

Digit Finds a Gun

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I set my alarm early this morning. Okay, maybe it was only half an hour earlier than usual, but I was anxious to check for email on my new laptop. Dad bought it for me a few months ago and we just configured it into a wireless network last night. He bought me a desktop computer last year when I started high school, but he's been using it so much lately that I think he was starting to feel guilty about it. Anyway, I prefer the laptop for its portability. This one has everything I need and it fits perfectly inside my backpack.

The laptop is in my room, on a makeup table that I never used. Mom got me this bedroom set a long time ago and the table was included. It all looks great together, but I wouldn't get caught dead wearing makeup! Dad wouldn't approve of my wearing makeup either, but that's not the point; it makes me feel painted up and I don't like that at all. That makeup table is a perfect place for the laptop, however. It's solid and it has a drawer for CDs, manuals and such, like the desk near the kitchenette, where we put the desktop computer. The laptop came with a built-in wireless port and Dad bought a compatible WiFi card for the desktop. Last night I configured the security so I can use the printer and our high speed Internet connection on the laptop in the privacy of my room, without worrying about hackers.

Not much email today and there are no text messages on my Sidekick, either. I guess everyone is getting ready for Spring Break. I'm not going anywhere this year. Mr. Paulson, my Math teacher, says he has a *research project* for me to work on that week, but he's being very mysterious about the details. I'm going to see him this morning to find out what it's all about.

I grab my stuff and walk into the living room to find Dad in his easy chair with his feet up, reading the newspaper. "We're very busy this morning, I see," I say smiling.

“Not much going on,” he replies. “I called in, but there isn’t anything for me to work on today.” Dad’s a private investigator who specializes in insurance fraud cases. He used to be a cop, but took an early retirement from the Force after Mom died.

“If you’re not doing anything important today, why don’t you take me to lunch,” I suggest.

“Having lunch with my best girl is *always* an important thing to do,” he says with a big smile.

“That sounds like an excellent idea. Where would you like to go?”

“They’ve got a terrific shrimp salad at Pappy’s,” I offer.

“You’re on,” he says as he pokes his nose back into the Business section. “I’ll meet you at Pappy’s around 11:45 am. Have a good day at school.”

I head out the door. There’s still a chilly reminder of winter in the air, but it’ll warm up again soon enough. I turn my collar up against the cold and keep trudging along. I pass Sam’s Bakery, with all its delicious smells and the beautiful wedding and birthday cakes in the window. Further along is the German Deli, with several dozen sausages hanging above brightly colored packages of cheese and bottled wine. Across the street I can tell the grocery store isn’t open yet because there is still a pile of newspapers and a bag of French bread by the door.

Chicago is the sum of its neighborhoods. Europeans, Asians, Africans and Latinos each settled here, staying near their countrymen, preserving their language and their culture for at least one more generation. Chicago is an awesome city and I’ll always feel at home here.

I can see my corner coming up: there’s the old homeless guy directing traffic. It’s an intersection with two major cross streets, and a side street that ends there. All the streets have lights, and all the lights are working fine; he just likes doing it. Some say he used to be a traffic cop, others say he’s just crazy. I say he’s good at what he does, and that’s probably the most important thing to him right now.

I turn left down the side street for about half a block, then right down a short, wide street to one of my favorite places in the city. This street tees off the side street and ends at train tracks that are up high enough for an underpass, but the street is too small to warrant one. It's really two parallel one way streets, one on either side of a grassy median, with a circular turnaround at the halfway point. There are big old homes on either side, each with a front porch where you can sit and watch the kids play after dinner. At the far end of the median is an oak tree that is so large that two of us can't get our arms around it. It must be two hundred years old. I stop there to admire it for a while, and wait to see if any of my friends might also be walking to school today.

At exactly 7:28 am the C&NW commuter train comes roaring out of the suburbs, heading for downtown Chicago. That means it's time to go. Our mutually agreed upon rule says we wait by the tree for any stragglers and continue our walk to school together. It's not far from here, and after the train comes through there is just enough time to get to school, drop off your coat and books at your locker, and still get to your first class on time. I guess it's just me today.

