

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING: A CONVERSATIONAL APPROACH

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Problem



Model



Compute



Analyze



Validate



Improve

The engineering workflow you will use throughout this book

by Taner & Sebnem Onsay,

CHAPTER - 5

PART 1 · ≈ 35 MIN

A Faster Way — Use the Slope

Chapter 4 ended with a question: bisection keeps only the SIGN of f , yet the values were pointing at the root. What happens when we let the values steer?



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CONTENTS OF CHAPTER 5:

Chapter 4 asked: can the computer earn the number intelligently — with a guarantee? **Chapter 5 asks:** can it move toward the root intelligently — by reading the slope — and what does that speed cost?

1

A faster way — use the slope

Bisection kept only the sign · the tangent line · the Newton step derived from a picture · the correction has physical meaning



2

Newton in action — fast when it works

Three steps by hand, then Excel, then Python · a stopping rule for a method with no walls · two steps where bisection needed eleven



3

When Newton goes wrong

A start that finds the wrong root · a flat slope that throws the iterate off the map · CONVERGED ≠ CORRECT, again · BREAK THE AI audits a “converged” root



4

Bisection vs Newton — which information do you have?

No universal winner · what each method asks of you and gives back · bracket first, move intelligently second · validate & decide



Prediction before computation is used throughout — as always. Every Part returns to the problem you certified in Chapter 4; what is new is one piece of information the hunt was throwing away.



A question asked at the end of Chapter 4

THE TOOLKIT YOU BUILT

one shape · the bracket · bisection · the contract

You can write a question as $f(x) = 0$, trap its root, close in on a schedule, and read the conditions behind the guarantee.

THE QUESTION

“ $f(20.0) = -1.43$ and $f(20.5) = +0.52$ — the values are pointing at the root. What happens when we let the values steer?”

Chapter 4's closing sentence. Today is that question, answered.

THE PRICE OF SAFETY

11 halvings

from $[0, 40]$ for ± 0.01 — thirteen model runs. Each halving bought one factor of two, and every one of them used only the SIGN of f . The value was thrown away.

STILL STANDING

RUNS $\neq$ CORRECT CONVERGED $\neq$ CORRECT

Chapters 2, 3 and 4 — plus “a guarantee holds only where its conditions hold” — undiminished. Today the ladder gains a rung of its own.

Chapter 4 taught you to trap the root and close in with a guarantee. This chapter asks whether the hunt can close in faster — and what the speed costs.

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DISCUSS

**At $v = 20.0$ you know two things:
 $f = -1.43$ m, and f is rising 3.86 m per m/s.**



You may spend ONE more evaluation. Bisection says: the middle, 20.25. But you know how steep f is at 20.0 — where would YOU jump, and why is it not the middle?

Draw it on the Chapter 4 picture. Whatever you sketch, you are about to meet its formal name.

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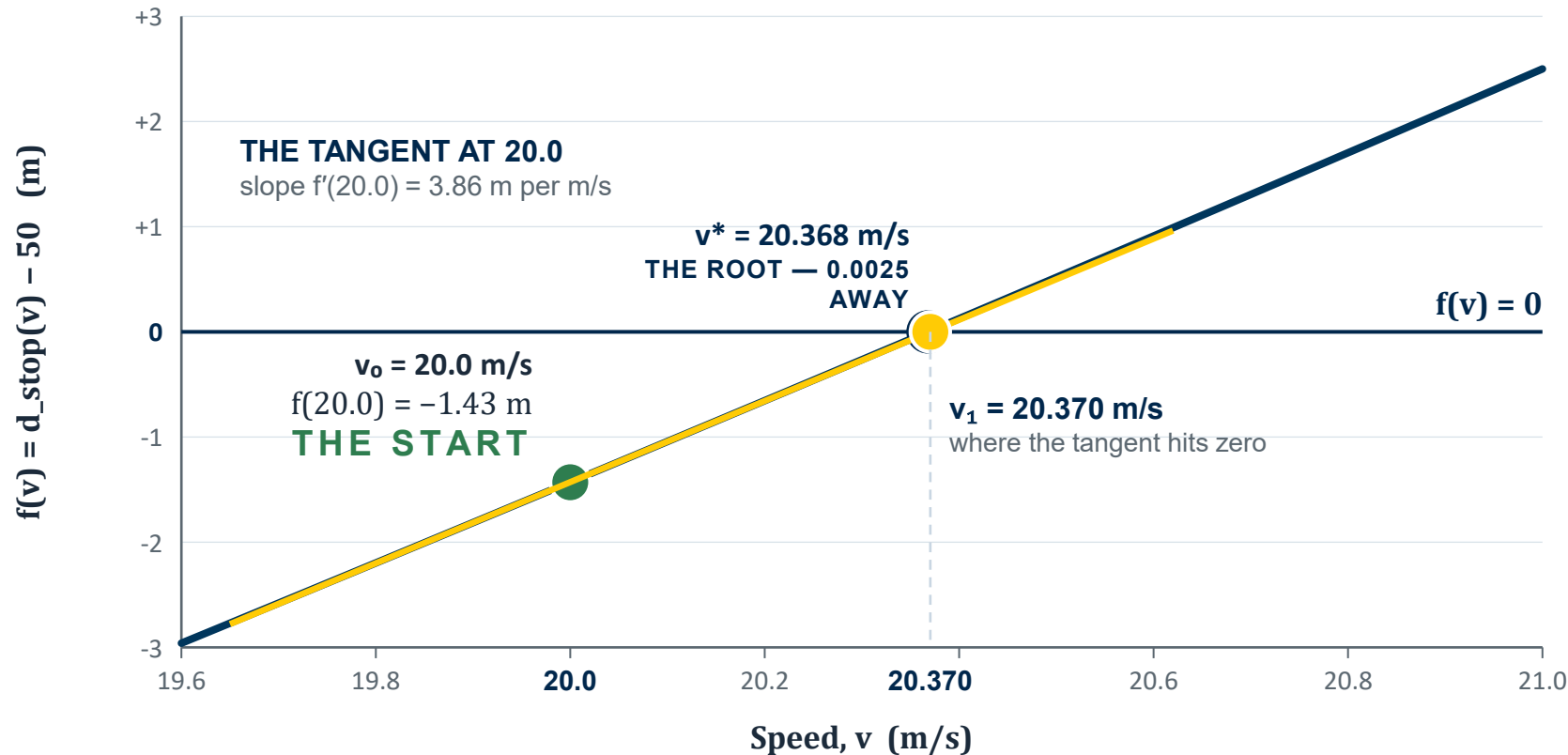
Validate



