ANALOG DRIVEN DEVELOPMENT

Harnessing the Conceptual Human Mind to Ensure Software Artifact Stability

Matthew James Swann, *Bachelor of Arts*

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Date of Graduation

PROJECT ABSTRACT

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Matthew James Swann, *Bachelor of Arts*

Directed by David Umphress, *PhD*

<insert meaningless summary here, good stuff comes later>

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**Chapter One – Introduction**

This document will explore the following perspective on software engineering: the discovery of a software solution does not necessitate the presence of a computer. Though the implementation of such a solution requires a machine, the software itself is a logic game. Control structures, loops, and Boolean variables are all evolutions from logic. Mathematical computation is based in logic and reasoning. And logic is inherently a mental game. As such, the totality of a software solution can be forged without a computer. Of course, the solution must be run on the computer to indeed be software. But the solution itself may be worked out in the natural continuous space venue of the conceptual human mind.

To validate what I have discovered, I will gather significant portions of my education and life experience. To prove computers are unnecessary to solve software problems, I must step outside of mainstream computer science thought. I will combine cognitive psychology, formal logic and current engineering practices to explain this mechanism. This document exists for the sole purpose of exploring the resultant. A combination of the arts and the sciences. A combination of creativity and structure governed by the laws of logic. A combination of my years earning a Bachelor of Arts and now a Masters of Engineering. The fusion allows for a stronger knowledge base than had I only studied one, arts or engineering. This is my work and this is my proof.

*1.1 – Of Predators and Prey*

The process of software development can be described as a game of cat and mouse; however, it is likely more similar to the struggle between the road runner and that coyote who ceaselessly blows himself up. Whether the developer has found the bugs or not, they do exist somewhere in the code. Known issues or bugs are still known instances of failure. Non-success in the realm of software engineering is a chronic illness more so than a temporary cold.

It is easy to see the potential for this struggle when one acknowledges both the human mind and the human capacity for problem solving are both analog in nature. A machine requires the rules of a digital world. The mind does not store information in bytes. A computer has no random thoughts, but uses procedural execution. Stream of conscious thought is flighty. The manifestation of action is inherently different between the mind and the machine. Modeling continuous space into a discrete digital realm is a difficult transaction. Considering their respective definitions, perhaps analog and digital play like oil and water. This realization does not permit this translation to be any more clear. Not directly. It may, however, be the most empowering consideration we as humans have in the fight to make computers behave.

Software development is a hunt. A hunt for the set of desired behaviors that will be evidenced by the machine. And the machine *must* behave is certain ways. The human is tasked with modeling the elusive behavior and ensuring its stability. And the hunt itself is consuming. It is important to remember the nature of the human species. We are a living, breathing, imaginative construct. We strive and struggle and cry. We find an obstacle and we have to climb over it. We want to win. By design, we have two lungs, two kidneys, a pair of eyes, and the instincts to eat and to procreate. We are animals. We are proof of life. We have so little in common with computers, our creation. Emotion and instinct bleed into the decision making process.

Even in our intellectual endeavors, we evidence animalistic tendencies. The hunt for a solution produces bio-physical responses. Like a lion trying to feed the pride, our hunt for answers causes our hearts to race, our breathing to change, our senses to sharpen. As he closes in on his prey, the feline can taste success. He can smell the prize. For humans, intellectual inertia torrents through the human mind as fiery blood courses though veins. We can feel ourselves approaching success. But even in moments of impending success, the desire result can evade our efforts. In a single moment, a minor misstep in reasoning can cause a major setback, leaving the human bereft of energy, dissatisfied and hungry. As humans, we might ‘*throw in the towel*.’ A machine will never ‘*call it quits for the day*.’

In order to better secure any target, humans attempt to refine their strategy. The refinement may originate from a desire to reduce requisite effort or to pursue perfection. One such software refinement takes the form of Test Driven Development (TDD). Further explored in section 2.1, TDD is a process by which tests for the software are written before the software itself. TDD was originally the brain child of Kent Beck. Ten years ago, Beck helped the software community refine development techniques by rearranging the software process itself. His argument: if we know what the software has to do, let us build the related tests first, then when we write the code we’ll know it is correct when it passes the tests.

Ten years ago, Beck asked and answered the question “How can we better set ourselves up for success?” TDD works. It would be disrespectful to say the process is old hat, but it must also be refined. It is time to stand on the shoulders of our patron to reach higher. In time, someone will stand on ours. For this is the nature of advancement. One day every action I now execute will be an obscene over usage of effort and every word in this document will be obsolete. I only pray that between now and then my efforts will help to set the table for those who come next.

The refinement I propose centers around a re-harnessing of the human mind. Beck attempted to make the process better by forcing the test code to come first. The tests are written before the source implementation. But Beck wanted to write one test at a time. And he did so using a computer. Analog Driven Development (ADD) will not write one test at a time, nor will it use a computer as a tool for algorithmic construction. ADD will resurrect old world engineering via pencil, paper and sketch books. The eureka moment occurs with frenzied hands scribbling notes ever attempting to keep pace with the mind. The search for the answer ends with an exhalation of relief. ADD will remind us of our human strengths. And ultimately, ADD will dispose of the unfortunate thought that curses the minds of our students.

“Listen, Timmy, you are going to have to learn to think like a computer.”

This sentence is nothing short of disrespectful to the power of the human mind. This suggestion in summary: take the most creative and forceful computing device we have at our disposal and make it work like a hunk of silicone manufactured by the lowest bidder. Do we need to *talk* like a computer? Yes, a necessary skill set. Understand how a computer *thinks* and how to efficiently utilize its hardware? Necessary skill sets. But to sacrifice our power, creativity and ingenuity in order to dumb ourselves down to the intelligence level of a non-conscious tool? Never. We are living creatures with inherent strengths. Our abstract thoughts, our ability to ponder in continuous space, our analog conceptualizations are how we naturally process information. We do not think in machine code. We think with symbols and representations. There is no resolution on the mental image of a chair. No refresh rate on our memories. No video card upgrade to make a mental image clearer. It just is. And that is what we are, thinking animals.[12] Our process for creation should be designed with this in mind. We ought play to our strengths.

Discussion now as to the merit of this mechanism is pointless. I will have to show you. I will begin my exploration with a dive into TDD, the nature of inquiry itself, and a discourse on the connection of language and concepts. Following, I will explore how these three venues assisted in the design off what has become Analog Driven Development. I will show the evolution of my test first practice from Beck’s own work. And, I will validate the practice through explorations of code repositories built using ADD. But first, definitions.

*1.2 – Definitions*

Before diving deeper into the substance of this document, it would be beneficial to establish meanings for the words that will be used herein. The following is not a set of meanings from industry or literature, though in most cases they closely match. The following definitions are precisely what is meant when the words are used.

*Analog* : involving continuous space; a ‘rule’; non-digital; the nature of a concept that does not yet exist in a manifested form; *i.e. the idea of a chair, any chair, versus the mathematical height and weight bearing properties of that object*

*Digital* : involving discrete space; an ‘instance’; non-continuous; explicitly manifested

version of a concept

*Inquiry* : the process of discovery, completed via novelty or an ampliative gain

*Production Code* : ‘source code’; executed code designed to fulfill requirements for a given project

*Programming* : the a process by which a conceptual abstraction is translated line by line into source

code

*Software Process* : methodology by which software is created in an intelligent, structured and

disciplined manner

*Test* : a mechanism for the atomic verification of a single unit of source code

*Test Code* : scaffolding by which production code will be measured and thereby verified

*Test Harness* : collection of tests, generally organized to match the package structure of a source

code itself

*Test Scenario :* a mechanism for the environmental verification of multi-component behavior

*T.D.D.* : Test Driven Development; a software development process employing a test first

programming strategy

*A.D.D.* : Analog Driven Development; a software development process originally fabricated

from T.D.D. in which complex testing scenarios are formally solved with the use of pencil and paper

A detailed breakdown of TDD can be found in section 2.1. The majority of this document enhances the above definition of ADD.