Once inside, I relearn just how noisy a high school hallway is. It's no wonder most kids plug into their music! I may get one of those things myself one day. I head toward the Computer Lab to find Mr. Paulson.

The Computer Club meets here after school, and it doubles as the Math classroom. Mr. Paulson's office is in here, too. Near the back of the room is a pair of folding tables that hold two rows of desktop computers, each with a monitor next to it, and a keyboard, mouse, and wooden chair in front of it. They're not that old yet, but my laptop is twice as fast and has twice the memory and hard disk space; technology changes pretty quickly nowadays. Mr. Paulson is in his office, but he seems to be totally absorbed in something on his computer screen. "Hi, Mr. Paulson," I say waving. He turns toward me and smiles.

"Come on in, Digit. I want you to see this." My name is Bridgett, but almost everyone calls me by that nickname he gave me in class last year. I get close enough to read what he's been looking at: Math Fair! Open to all high school students... "Wow, what's this about," I ask.

“I want you to enter the Math Fair this year. I’ll sponsor you; I can give you some guidance, but you’ll have to do all the work. I’ve got an idea for the project and I want you to do some research on it,” he says. “Go to the library and find some background material to read. The Internet should be a big help, too, but don’t believe everything you read online.” I am a little overwhelmed, but he wouldn’t challenge me with a project that I can’t handle, so I just listen. “I want you to read about the development of the earliest computers, and write a paper about why they were designed and built in the first place,” he says. “The title of the paper should be something like *A Historical Perspective on the Development of the Computer*. Make it about four pages.”

“Okay... but how much time do I have,” I ask haltingly. “And why did they develop computers, anyway?”

“Well,” he says, “that’s what you’re going to find out. I want you to draft a paper over Spring Break and we’ll polish it up when you come back. The final paper is due April 15th. It will become our proposal for the project that you’ll present to win a \$5000 college scholarship at the Math Fair,” he said, and with some confidence – a lot more confidence than I’ve got; that’s for sure!

I felt like I was going into shock. “Uh, okay. I’ll get started on it right away. Did you say five thousand dollars?”

“Yes,” he said. “You’re a shoe-in. We’ll have a talk with your dad about *which* college later, after you’ve got most of your freshman year paid for.”

I spend the morning half dazed, unable to get my head around what Mr. Paulson told me. Fourth period ends and I head for Pappy’s Restaurant, a small seafood place about three blocks from school. When I get there I see Dad’s car in the lot. “Hi,” I say, as I slip into the booth across from him.

“How did your meeting go with Mr. Paulson,” he asks.

“Wait till you hear about this!” I tell him about the Math Fair, the paper I need to write, and the \$5000 scholarship. He whistles. “My head is swimming,” I say. “I am a little overwhelmed.”

“That’s an interesting project, though” he says thoughtfully. “If he thinks you can handle this, then I know you can. We got that laptop connection working just in time. You can start by doing an Internet search tonight. What exactly are you going to write about?”

“The paper examines the reasons why early computers were invented,” I explain. “I think they had a lot of backing from the military, early on, and once they found out that a computer could be useful in the scientific and business world, the commercial industry took off. But I don’t know exactly why they were built in the first place – I guess I’ll find out, though,” I add with cautious enthusiasm.

We both had a shrimp salad. Neither of us spoke much. My head was clogged with ideas about exactly how I was going to dive into this project. After lunch Dad drove me back to school. “I know you can do this,” he says as I step out of the car. “Thanks, Dad,” I reply.

How come everyone but me has all this confidence, I wonder.

My afternoon classes at school go by uneventfully. I can’t help thinking about starting that paper tonight. When I get home we hardly talk about anything; my mind is racing. Dad must sense what’s going on because he just lets me be.

