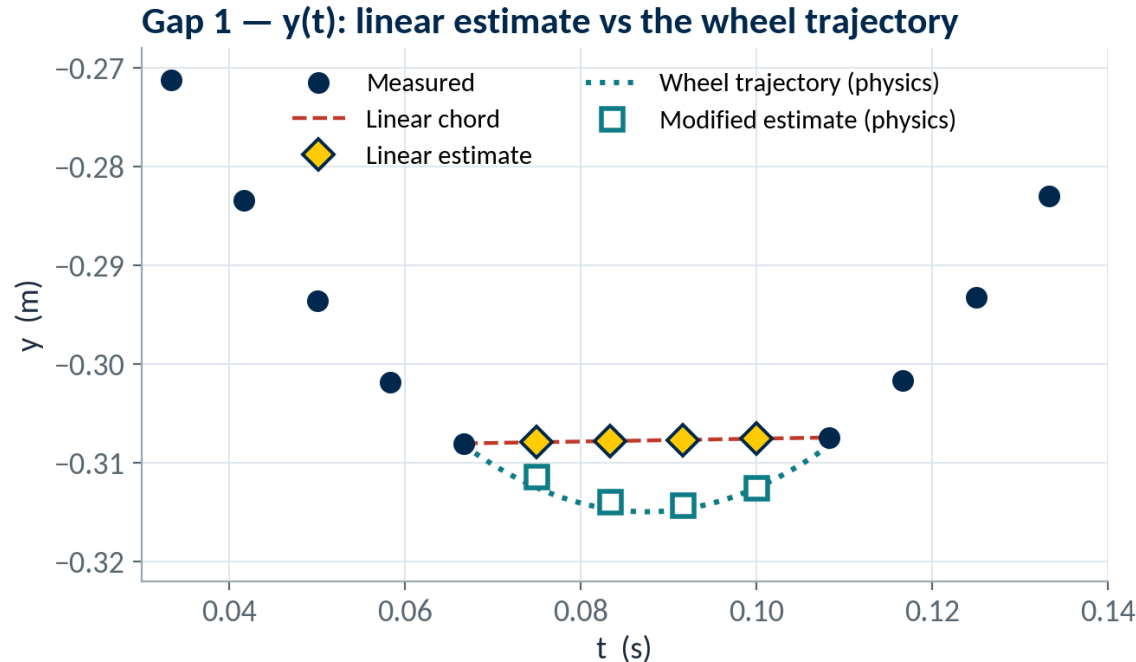
Analyze

**Validate**

Improve



ACCEPT x. MODIFY y.



ACCEPT x

The linear x estimates sit on the wheel trajectory to within a fraction of a millimetre — smaller than the scatter already visible in the measurements. No evidence against them. Accept, and keep the label INTERPOLATED.

MODIFY y

The linear y estimates fail the trajectory check by 5–8 mm. Keep the accepted x; take y from THIS system's physical constraint:

$$y = -\sqrt{r_{\text{local}}^2 - x^2}$$

r from the measured neighbours;
open squares on the plot

This square-root relation is NOT a general interpolation formula. It is additional physical knowledge about a bead on a wheel, used to repair an estimate that failed validation. A different system would need a different fact.

When a data-based model fails validation, the engineer can modify the estimate with independent knowledge — and must say so. The modified y values are still estimates. Label them.

Problem



Model



Compute



Analyze



Validate



Improve



Three kinds of evidence — and one verdict

DATA

The measured neighbours and their local behaviour. Where the points on either side line up, a chord is credible; where they bend into the gap, it is not.

COMPUTATION

The hand calculation and the Excel formula — the same arithmetic, twice. Their agreement validated the implementation, never the model.

PHYSICS

The bead stays on the wheel trajectory. Independent of the model, so it could test the model — and it did.

THE YARDSTICK

Is the disagreement small compared with the variability already present in the measurements? For x: yes, by a wide margin — ACCEPT. For y: no — roughly ten times larger — MODIFY. No cutoff was needed; the measurements themselves set the scale.



One complete arc, closed. After the break: what happens when the gap grows, when the request leaves the measured range, and when a program does all of this for you.



SHORT BREAK · $\approx$ 10 MIN

One arc is closed: four missing frames, estimated, checked, judged.

Next — Part 4: how far can a straight line be trusted, what changes when the request is outside the measurements, and a Python program that does all four estimates at once (and checks itself).