Highlighting the differences between analog and digital aspects is important for continuing conversation. Analog representations have meta-connections and conceptual implications that digital representations do not exhibit. [14] Justice, for example. A just action exemplifies what it is to execute justice; however, there is more to the idea of justice than can be fit into a single action. Justice entails a legal system, ideas as to fairness, religious connotation, etc. This is just a common set of American concepts that float to the surface of the mind when justice is thought upon. And this is the analog representation of justice. Thoughts of famous persons who have spoken on justice, things we have been taught about justice. The collection of our knowledge on the topic does not exist in any one story or example. Our human understanding of justice is an amalgamation of experience, time and exposure. And our analog definition of justice is further refined by digital manifestations. Such an example might be: upholding academic integrity. The distinction in based in the segregation of *idea* versus *example*; or, of rule versus instance. . Software too has analog and digital portions. This is seen in the design of a class structure and the impending instantiation of a discrete object; there exists a difference between the generalized concept and the specific version.

Humans were designed to execute action based upon a collection of information. Computers were designed to execute an action based upon what a variable means at a particular moment. Computers view the here and the now only. One single set of instructions to be executed right now under current circumstances with little or no regard for historical knowledge or future consideration. For the computer, the action has no place in a conscious history. Humans take more into thought. For a human, every action can become a memory, or a fear, or a hobby. Novelty can be attached to growth or self-degradation. For the human, concepts and thoughts are naturally connected. Computers must have a series of actions explicitly pre-determined as no action a machine executes promotes any cognitive inertia. This is the functional difference between analog and digital.

*1.3 – Future Lab : The Venue of Advancement*

Analog Driven Development was developed out of need in connection with the FutureLab Project at Auburn University. The project’s goal was to reversion a piece of educational science software for middle school students. The program contained several experiments that can be worked through; balancing a scale with weights or freefall from a platform. The benefactor, Auburn Engineering alum Walt Woltosz, ’77 Aerospace Engineering, donated the original FutureLab program. [13] FutureLab, as a piece of software, would undergo a rebuild from the ground up. The program was being moved C to Java and from mid-1990’s operating systems to the Android OS. FutureLab, as a project, would provide a number of challenges, the most pertinent of which required the design of a homemade physics environment.

The physics designed for FutureLab required that any object to be simulated also be mapped to a location within the designated simulation space, the container where the experiment takes place. This space is an abstract grid system layered on the pixel display of the Android screen itself. Each point within the grid system, a measurably discrete location. Points within the simulation space are combined with metadata into node structures. These nodes are connected via pointer chain creating enclosed shapes. Shapes congregate into the skeleton of simulation objects: a ball, a standard mass, a cannon, etc. Further data is combined with the shape: mass, labels, acceleration vectors. The laws of physics are recapitulated into mathematical functions and managed by event watchers. The watchers themselves are a set of reactionary algorithms that respond to physical events such as a collision. All of this taking place within an abstract grid system.

ADD evolved into a mechanism for stable software design, but it began as a resource for variable tracking. The development of tests for a system that models physics in an abstract space proved difficult. In order to keep track of the location of objects and their shapes within the simulation space, I began to sketch a blue print for each test. Engineering paper, rulers and a compass became power tools software construction.

**Chapter Two – Background**

Chapter Two explores the foundational elements encompassed by analog development. In terms of primary function, ADD is a test first design paradigm that evolved from Beck’s test driven process. ADD is also a process of intelligent discovery. Analog development, as mentioned above, was originally a product of need. However, as the development tool was refined, ADD itself was intelligently re-designed. It was crafted with acknowledgements as to the strengths and weaknesses of the human mind.

There are several building blocks for the analog process. There are two baselines, each representing a single thread of thought from a major field of study. The first baseline, test driven development, offers the primary goal of this effort: to improve the manner in which software is made. TDD also provides the scaffolding and organization for the analog process. This baseline originates in the field of engineering. The second major building block comes from cognitive psychology: inquiry ought to be precise and intelligent. The second baseline provides an understanding as to the author of the software. The third piece is a catalyst. Disciplined execution of logic will mix knowledge of engineering practice, software design and intelligent discovery. There are two premises: 1) thought takes place before speech; and 2) humans ‘*think*’ differently than machines ‘*think*’.

Analog development is made of all these pieces. The two premises will serve as a spring board into the mechanism’s very development. TDD will provide the *what* and the *why*. The nature of inquiry will provide the *how*.

*2.1 – Test Driven Development : The First Baseline*

Beck’s desire to overhaul the development process appears to stem from the work environment of a less disciplined era of software engineering. He references a time when testing was not a part of every team’s process. A time when a developer would have to wait through the night to see if the tests passed or failed. [2] Software development was not as comfortable as it is today. One primary issue was the human’s confidence in the software artifact itself. Testing and quality assurance practices were not as conversed as they are today. As such, the industry needed thought on how to improve quality.

A snapshot of the test driven development mechanism is as follows :

1. Make a test,
2. Run all tests; verify the new one fails,
3. Make a change to the source,
4. Run all tests; verify they all pass,
5. Refactor to remove duplication.[2]

This multi-step process is cyclically repeated. To build a new piece of source code, you must first have a test that fails because the source is not written; to build that test, you must first pass all other tests. This structure mandates stability. If the last function install fails the related tests, that function and the related test must be examined for defects before anything new can be generated. Also, if the last function install has a negative impact on other pieces of the software, running the entire test battery will evidence the problem. This structure provides a controlled development environment. Throughout his exploration of TDD, Beck identifies with the human side of engineering. He acknowledged his own humanity. He went so far as to say “If you’re upset, take a cleansing breath.” He then went on to explain how to do so. Beck understood the strain of a negative work environment. So, he supplied us two mechanisms for confidence and stability. The first, related to squelching emotional uncertainty by reducing the unknowns in an ongoing project; the other, a respiratory mechanism to calm bio-physical tension.

The test driven process itself is not complex. However, it can be tailored and is therefore flexible. Beck suggests one start small. Test for a class that has yet to be created. Fix the error by installing the class. Then test the constructor of the class to see if a certain value is set. Fix the error by going back and setting the value in the source. Each step has a small test for a small piece of code. As the developer becomes more familiar with the process and how they intend to self-tailor, larger tests can be written for much larger installations. These tests can be as small as an assertion on the return of a ‘getter’ function, or as large as the verification of output from a database query.

<*Inustry notes on TDD – one paragraph on use in industry*>

The process allowed for great strides in the development of quality software’ however, the mechanism has a greedy heuristic to the design. It is quite powerful, but places do exist for refinement. Most notably, TDD requires a certain amount of duplicative effort, “…speed trumps design, just for a brief moment.”[2] But this brief moment happens once per cycle. Long term design decisions do not receive immediate conversation. Alterations to existing code are a necessary evil. These tedious changes are the price paid for confidence and stability. Refactoring is a must. Common code spread across same depth in class structure ought to be transplanted to higher, more appropriate tiers. Support functionality that can be refactored often requires the generation of related tests. This upkeep is necessary and often temporally random in nature. And as such, emotional and intellectual flows of development can be turbulent.

When Beck moved test based activities to the front of the process queue, he overhauled the system. Traditionally, production code was written and then tests were created to exercise the source. But this organization also acknowledges a tenant of human behavior. We will always do what we have to do; we will not always do what we should do. The production code has to be finished. The test code does not. [2] If the test code is written first, it cannot become a cut-corner. Also, pre-emptive generation of test code would not be subject to the biases of having already written the source code which in turn would have to pass the tests. Test driven development also began to answer the question, “*When is this piece of software complete?*” Well, this small piece of code is done when it passes the associated test. The artifact itself will be complete when it passes every necessary test. By re-structuring the process, Beck gave us the ability to generate small milestones over the course of a large project. Creating an entire database takes time. However, creating one table or one query at a time lessened the emotional gravity of a long term project. That allowed for better focus. That is an example of understanding the human.

*2.2 – The Nature of Inquiry : The Second Baseline*

James Blachowicz, PhD, author and retired professor at Loyola University Chicago provides the necessary foundation for a definition of inquiry. In *The Nature of Inquiry*, Blachowicz suggested inquiry itself is a dualistic process that mandates “the partial generation from experience of ideas which come to explain experience, and the partial generation from ideas of consequences which come to match experience.” Blachowicz goes on to simplify this definition into a two-sided process involving both experience and thought. [1] One must be able to interact with the known portions of the problem while wrestling with the unknown portions. As the window of exposure to the object of inquiry is lengthened, conceptual understanding of the object is refined.