After supper I Google “early computer development,” and find a link to an Encyclopedia Britannica article on computer history. That sounds like a good place to start, and it’s a *free* article!

The article is not a history so much as a survey of books on computer history. There are plenty of references, including *Computer: A History of the Information Machine*. That looks like a good starting point, so I open another browser to the local library branch, cut and paste the title into their search page, and jot down the Library of Congress call number. The book is in; a good sign! I shut down everything and head for the library. This is starting to get exciting.

It's still only 7 pm and the library is open until 9. I find the book I want, along with several others from the same shelf, and settle down into an empty carrel.

This is interesting: one of the books has a photo of a room full of women, each sitting in front of a hand-crank calculator. The caption says these were the *computers* that scientists used to perform complex calculations. A small piece of the computation was parceled out to each woman, who passed her result back when she finished. A scientist would collect all their results and combine them into a final answer. (That sounds like the *distributed systems* I've been reading about!) This book also says that these computers made ballistic calculations, built firing tables, and tested code-breaking algorithms. Each was of utmost importance to the military during World War II. In parallel with the use of manual calculations was a push to develop an automatic computing machine, to speed up the process.

One of the first working mechanical computers was a collection of shafts, gears and wires called a *differential analyzer*, built at MIT back in the 1930s. It was still very slow, it wasn't portable, and it took days of set up time before it could even begin to solve a problem. In another book I find diagrams describing how gears are used inside mechanical computers. Simple equations: like $y = 2x$ require only two gears, one with twice the number of teeth as the other. Interesting stuff, but I better stick to my subject.

When you fire an artillery shell, the path it travels is called the *trajectory* and the distance it travels is called the *range*. The trajectory of the projectile is *parabolic* in shape. (And I remember from Algebra that a parabola is a U-shaped curve that can be described by a *quadratic equation*.) Wind resistance and other factors make calculating where the shell will land a lot more

complicated than a quadratic equation, but a parabola is a good approximation of its trajectory, from what I'm reading. That gives me a lot of ideas – time to collect my thoughts.

Okay, what do we know so far? During WWII, the military used rooms full of people to calculate firing tables. Artillery commanders used these tables in the battlefield to set the cannon's barrel at an angle of elevation. The mechanical computer was the first result of an effort to speed up this process, and electronic versions were soon to follow.

The calculations used to produce firing tables are horrendous looking: a lot of Calculus and Trigonometry. But if a parabola can approximate a trajectory, a quadratic equation solver should make a good basis for my project. I wonder if I can build a mechanical computer that can solve a quadratic equation – hmmm.

My Sidekick buzzes softly in my pocket, interrupting my daydream. It's Dad wondering where I am. I look at the time: it's almost 9 o'clock! I stack the books neatly, collect all my notes and head out the door.

It's Monday morning and back to school. Spring Break went by pretty quickly. The paper was fun to write and it looks pretty good to me. I drop it off in Mr. Paulson's faculty mailbox and head to my first class.

Later that day I stop by the Computer Lab. "Hi Mr. Paulson," I say, "did you get a look at the paper I left for you?"

"I did," he replies, "and it's an excellent start. I'll look at it more carefully tonight, but right now I want to talk about the actual project. Do you have any thoughts on that subject?"

"Yes, I do. I was thinking about building a simple, working mechanical computer. A computer that solves real trajectory calculations is way too complicated, but I found out that a parabola is a good approximation of a trajectory, and a mechanical quadratic equation solver sounds like it

might be easy to build.” He didn’t interrupt me, but he was staring at the floor, as if he was deep in thought.

“Digit,” he said, after a long pause, “building a mechanical computer would be a wonderful idea, and it would probably be a big hit with the judges, but this problem may be more complicated than you think. The object is not to calculate a parabolic trajectory, but to find the barrel elevation angle that gives you the required range.”

“Assuming flat ground between himself and the enemy, a field commander starts with the two solutions to that parabolic equation: where he is, and where his target is. The trajectory obviously passes through those two points, but a *third* point is needed to determine its equation,” he explained. “Do you remember discussing this in class, just before break?”