Improve



See the slope — let the curve tell you where it crosses



USE WHAT YOU KNOW

FOLLOW THE TANGENT.

20.0 → 20.370

One slope replaced five halvings. The tangent is a straight-line guess of where a curve crosses — and near the root, the curve is nearly straight. *f*

Chapter 2 arithmetic + one slope:

$$f(20.0) = -1.43 \text{ m}$$

$$f'(20.0) = 1 + 20/7 = 3.86 \text{ m per m/s}$$

“Where does the tangent cross zero?” Shortfall ÷ steepness: $1.43 \text{ m} \div 3.86 \text{ m per (m/s)} = 0.370 \text{ m/s}$. One jump lands 0.0025 m/s from the root — bisection needed five halvings for that.

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From the tangent to the Newton step

THE TANGENT, IN WORDS

“Rise over run” at x_n is $f'(x_n)$.

To reach zero along a line that steep, move by $f(x_n) \div f'(x_n)$ — toward zero, against the sign of f .

THE SAME MOVE, AS A FORMULA

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

The Newton-Raphson step. Not a formula to memorize — a picture you can redraw: start, tangent, crossing, repeat.

$f(x_n)$ — THE SHORTFALL

the shortfall, in metres

$f(20.0) = -1.43$ m: the stop is 1.43 m short of using the road.

$f'(x_n)$ — THE SENSITIVITY

the sensitivity, in m per m/s

$f'(20.0) = 3.86$: each extra m/s of speed uses 3.86 m more road.

$-f / f'$ — THE CORRECTION

shortfall $\div$ sensitivity, in m/s

$+1.43 / 3.86 = +0.370$ m/s: speed up by this much to use the road exactly — if f kept its slope.

The correction is shortfall divided by sensitivity — a physical statement, not algebraic decoration.

Units check: $\text{m} \div (\text{m per m/s}) = \text{m/s}$. If the units of your correction are not the units of x , the step is wrong before it is taken.



Where does the slope come from?

1 · DIFFERENTIATE

Your $d_{\text{stop}}(v) = v \cdot t_r + v^2/(2a)$ is a formula, so its slope is one line of calculus: $f'(v) = t_r + v/a = 1 + v/7$. Exact, cheap, and yours to check. This is the chapter's source.

2 · TWO NEARBY POINTS

No formula? Evaluate f a little to either side and take rise over run — an ESTIMATE of the slope, with its own resolution questions. Chapter 10 does this properly; today, know that it exists.

3 · ASK, THEN VERIFY

An AI analyst will differentiate anything on request. A wrong slope does not crash Newton — it steers it. Check the derivative at ONE known point before it steers anything.

AND ALWAYS — CHECK THE SLOPE AT ONE POINT YOU CAN COMPUTE

$d_{\text{stop}}(20.0) = 48.571$ and $d_{\text{stop}}(20.1) = 48.964 \rightarrow \text{rise/run} \approx 3.93 \text{ m per m/s}$; the formula says 3.86. Close — the gap is the curve bending over 0.1 m/s. Now trust f' .

The slope is part of the model — and the model is yours. Getting f wrong stops the hunt in the wrong place; getting f' wrong sends it there by a stranger route.

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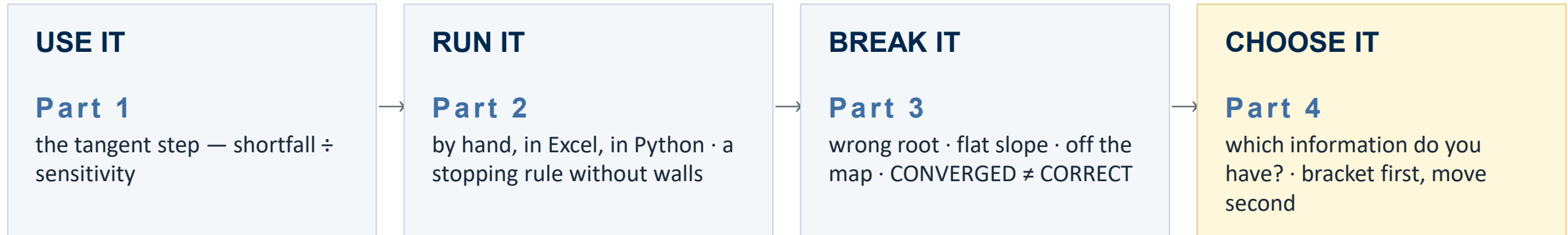
Improve



Can the hunt read the map while it runs?

CHAPTER 5 · PRINCIPLE No. 1

THE SLOPE IS INFORMATION — SPEND IT. EVERY EVALUATION CAN TELL YOU WHERE TO GO NEXT.



Every Part returns to the root you certified in Chapter 4. No new physics enters this chapter — again.