This dualistic consideration is important to the definition of inquiry as it contains the necessary pieces to solving a problem of any venue, engineering, mathematics, logic, etc. The need to solve a problem requires one to know various pieces of the problem while simultaneously not knowing the problem in some way. [1] (For Blachowicz, this is the first law of inquiry.) Strictly speaking the solution to the problem is unknown, and other pieces of the puzzle may also be obfuscated. Examples of obfuscation are: a variable’s behavior over time, or the effect of multi-variable interaction. However, a starting point is needed. The problem itself must have a definition. Without a bounding definition, no problem is resolved in an intelligent manner.

Accidental solutions may be discovered for various problems, but for the purposes herein the premise is that we have a specific software problem that must be solved. As such, there is a desired result and intelligent observation of the distance between the known position and the goal can be made. (For Blachowicz, this is the second law of inquiry.) This provides a means for intelligent inquiry. Spontaneous discovery and randomized creativity are outside the scope of this discourse.

Each piece of software that must be written is a unique problem requiring a unique solution. If a solution to a software problem already exists, generally the problem is not resolved again. If a program can be purchased for seventy dollars, it likely took more than seventy dollars of effort and time to produce that program. Reusability is a primary tenant of development. This focus has a twofold purpose. One, reusing existing code promotes confidence if the code is known to “work”. Two, reuse detracts from overall development time. Therefore, almost every software solution is a solution unique unto itself even if the uniqueness takes the form of refinement. Facebook must only be made once. The database aspect of Facebook remains the same from access medium to access medium. The rendering of that information may change from device to device, but therein lays a novel problem requiring a novel solution. The code executed by my Playstation when I load Assassin’s Creed is the exact code run by every Playstation when Assassin’s Creed is loaded on each gaming console. It would not be Assassin’s Creed unless this held true. It might be a second installment of the game. It might be a similar game. Metaphysically speaking, it would not be the same.

As each piece of software inherently contains the resolution to a problem, each piece of software necessitates inquiry. We must discover the solution to what it is we wish to build. Later I will discuss the location of problem resolution, but for now knowing we have a unique problem is sufficient. Above, I discussed the ability to simultaneously know and not know the solution to a given problem. Meno’s paradox suggests that this type of knowledge is impossible :

“And how will you inquire into a thing when you are wholly ignorant of what it is? Even if you happen to bump right into it, how will you know it is the thing you didn’t know?”[10]

Firstly, and necessarily, it may be impossible to inquire into a thing that one is wholly ignorant of, for how would one know to inquire of it in the first place? The act of inquiry inherently requires an object. For there to exist a predicate to the question, there must be an acknowledgement of that very predicate by the subject. Secondly, we are not inquiring into something we are wholly ignorant of. When solving a software problem, one knows what the desired result is. This follows suit with Blachowicz’s second law of inquiry. One also defines both the functional and aesthetic portions of the desired result. This knowledge can be converted into a first order map, a mechanism that intelligently determines a specific direction to head when traversing a problem. [1] (First order maps are discussed further below. For the time being, they can are synonymous with a plan, or a route from A to B.) The software developer also is well aware of several use cases or testing scenarios that must be passed before the software is completed. Behaviors have been explicitly defined to their end, but not means. This amalgamation of knowledge paints a picture as to what the desired result of the effort is. We know exactly what we want the end behaviors to be and we know how we want the software to look and feel. We do not know how we are going to model those behaviors, their actors or their user interface. We have simultaneous knowing and not-knowing.

Less amorphously, we have two points in a journey to solving a problem. The origin is the current location. The desired result is our expected location upon completion. Simply having a task necessitates that the current location and the goal are not the same. If one were where they needed to be, movement would be a divergence from the desired result. Consequentially, if we were to represent our current location in reference to our desired location in some measurable manner, we would be able to diagnose the differences between the spots. This is a first order map. This is the mechanism for defining the avenue from A and B. [1]

When Kepler began to search for the true orbit of Mars, he began by examining a large number of observations as to the orbital pattern of Mars. Kepler “knew” these observations were incomplete as there was no correct mathematical explanation for the orbit of Mars. The incomplete observations gave Kepler a springboard. He was able to compare his findings with those of others. Ultimately, he was able to resolve the mathematical explanation for Mars’ orbit by figuring out how wrong the current solution was. [1] The resulting solution bloomed from an understanding of what already existed. Known elements helped to prescribe the behaviors of unknown elements. The solution began to betray itself through the observations of the algorithm’s creator.

The definition of inquiry is: a process for intelligent generation of novelty. Firstly, known elements and unknown elements are segregated. Known elements are then reviewed in light of each other. As a conceptual understanding as to their whole is formed, the current assessment of the solution is compared to the desired result. The differential is quantified and systematically dissolved.

Intelligent discovery, the orchestrated removal of unknowns.

*2.3 – The Temporal Relationship of Thought and Expression : The First Premise*

Any expression that has not spontaneously occurred from the human must first have been a thought. A reflex is an example of spontaneous reaction from the physical body without premeditation. Story writing is not. Even if the story was written as a stream of consciousness, it must occur in the mind before the hand can begin to craft the letters representing the symbols which represent the concept that occurred within the mind. This is a necessary tenant of language; words simply represent ideas and concepts. [14] Concepts necessitate a symbolic representation to serve as a key back to that concept. Words themselves do not beget abstraction. Without expression existing within the confines of a mandated form, communication does not occur. The story of Don Quixote is not a Spanish story. It is a story written in Spanish. Had the author decided to write in Italian, the book would be in Italian. But the essence of the story would remain the same. Perhaps linguistic differences change small portions an event or two. However, the tale of the ingenious gentleman occurred in the mind of Miguel de Cervantes Saavendra before it occurred on paper. The story was not produced by an involuntary set of muscle spasms happening to manifest into one of the world’s literary classics. Spanish was the encoding language for Miguel’s imagination.

Consider the following sentences. Which two are most similar in meaning?

1. “sabe mas el Diablo por viejo, que por Diablo”
2. “the devil knows more because he is old, than because he is the devil”
3. “age breeds knowledge”

Although sentences 2 and 3 are in English and contain similar meaning, numbers 1 and 2 are translations of each other. By definition a translation is a representation of the meaning contained in one language, yet represented in another. Both 1 and 2 contain a force and vivacity that directly compares the Devil’s wickedness to his age in terms of each quality’s ability to correspond to garnered knowledge. Sentence 3 has no such comparison and is therefore the most dissimilar. This example promotes the conclusion that language itself is simply an encoding of a conceptually based idea. Though this example contains human-to-human communication in the form of spoken or written language, this analogy is also observable in congruent software architectures implemented in distinct programming languages. The backend for a website can be scripted in PHP, MySQL or Django while still containing the same database structure. A student versus teacher relationship can be modeled and keyed in any of these. The language itself does not open the door for communication. The language is nothing more than an aesthetic encoding. It is the medium of communication

As the software’s language can be reduced to a simple encoding scheme for a known solution; one can begin to equate the design of a software solution with a problem to be resolved by the conceptual human mind. It is in this realization that both power and flexibility are restored to the human intellect. The search for a solution is removed from the confines of computational logic and Boolean algebra. The assertive human is awoken by the realization that the fight has been revenued to the home field of continuous space analysis and playful tinkering. A decisive advantage. And the human knows the beauty of this advantage. Unbridled and rejuvenated, the human can attack the problem at will and without reservation. Once captured, the solution is transmogrified into the digital aspect of the chosen language, Java, Python, procedural C. The lines of code themselves will differ. Library imports and custom modules varying from implementation to implementation, but the solution will be translatable nonetheless.

*2.4 – Conceptual versus Mechanical Representation : The Second Premise*

In section 1.2 of this document, there exists a list of foundational definitions. Words that will be used repeatedly, many of which have evidenced already. For communication to take place, two humans must be on the same linguistic page. The suggestion here is that the verbal and visual symbols of the language must be the same for two people to communicate.[12] If I say “dog” and you think “cat”, there is a problem. One individual might define programming as: “messing around with code until it works” or “writing software”. These two ideas could be seen as similar, or vastly different. “Messing with code” *could* be analogous to refactoring, reworking a database schema, or removing a bug. “Writing software”, could be an entry level person working at Microsoft, or a student completing ‘Hello, World!’ for the first time. “Writing code” and “engineering software” should never be equated. The act of writing is simply the execution of a detailed intellectual endeavor. However, not many have proposed that software development is nothing more than a line by line translation of a basic logical solution that ultimately requires a computer for manifestation. Had I not explicitly set forth my definitions, you would be using yours… would you not? And that could be a problem. It is my duty as the communicator to ensure I am as precise in meaning as possible. By giving you my definitions, I have avoided large missteps in the conceptual mapping of the visual and verbal symbols we call words. The odds for successful communication have sky rocketed. Hopefully, there has been normalization in connection with the pairing of words and their associated mental images.