“Yes,” I said sheepishly.

“Once the third point, defined by the weight and acceleration of the artillery shell, is found, the equation of the parabolic trajectory can be determined. But what we really need is the elevation angle of the barrel. This angle aligns the barrel with the rising leg of that parabola, so the shell follows its path to the target. Can you see that?”

“Yes,” I repeated.

“Give this some more thought and we’ll talk about it again tomorrow.”

That could have gone a lot better, I thought, and headed back to my locker.

“How was school,” Dad asked, as I tossed my books on the counter.

“Pretty awful,” I reply, explaining how I made a fool of myself trying to impress Mr. Paulson with my plans for the project.

“Let it go,” Dad says. “You may have lost some points, but I’ll bet you’re still pretty far on the plus side with him. You are with me, you know.”

Dad can always make my cares disappear with just a few words. He’s the greatest father ever. “What do you think about going out to dinner tonight,” I ask.

“Are you up for some cheese burgers? I know just the place.” We drive to a 1950s style diner with some great oldies blaring from the juke box, where the waiters and waitresses are all dressed in period costumes. This radical change of atmosphere really worked for me. I feel a lot better already. We’re looking over the menus when Dad’s old partner on the Police Force walks in.

“Hey Frank,” Dad shouts over the din.

“Hi guys,” Frank says, turning toward us.

“We just got here,” Dad says. “Care to join us? We didn’t even order yet – have a seat. Excuse me, Miss?”

We all order cheese burgers, fries and extra large chocolate malts. The conversation is light and friendly. I like Frank. He and Dad were very close and they seem to still share a special bond, even though it’s been a few years since Dad went out on his own.

When we get done eating we’re all too full for dessert, so we ask for the check – Dad insists on buying.

“How’ve you been doing lately, Frank,” Dad asks on the way out.

“Pretty good,” he replies. “Oh, I caught a really screwy case today – you might even find it funny. A prize cow is killed in a barn out near the edge of town, by a metal object that fell through the roof. Everybody assumes it fell off an airplane, so they write all their reports and close the case. End of story, right?”

“Wrong,” Frank continues, “Three days ago another metal object smashes through an apartment building, destroying a guy’s digital media center. And yesterday, a car parked inside a garage is damaged by a third metal object from the sky.” Dad and I just stare at him in silence.

“We don’t think they fell from the sky anymore,” Frank says, “but we don’t have a clue where they might have come from, either. I haven’t the slightest idea where to start on this case. And don’t you hold back any ideas that you might have,” he adds smiling.

Dad whistles. “Do all these *metal objects* look the same?”

“Yep, they all deformed on impact, but they are all made of the same soft metal; we think its lead. They may even be cannon balls, but nobody with any ambition toward promotion is suggesting that!” Frank says with a smile.

“What?” Dad asks me after I tug his sleeve for the second time.

“My project might help,” I say. I give Frank a brief explanation of what my Math Fair project is all about and then add, “If the objects all came from the same place I might be able to help you locate it.”

Frank looks at us in disbelief for a moment, considers his options, and asks “What are you guys doing Saturday morning?”

I'm up early Saturday – I've never been to a real crime scene before. Dad's still fumbling with the coffee pot, saying "He's not coming for another hour! Have some cereal."

"I know," I say, "I'm just nervous." Cereal does sound like a good idea. We'll probably be out most of the day, and then stop for a late lunch somewhere on the way home. "I'm going to need a compass, two balls of twine, and a long tape measure," I tell him. Dad decides not to question my ideas at this point, and stuffs the gear in a duffel bag.

Our first stop is at the farm house. Frank introduces us to the farmer who leads us back to the barn. The hole in the floor is deep, and there is one in the roof above it. Two points, I muse, and go back outside. The weather vane is crooked, and the N is missing. I lay out the plan.

"We need a baseline," I say. "Help me run some string directly under the front edge of the roof."