Back to the machines. Consider the following line of code :

int x = 4 ;

This assigns the variable ‘x’ with the value four. Where ‘x’ exists in memory contains a value of ‘4’.

long x = System.currentTimeMillis();

This assigns the variable ‘x’ with the current system time as a ‘long’ which is simply a digital reservation for a number.

for current\_student in Students.objects.all( ):

print current\_student.unicode()

This grabs every student in a database and prints them out based upon a unicode encoding. These lines of code have no relation to each other. But they have something specific in common. They will each do exactly one thing. If a programmer in Spain wants to assign the value four to a variable named ‘x’ in Java, there is one way to do it. Java asks the operating system for the time in one way: System.currentTimeMillis(). A human can ask for the time in many ways: *what time is it?*, or *do you have the time?* Though the question, “Do you have the time?” is a yes/no question strictly speaking. The responding human will generally give you the time, not just look at their watch and say “yes”. Humans understand what is being asked based upon context. Machines do not have this ability. Therefore, a database query will always query the same data. They only do exactly what you tell them to do. They only answer the questions you explicitly ask.

It is possible to design duplicative functions. It is indeed possible to have two different mechanisms for the same input and output pairing. However, there still exists a one to one relationship between the input and the output. One knows explicitly what they should receive as output. This is the very nature of an API. Having erratic behavior is considered a bug and bugs must be expunged. Proper behavior, the way computers *must* behave, has one explicitly designed input for one explicitly designed output.

Now, we have explored the explicitness of programming languages, does that not make them a better tool to solve computational problems? If the computer takes one input and produces a single trustable output every time, is that not better than starting a conversation without even knowing what someone might mean when they use a certain word? A logical objection, but no. A human can look at three apples and divide them among three people. A human can experience the number one-third conceptually. One-third of the pile is given out to each person. A human can visualize one-third of the original pile in the possession of each of the three people. They can see one-third of that pile. A computer has no ability to experience and no ability to accurately represent one-third. Floating point arithmetic is powerful. But let us breakdown those very words: ‘arithmetic’ and ‘floating point’.

*Arithmetic* : the branch of mathematics dealing with the properties and manipulation of numbers.[11]

*Floating point* : denoting a mode of representing numbers as two sequences of bits, one representing the

digits in the number and the other an exponent that determines the position of the radix

point[11]

*Sequences of bits*. This mathematical operation transforms a number, inherently an abstract conceptual mechanism for measurement and counting [12], into a sequence of bits. Computers have finite memory and finite bit reservation for numeric storage. Therefore, a sequence of finite bits will not be able properly represent one-third as point three repeating, 0.333333 ad infinitum. Does this cause a lack in precision that is noticeable? Yes. Banking software consistently wrestles with rounding issues. Flight simulators may be able force a training pilot to experience a simulated emergency. However, the pilot’s life is not actually in danger in the simulator. The *real* experience is not properly mimicked. This is not a discourse on emotional or psychological training. It is a note that computers do not always represent what it is that truly humans experience. The conceptual resonance of a one-third fraction contains the ideas of division and infinity. The digital representation of a one-third fraction, by definition, is a sequence of bits. There are no conceptual links between 1’s and 0’s. This implies a fundamental difference between machine and human processing.

Looping back to the most recent objection, is it not better to just work in a computer’s digital set of rules? No. Most recently, it has been discussed that computers are not always *able* to represent the reality of a concept. They are also not always *designed* to represent reality. We could build a flight simulator that kills a pilot if he or she does not act appropriately. But we do not. Machines also do not encode ideas with conceptual bridges. A computer will not understand an analogy. A complier cannot say “I bet the human meant to make this Boolean true and not false. Silly human. Let me fix that.” There has been a discussion as to the nature of implication and how it affects the similarity between statements. And there has also been an exploration as to the difference in intellectual capacity of humans and computers. A computer cannot create. A machine cannot ponder, nor argue. It can only calculate by the rules we give it. We are imperfect creatures that produce less perfect creations of our own. Engaging a problem by the rules which we teach our less perfect creations seems a bit unwise from a gut reaction. Though, the option is appealing because it appears to simplify the problem.

“*I just need one line of code to print something I think. Let me start printing things… now where’s that line of code? Wait what am I printing again? Should I string literal or just string variable?*”

This stream of human consciousness evidences digitally effected thought. No civil engineer allows the construction workers to begin building until she knows where every piece is going. The conceptual design of a hospital, the theoretical mathematics of beam structure, and the aesthetic placement of non-functional accoutrements are all formally in place. And this is done before ground break. Likewise, the software solution can be discovered before the programmers show up to install it. Beck’s test driven development was a major step in this direction.

ADD will not create small unit tests. ADD sketch entire classes, sub-packages, even full packages of source code. Large portions of development time are spent with a pencil and paper. Not as many long days with eyes bloodshot and tortured by computer monitors. Not as many frustrating moments implementing an intra-process design scheme.

**Chapter Three – Implementation**

Ultimately this chapter will explain the step by step process of analog development. This chapter will explore promised mechanism capable of designing and verifying large piece of software without a computer. First, the baselines for the mechanism must be revisited. The background for each field has been put forth. Now we must grab the specific pieces needed to build the new process. TDD provides the ending goal and the base structure. Cognitive psychology provides acknowledgement as to our inherent strengths and weaknesses. Reasoning will marry the two.

*3.1 – TDD Influences : Similarities and Differences*

Analog development borrows significant knowledge from Beck’s test driven process. A number of similarities are found between the two methodologies. The primary goal of the each mechanism is the same: to produce stable, reliable and clean code. The aesthetic structures of both processes look similar in their coded forms. However, the step-by-step processes of the mechanisms vary to a large degree.

Each software test created using these methods contains the same three building blocks. The first similarity is the arraignment of objects to be exercised by the test itself. This is set of objects and data structures. This group of actors is called ‘the setup’. The second commonality is the behavior being tested. This can be referred to as the target behavior. This can be a script, a formal function, a database query, anything that encapsulates machine behavior into a custom call of some kind. Lastly, the assertion of the behavior is a part of every test. Ultimately, the purpose of the test is to ensure a behavior is being executed and that the resultant is appropriate. One example might be to ensure a mathematical calculation produced the proper product. Or, that a database query fetched the proper data entries.

The test suites created from TDD and ADD are also aesthetically similar. The organization of the suites themselves reflects the package structure of the source code in both instances. A database which models an academic environment will have an individual package for the human classes and tables: students, professors, administrative staff, etc; while another package exists for the modeling of courses, majors and degrees. Each of these packages will have unique test suites that internally organize and breakdown classes into atomic behaviors. The greater test harness for the entire artifact is comprised of these package specific suites.

The differences between ADD and TDD begin to evidence when the immediate purpose of each method is explored. TDD does not strive for perfection, and TDD promotes speed and simplicity over performance and accuracy. Beck himself admits such. [2] As such, TDD requires a number of ad hoc repairs to both test and source implementation over time. ADD attempts to answer every question as to every component and behavior before any code is written. As such, ADD requires very little upkeep in terms of modifying code so long as the design appropriately matches the requirements of the project.

Beck suggests that in the natural course of TDD “one cannot rely on the idea that appropriate flashes of insight will occur at the appropriate times.” This is true. Temporally harnessing insight is not practicable. As such, TDD ventures forth making the best decisions that can be made at the time and writing the line of code which seems most appropriate. ADD attempts to write no lines until the unknowns are resolved. As such, ADD has a significantly strong focus on design work. ADD attempts to kick start flashes of insight through problem dissection. In turn, ADD requires and yields a deeper understanding of the greater system.

The measurement of the numerical difference between the two becomes difficult to calculate. The obvious question, which is faster? Firstly, ADD designs, tests and implements in much larger chunks of code and time than TDD. Properly dissecting the time needed for each phase within the larger pieces that ADD tackles, is possible over several experiments, but both tedious and delicate. However, the benefits of in depth design and test documentation are difficult to quantify, as are the benefits of dividing a complex problem into two more distinct problems. In the case of FutureLab, ADD was developed because TDD was insufficient in terms of the ability to track variables. Building an environment that calculated collisions of organized pixels with individually representative mass values on a synthetic grid system required a test driven process that relied on design work. Too much to keep straight in the mind at one time. So the system was drawn. For now, that acknowledgement will suffice as the strongest indicator of ADD’s value. A tool that successfully allowed an engineer to escape a cognitive limitation: simply keeping all the variables straight.

*3.2 – Influence of Intelligent Discovery : First Order Mapping*

Section 2.2 introduced the idea that the analog solution to the software problem would be a map, a first order map. The first order map, as defined by Blachowicz, is a mechanism that intelligently determines a specific direction to head when traversing a problem. This map is built from the human’s conceptual understanding of the problem’s variables. In inquiry, this map is rather dynamic in nature. Information is collected over time. A growing knowledge base of the problem’s input variables will change the landscape of the known problem. Second and potentially third order maps are needed for dynamic problems. In this instance, there exists a very well defined first order problem for a static problem: a given software product needs to be manufactured and someone knows what it should do. The problem is, “*How do I get that guy’s idea out of his head… and into that phone?”* Unless the desired behavior of software changes, the first order map can be created just once.

One elicited, the requirements of the project are transformed into test cases. This process is further detailed below. The source code must ultimately pass each test case, though the form of the code is currently unknown. This ties back to the first law of inquiry: *knowing while not knowing*. A sketch of the resolved test cases for a sub-set of the code provides the first order map. This sketch is a conceptual encoding of the problem space and gives an arguably *digital* resolution of a singular instance of the greater system behavior. This ties back to the second law of inquiry: *determining proximity to the target*. If one were to create an instance of a database that contains known data, then that individual could:

1. Design a query;
2. Resolve the query against the testdata by hand;
3. Encode the test into the test suite;
4. Write the source; and,
5. Compare the return of the implemented query to the ‘by-hand’ solution in the test.

The map’s integrity is verified by implementing the source code itself to a passing state. If the test code is translated from a sketch of the solution space, which is in turn reflective of the desired behavior of the end game software, then one can be confident that the source acts as intended if it passes those tests. Each time a new test is passed, ampliative knowledge of the software solution has been garnered. The avenue to achieving a particular behavior is now known because the tests created to ensure the behavior have been passed. The developer can intelligently discover the solution. The definition of intelligent inquiry has been preserved.



Figure 3.1 – ‘Analog’ Aspect of test\_collision\_31\_01\_00\_check



Figure 3.2 – ‘Digital’ Aspect of test\_collision\_31\_01\_00\_collision\_check

*3.3 – The Analog Process : A First Pass*

Software development requires an understanding as to how the individual pieces of the project will interface. Having a collection of code segments that work independently, but do not work together is unacceptable. The analog process conceptually unites individual modules and components into a global picture; the forest through the trees. This is accomplished by creating a visual solution. This section will explore the creation of such a solution.

Analog development entails the following steps:

1. Escape technology;
2. Intellectually prepare;
3. Sketch the problem and a potential solution;
4. Repair the solution; and
5. Pseudo-Code the solution.

In order to illustrate these steps, an example from FutureLab is explored. The visualization was drafted to depict the algorithm created to check for collisions of shapes within the simulation grid. In FutureLab, each object within the simulation space has a shape. That shape is used to determine the boundary of the object. Collisions are detected by determining whether or not one shape has touched another. The sketch above, in Figure. 3.1, shows a number of individual use cases:

1. Homogenous collisions (*i.e. Circle vs Circle, Square vs Square*);

*(seen in the Alpha and Beta circle interaction and the Delta and Iota square interaction)*

1. Heterogeneous collisions (*i.e. Circle vs Square*); and,

*(see in the Alpha and Delta circle-square interaction)*

1. Non-collisions.

*(see in Eta and Gamma which sit off to the sides not interacting with other shapes)*

Figure 3.1 has a significant amount of information. First off, the top right corner of the document contains the test scenario’s date of creation and name, test\_collision\_31\_01\_00\_collision\_check. The top left of the page contains collision types by shape: those involving circles and those involving squares. The central portion of the page depicts a *potential* state of the physics simulator itself. Each shape has a name and a location. And each can be seen to touch, or collide, with various other shapes within the sketch. The FutureLab software must be able to resolve this state should it exist within the simulation space. If three circular and three square objects existed within a simulation, the software would have to be able to resolve any collisions. The algorithm used to check for collisions *must* be able to resolve the instance of state depicted in Figure 3.1. The formal test created from this visualization can be found above this section in Figure 3.2.

*Stage One – Escape Technology*

Stage one immediately addresses the nature of software’s author, a human, a thinking animal. Humans are habitual creatures and software developers spend significant time in front of a keyboard. It is easy for a developer to jump to a computer to “*check something*” during a design meeting. A natural tendency exists to spontaneously seek verification through a tool humans are familiar using. This stems from an emotional trust in the machine. In order to remove this crutch, it is easiest to move away from the computer altogether. Let there exist no digital temptation.

*Stage Two – Intellectually Prepare*

The second stage can be ritualistic. Psychology has proven that working in a single environment improves recollection. A student taking an exam in the room where lectures were given has a greater capacity to recall pieces of information that are difficult to recollect. Unifying environment with intellectual work or practice has beneficial side effects. This stage can be executed as part of a weekly or daily schedule. The purpose here is to begin churning cognitive inertia. This can be accomplished through several means, or a combination thereof: review of pre-existing design documents, review of meeting notes and sketches, or mentally walking through the requirements for the given package. Even a simple phone call to a fellow developer to ask for clarification on a feature can begin to build intellectual steam. This preparation is synonymous with an athlete stretching before a game.

Proper preparation requires the developer ask two questions. One, “*What am I building?*” In this instance, an algorithm that will check for collisions within a simulated physical environment. Two, “*Why am I building this?*” This particular algorithm was needed in order to collect information regarding which objects were colliding. That information will be turned over to another algorithm that executes the necessary calculations of impulse acting on objects found to collide with one another. The collision\_check function has a specific purpose: to ascertain which objects are colliding with which other objects. Nothing more. Nothing less.

*Stage Three – Sketch the Problem and the Potential Solution*

Stage three requires that the developer sketcher the problem into a solution. In this stage, the developer will take up pencil and paper and draw the answer to the problem. Returning now to Figure 3.1, this test scenario attacks the use casing associated with checking for collisions. The use casing requires: 1) collisions between shapes of the same class; 2) collisions between shapes of differing classes; and 3) non-collisions.

As givens, there exists a class representing a Circle, a Square and an abstract-class representing a generic event within a physical environment. This abstract-class is the Event\_Interaction class. The Collision Event has been scheduled to derive off of Event\_Interaction, and as such will inherit a method to check the simulation space for the particular event. In this case, the collision\_check method will look for any collision. The Circle class is an aggregation of data: a central point where the object is fixed on a grid system, a shape with a radius, and some miscellaneous fields for user interface display and other administrative purposes. The Square class is quite similar, both being derivatives of a higher level Shape class.

Before a resolution of collision state can be crafted, an instance of colliding objects must be depicted. First, the grid system is marked off on engineering or graph paper. Arbitrary values may be applied to the grid. However, having the origin near the center of the paper promotes simpler math by hand. Circles can be drawn on the paper in such a way that they collide (*Alpha vs Beta*). Their positions are determined by their locations on the grid. Other shapes are drawn to collide (*Delta vs Iota*). *Eta* and *Gamma* are not colliding with any other objects but represent non-collisions. The collision\_check algorithm must properly flag *Alpha* and *Beta* as colliding, but not *Alpha* and *Eta*. When crafting the sketch, it is beneficial to depict as many use cases as practicable for the size of the canvas.

*Stage Four – Repair the Solution*

Stage four mandates a review of the initial sketch in light of the project requirements through the use cases. Various sketches may be required to depict all use cases. However, each use case must be accounted for within the set of visualizations. If a use case has not been translated into visual form (*i.e. a collision between a circular object and a square shaped object*) then this interaction must be drawn.