The farmer gets up on the roof and drops a weighted string down to the ground from two opposite ends of the front edge of the roof. We fix a string from those two points on the ground, and record the angle it makes with magnetic north.

Next the farmer measures the distance from the roof's edge to the center of where the letter N used to be on the weather vane. We mark the string directly below his measuring point on the roof's edge and record the distances up to and across the roof that he measures. We use the same method for the center of the hole in the roof. Finally, we measure from a mark on the string outside the barn door to the hole in the floor. We record the distance from this last mark on the string to the other two marks, collect all our reference material, thank the farmer and bid him a good day. We're off to the next site – this is really exciting!

At the apartment building we find a hole in the roof, one in the guy's ceiling, and one in his floor, where the ball came to rest after demolishing his equipment. At the garage we have a hole in the

car (unmoved, awaiting an insurance adjuster) and one in the roof. Careful inspection outside the garage reveals a freshly broken tree limb: we've got our third data point!

I'm really sleepy after all that outdoor work in the fresh air, but when we get home I enter all the data into a CAD (computer aided design) program that came with the desktop computer. In each case we end up with x - y coordinates of three data points and an angle: the first point is defined as zero-zero (the *origin*) and the other two points go up and to the right in a positive direction. Finally, we adjust each of the angles relative to our local magnetic north.

Now comes the really interesting part – I get out my Algebra book. Given three data points on each of the three parabolas, I set up the systems of three equations in three unknowns in each case and solve them all. Now each the three trajectories is described by a quadratic equation. If the surrounding terrain is relatively flat, and each crime scene is at point $(0, 0)$, the other point where it crosses the X -axis should be the source of the projectile. Now I've got an angle and a distance from each of the three crime scenes to what I hope to be a single point of origin.

"Where's the map," I ask Dad. He pulls it out and lays it on the counter. We place a red dot at each crime scene's location and draw a blue line through each representing magnetic north. I carefully draw three red lines, one from each dot, at the angles relative to magnetic north that we calculated. (They seem to be converging, and that's a good sign!) Finally, I measure and mark off each the three distances on these lines.

"Well," I am happy to say, "they don't all end in exactly the same spot, but they do define a pretty small triangle." I outline the edges of our little triangle in yellow.

"I'll give Frank a call," Dad says.

Frank comes right over and we spend several minutes explaining the significance of that yellow triangle how we got it. "Wow," he says, "this is really impressive police work! Mind if I borrow

this map,” Frank asks. He heads out the door with it before we could answer, and Dad and I can only just look at each other and smile – and with some pride, I might add.

“That distant look means he’s on his way to the Station,” Dad says.

We don’t hear anything from Frank that night, but we assume he’s following up on our lead. He stops by Sunday morning to thank us profusely for our help. He sits down and joins us in a cup of coffee.

“They spent less than an hour cruising around inside that triangle,” he explains, “They found an old Civil War cannon in some guy’s back yard. It had been fired recently and a quick canvass of the neighbors confirmed that he has fired it a lot lately. Some of his neighbors even put the firing times pretty close to the three crime reports! He’s in custody, under arrest; he confessed pretty quickly when I showed your map data to him,” Frank added smiling.

“And you, young lady,” Frank continues, “are pretty impressive. I’ve got something for you to commemorate your first crime scene investigation.” He hands me a small gift box with the Chicago Police Department seal on it. Inside is a yellow lanyard with the words POLICE LINE DO NOT CROSS emblazoned on it.

“We have to wear our ID cards around our neck at school,” I tell him. “Wait till my friends see this!”

I spent that evening writing another paper. On Monday morning I drop it off in Mr. Paulson’s mailbox with a smile, and head off to class. That afternoon I find him reading my paper in his office. “This is... utterly fantastic,” he manages as I walk through the door.

“Using Algebra in Crime Scene Investigation,” he reads from the title of my paper, “You’ve made me very proud of you, Digit,” Mr. Paulson says, “I believe you *will* win that scholarship!”