There are two purposes to stage four. The first is to ensure requirement coverage. The second is perform a moment of self-reconnaissance. Stage three requires the depiction of the problem space as it is currently understood by the developer. Stage four requires that the initial depiction be repaired for any missing considerations. The developer is able to gage their level of comfort with the problem. The transition from phase three to four allows one to determine any discrepancy from their current knowledge base to the one they ought have.

In the instance of collision\_check, heterogeneous collisions are important. Had the collision between *Alpha* and *Delta* been missing from Figure 3.1, such a collision would need to be created within the sketch. A review of use cases will determine the completeness of the set of visualizations.

*Stage Five – Pseudo-Code the Solution*

Stage five begins the transition from human thought to machine code. The algorithm crafted to check for collisions within FutureLab must be able to pass every collision instance drafted as a test. The conceptual logic for the algorithm can be deduced directly from the sketches. A collision will not occur between *Eta* and *Gamma* because they do not touch. However, a collision will occur between *Alpha* and *Beta* because they do touch. The properties of the shapes themselves begin to betray the solution into light. In the case of two Circles, if the distance between their central points is less than the combined length of their radii, then a collision has occurred. If a Square is involved in a potential collision, one of its vertices may be inside of another shape (*i.e. the bottom-left corner of Delta is currently inside of the area contained by Iota*).

An initial draft of the algorithm might look like:

1. F(x) collision\_check( Shape shape\_one, Shape shape\_two )
2. bool result = false;
3. if shape\_one == shape\_two:
4. // do nothing, identities are not collisions
5. else if shape\_one && shape\_two are Circles :
6. distance = calculate\_distance( shape\_one.location, shape\_two.location )
7. if distance < ( shape\_one.radius + shape\_two.radius )
8. result = true
9. else :
10. for each vertex of shape\_one :
11. if the vertex is inside shape\_two :
12. result = true
13. return result

Figure 3.3 – Pseudo-Code for collision\_check

This first pass of pseudo-code will often be incomplete. However, it can be amended in time. The purpose of drafting this algorithm is to peek at what support pieces are needed. It is non-consequential to have a ‘java’ or ‘python’ version of this algorithm. For the time being, the flow of logic and data is important. Understanding what support functionality will be required opens a semi-recursive dive into the nature of the greater system. As will be discussed later, this particular dissection can lead to pre-emptive refactoring.

Before the first draft of the collision\_check algorithm, the developer may or may not have known that determining the distance between two points was a necessary sub-routine of (*line 5 of the above*). The developer may not have realized the need to have a sub-routine check for the presence of a single point within another shape (*line 10 of the above*). These support functions can be visualized as well. Figure 3.3 shows the depiction of the algorithm which checks whether or not a given point exists within a shape. Figure 3.4 is the digital aspect of 3.3. These can be found at the end of the next section.

Within Stage Five, the ampliative nature of analog development can be witnessed. As one problem is solved, others come to light. The generalized function designed to check for collisions needs support that the developer was unaware of before exploring the problem. The knowledge gain associated with the functionality of the software itself can take a on a life of its own. As the pseudo-code for a given scenario is written, the human can begin to sketch the support functionality. Or, whatever greater function will use the currently drafted algorithm. Conceptual granularity can take either course.

*The Aftermath*

Aftermath includes the activity of translating the sketches into encoded test scenarios. Nothing of consequence will be added to the *intent* of the sketch, which is to resolve a given instance of a collision. The test will carry the same *intent*, to resolve an encoded version of that very instance. The *digital* aspect of figure 3.1 can be found in figure 3.2.

Secondly, this involves the creation of production code to pass the newly drafted test scenarios. The purpose of analog development is to create a robust test harness that sufficiently exercises project uses cases. The custom test environment exists as a digital scenario to be resolved by source code. Assuming proper encoding of the test sketches themselves, code that properly resolves the digital scenario confidently meets the requirements of the project. This is because requirements have been transformed into explicit use cases, each use case has been transformed into a piece of a test. Passing the tests passes the requirements.

Within this final phase, it is possible that defects in the sketches will evidence. Missing or incorrect considerations require the sketches themselves to be amended along with the encoded test scenarios. This is often due to an error related to project requirements; not having them all, not understanding them correctly, etc.

*3.4 – The Analog Process : Secondary Discovery*

Section 3.3 details the breakdown and design of the collision\_check algorithm. Stage five yielded a pseudo-code necessitating a function that would determine if a given point was within a given shape. Singular points within FutureLab are represented as Nodes. The Nodes are a container class that aggregate x, y, and z location coordinates and also have a pointer to the next Node along the outside of a Shape. As such, Shapes are comprised of Nodes. Each polygon contains a chain of Nodes enclosing a given area of space between the locations of each point stored in the Node. If an area is encompassed by more than one Shape, a collision is present. For polygons, an iterative check of each Node’s location will determine if there is overlap. If any point of a Shape exists within another Shape, there exists a collision. The acknowledgement as to the need for this support function is secondary discovery.

The algorithm designed to determine if a single point was within a Shape is called point\_inside\_shape. This support function was designed to yield a Boolean return reflecting whether or not a given point existed within another Shape, and in turn if a collision had taken place. The function required resolution to the following use cases:

1. Does a point exist within a Circle;
2. Does a point exist within a polygon; and,
3. Does a point exist within an aggregate of Shape, a combination of Circles and polygons.

As such, a test scenario was designed with the following:

1. Two distinct Circle objects;
2. Two distinct Square objects;
3. Two distinct Rectangle objects;
4. A complex object made of a Circle, a Square and a Rectangle; and
5. Five distinct points.

The point\_inside\_shape function would have to determine for each point if it existed within each Shape. A review of Figure 3.3 indicates that each point is within a given Shape, but no point is within all shapes. The resulting test in Figure 3.4 shows how each point was checked against each Shape.

The pseudo-coding stage for this algorithm did not indicate the need for additional support functionality. As such, this phase of secondary discovery came to a close. And as the design of collision\_check required no additional support, that process also came to an end. However, should either have required further logic, secondary discovery would continue until the atomic pieces of logic were defined.



Figure 3.4 – ‘Analog’ Aspect of test\_collision\_25\_01\_00\_point\_inside\_shape



Figure 3.5 – ‘Digital’ aspect of test\_collision\_25\_01\_00\_point\_inside\_shape

**Chapter Four – Validation**

Analog development has been found to result in a rich understanding of the software artifact. The visual representations allow the developer to tinker with a potential state of the software and logically resolve same. However, analog design goes further than simply providing a conceptual interface between the human mind and the machine. This process has been advantageous in the design of class hierarchies. Detailed in section 4.1, analog development facilitated the design of a single abstract class and its three derivations. This mechanism was also found to assist in the design of flexible test scenarios and code implementations. The related exploration takes place in section 4.2. Additionally, the analog process allowed for a logical stress test. Section 4.3 discusses how the process was used to explore the logic path limitations of FutureLab’s collision\_check algorithm.

*4.1 – Class Normalization & Multi-Layered Design*

FutureLab required a plurality of wall-like structures that served as barriers within the simulator. Three barriers were designed each with different functionality. Figure 4.1 depicts the visual and functional requirements for each Barrier type. Figure 4.2 is a listing of the subsequent class organization. This section will detail the design process for the Barrier\_Event class and its descendants.

The project requirements mandated three specific Barrier behaviors. Each class was sketched and given a temporary name for the design phase. These names were later amended for clarity and meaning. The specific behaviors of each are listed in the table below.

|  |  |  |
| --- | --- | --- |
| *Name in Figure 4.1* | *Implemented Class Name* | *Functionality* |
|  Barrier | Bounce\_Barrier\_Event | Objects colliding with this Barrier should bounce backwards.  ( *i.e. A ball hitting the ground should bounce back into the air*) |
|  Barrier | Pass\_Through\_Barrier\_Event | When an object’s center point hits this Barrier, it should be reflected across the simulation space.  (*i.e. A ball hitting this wall would wrap around the environment to the other side.*) |
|  Barrier | Non\_Render\_Barrier\_Event | When an object hits this Barrier, it should become invisible and no longer be rendered by the Android device.  (*i.e. A ball escaping the current view port of the simulation space would disappear from visual processing, but continue being evaluated for collisions, etc.*) |

Table 4.1 – Barrier\_Event Class Breakdown

Visual depiction of the requirements evidenced a number of similarities between each of the Barrier classes. Each would rely upon an enumeration of planes: to which axis the Barrier itself was aligned. Each Barrier also required localization upon that axis. Additionally, enumeration was required to determine the direction the Barrier faces. For instance, a Non\_Render\_Barrier should turn off visibility for an object that exits the simulation space that the Barrier encloses; however, it should return that object to visibility should it pass back inside.

Each Barrier required a specific algorithm to check for an interaction and subsequently engage behavior. Each Barrier was derived from a generalized Barrier\_Event class that contained the above common functionality. The Barrier\_Event class itself was a derivation of the Event\_Interaction class, which was also the parent class for Collision. Being an abstract class, Event\_Interaction required decedents to implement functions for *check* and *execute*. As the Barrier\_Event class was not designed for instantiation, it was also made abstract. As a result, each Barrier type would be required to implement the *check* and *execute* functions. By design, these were the only two requirements for the specific classes. They contained no other significant differences. Analog design assisted in pulling all duplicative fields and behaviors into an umbrella class. This normalization was resultant of forethought.

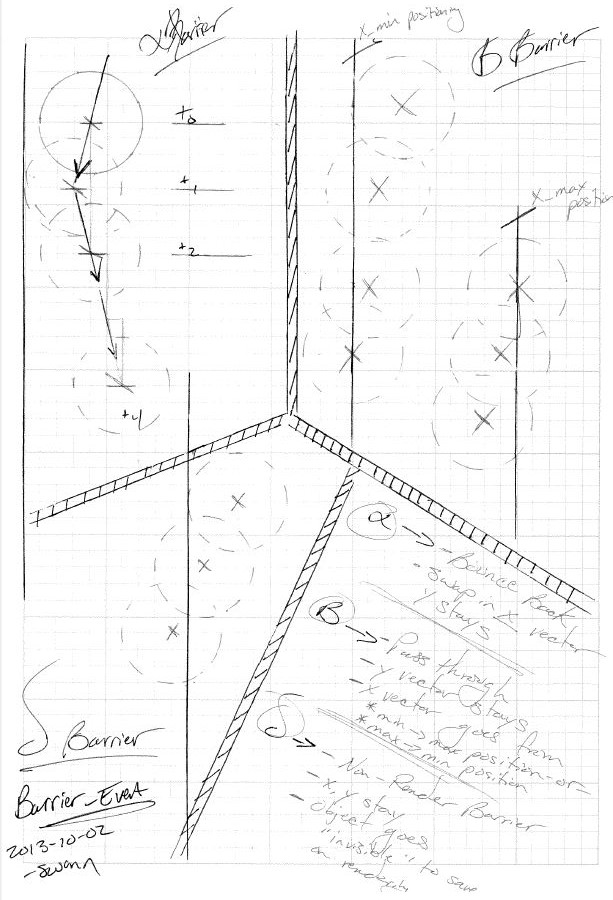


Figure 4.1 – Barrier\_Event Behavior Mapping

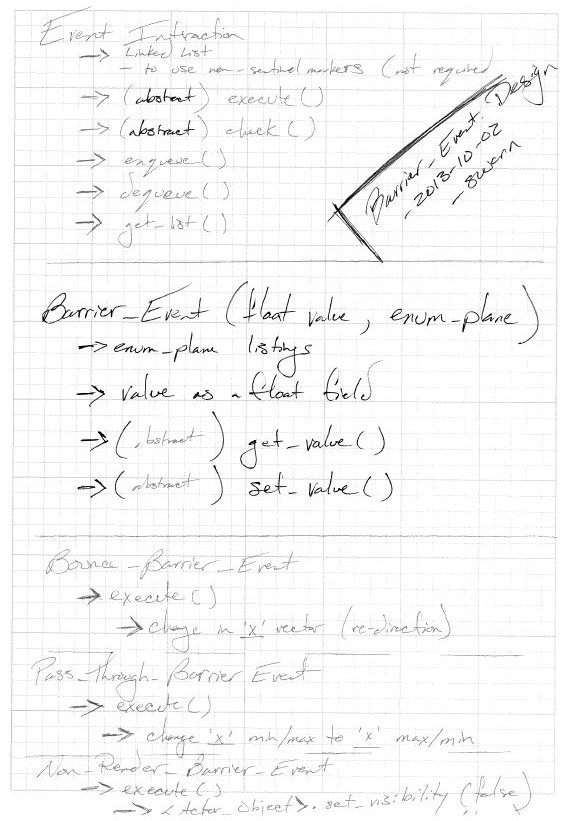


Figure 4.2 – Barrier\_Event Class Notes and Sub-Class Notes

*4.2– Relative Math & Test Scenario Flexibility*

A particular point of discomfort in software development is process of adjusting tests when requirements change. This often results in a need to either restructure tests or recalculate expected outcomes. The effort needed to make these adjustments would have been unnecessary had the change not occurred. Understanding the proportional mathematics behind a calculation, if such a relationship exists, can ameliorate the situation.

Figure 4.3 depicts the design of a Drop\_Tower and an associated Swing\_Arm. A Drop\_Tower is a simple structure with an attached platform, a Swing\_Arm, which is designed to allow objects to rest upon it. Given a trigger event, the Swing\_Arm will drop allowing gravity to enact upon any objects once atop the tower. The Drop\_Tower and Swing\_Arm classes were designed to co-exist. As such, analog design was used to explore the proximal relationship between the two objects.

As can be seen in Figure 4.3, the Drop\_Tower itself has a central location at a given x, y coordinate pair. The related Swing\_Arm is situated off to the side of the tower with a central location of its own. Any function called at runtime to create a Swing\_Arm off of a given Drop\_Tower would require a dynamic look at the Drop\_Tower’s location in order to determine the proper placement for the Swing\_Arm. Any change to the sizing of either the tower or the arm would require revisiting the math which calculates the center point of the Swing\_Arm.

Resolving the problem began by designing static variables to represent the height and width of each structure. Static variables were appropriate as FutureLab did not require various sized towers.

|  |  |  |
| --- | --- | --- |
| *Component* | *Variable Name* | *Variable Value* |
| Drop\_Tower | Tower\_Height | 20 |
| Drop\_Tower | Tower\_Width | 5 |
| Swing\_Arm | Arm\_Height | 3 |
| Swing\_Arm | Arm\_Width | 5 |

Table 4.2 – Static Values for Drop\_Tower & Swing\_Arm Classes

The explicit math on this scenario is embedded within the below figure. A simple triangular relationship is seen. Given values from Table 4.2 and an (x0, y0) coordinate pair of (10, 15) for the center of the Drop\_Tower, a Swing\_Arm should be created at (x1, y1) coordinate pair (15, 23.5). This offset location is found in two steps: 1) the *x* differential is a sum of half the tower width and half the arm width; and 2) the *y* differential is the difference between the half the tower height and half the arm height. As a formula, the (x1, y1) for the arm’s location:

This formula was implemented within the function which created a Swing\_Arm adjacent to a Drop\_Tower. It directly pulled the static values for the sizing of each object. The related tests also calculated their outcomes by accessing these static values. As such, regardless of how many changes were made to the sizing of either object, the Swing\_Arm would be created flush with the top of the tower and off to the right due to the implementation of formulae. Also due to the use of this relative math, test scenarios can be run and immediately passed as they call the same accessor methods. A change in requirements regarding the size of either structure would only require the update of a few values. The flexibility of logic handled the rest.

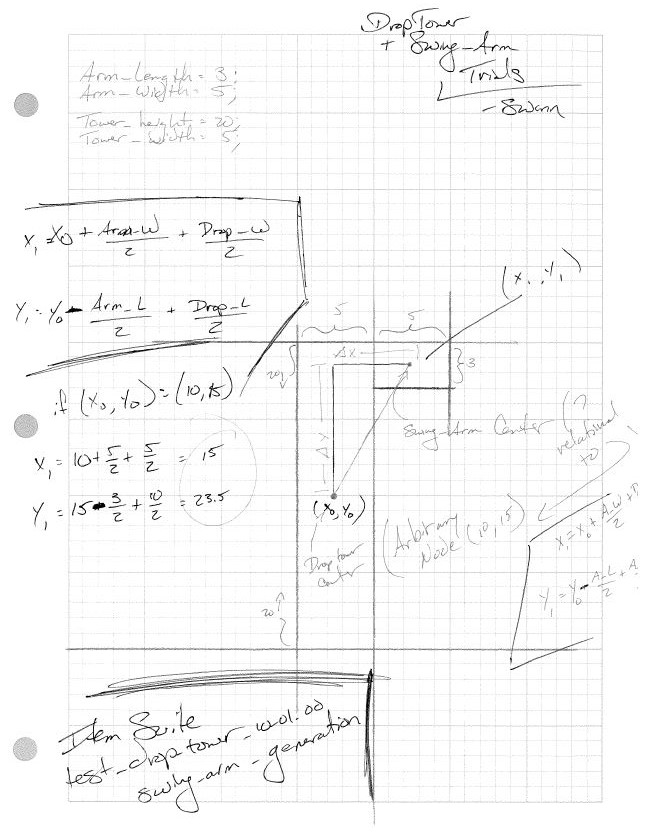


Figure 4.3 – Relational Math Exploration

*4.3 – Self-Reconnaissance & Won’t Fix Designations*

It is not practicable to design software in such a way that no bugs exist within the artifact. Algorithms may indeed fail for requirements outside of the project scope. There exist too many logic paths and too many scenarios to perfect each algorithm outside of intended use. The goal of software development is to create a code base that passes the project requirements, not a code base the handles every imaginable scenario. Though these two may coincide, often they do not. And though the developer may not be responsible for the creation of code that passes use cases outside of the project requirements, knowing the limitations of the system has significant advantage.

In order to explore the true limits of the collision\_check algorithm explored in section 3.3, a test was created that contained aggregations of complex shapes that were not designed for FutureLab. Figure 4.4 depicts the related test scenario. The depiction has numerous simple shapes, those with just one instantiated shape. These are all named after letters of the Greek alphabet. The complex shapes, amalgamations of simple shapes, were outside of project scope and are as follows:

|  |  |  |
| --- | --- | --- |
| *Complex Shape Name* | *Location ( x, y )* | *Aggregation Of <Shape> – <Type> at (x,y) – Dimensions* |
| Ares | ( 7, 3 ) | Delta – Rectangle ( 8, 3 ) – 2 x 14  Iota – Circle ( 5, 3 ) – Radius 3 |
| Durga | ( -4, 5 ) | Omega – Rectangle ( -5, 5 ) – 2 x 20  Omicron – Square ( -3, 4 ) – 8 x 8 |
| Hades | ( 0, -5 ) | Lambda – Circle ( 0, -7 ) – Radius 4  Mu – Circle ( -3, -5 ) – Radius 2  Tau – Circle ( 0, -3) – Radius 4  Theta – Circle ( 3, -5 ) – Radius 2 |
| Kali | ( 2, 7 ) | Alpha – Circle ( 0, 10 ) – Radius 4  Gamma – Square ( 7, 6 ) – 2 x 2 |

Table 4.3 – Complex Shape Aggregation for test\_collision\_30\_02\_00\_collision\_check

Though this *potential* state for FutureLab is outside of the requirements, a perfect collision algorithm would be able to handle it. The encoded version of the test does not pass to completion. It will fail. However, the resolution of each collision between simple shapes and the complex shapes designed for implementation within FutureLab do indeed pass. Those assertions which fail have been commented out of the test code and documented.

Dissection of the failures within this test scenario revealed that a logical error exists within the calculation of the boundary detection algorithm used as a part of the collision\_check algorithm. Specifically, if a complex shape is evaluated for collision it may return a false negative for a collision if the shape has a plurality of Circles. The external boundary of the shape is miscalculated to a small degree allowing for a collision to go unresolved. The margin of error is a proportion of the last Circle’s physical radius. However, FutureLab was not designed to contain objects with a plurality of circular components. This logic error is depicted in Figure 4.5 and has been designated as *won’t fix*. Should there be a change to the project requirements the bug is documented in the version control software used for the project, the design documents, and the code itself. A developer stepping into my place on the project would know exactly where and why the code fails sections of this test. This allows for expedited repairs on a known bug.

The data pulled from this test was primarily positive. The collision\_check function was able to handle portions of an impossible *potential* arraignment of shapes within project scope. Complex shapes with central points far removed from their internal components were found to be evaluated properly in regards to collisions. Proximity of shapes had no ill effect. This boded well for future developments involving angular rotation. Time to test-completion for a large arraignment of shapes was also found to be positive. No difference in execution time was noted between tests with a single object or a plurality thereof. This suggested the algorithm was acceptably efficient.

The self-reconnaissance preformed through this test greatly enhanced knowledge of the software’s capabilities, where it stood in regards to future developments, and where it will not succeed as currently implemented. This information was, and still is, quite valuable.

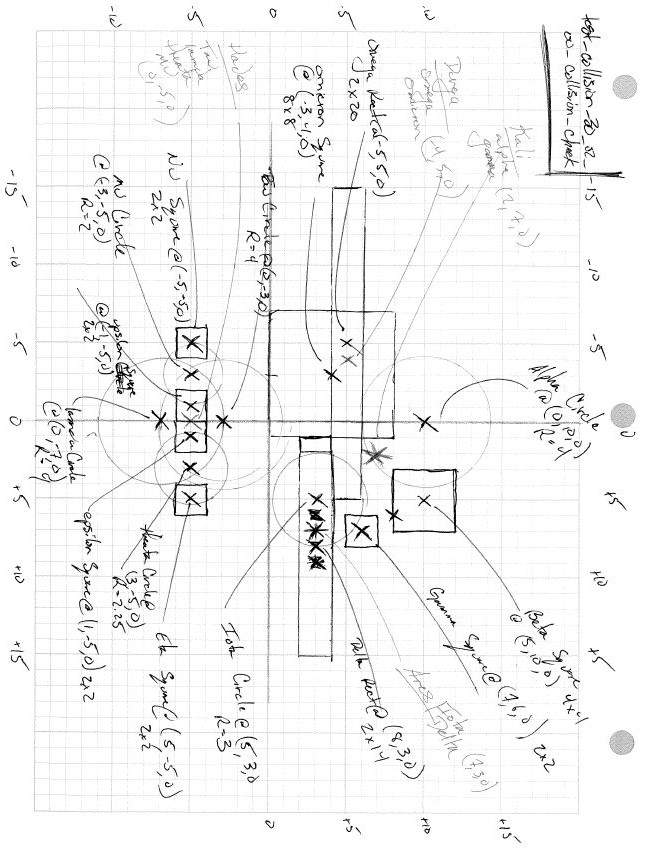


Figure 4.4 – ‘Analog’ Aspect of test\_collision\_30\_02\_00\_collision\_check

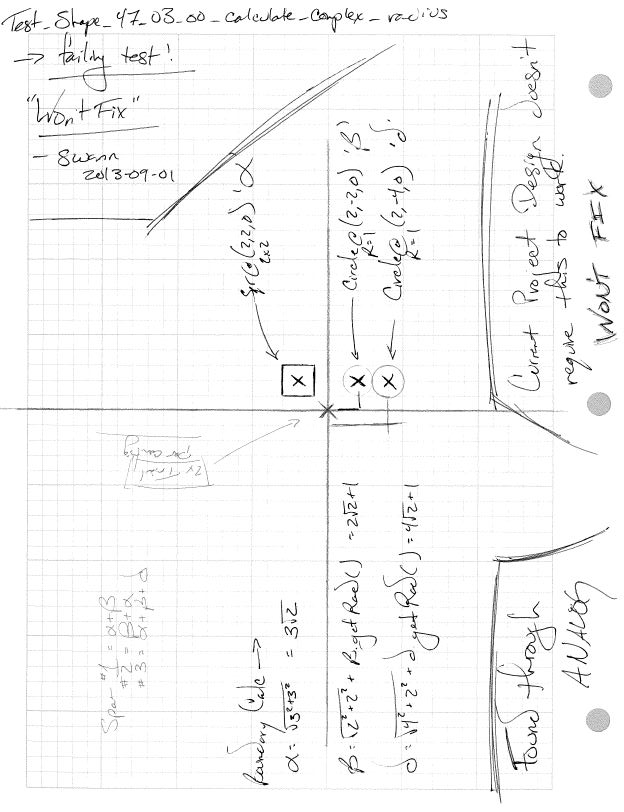


Figure 4.5 Won’t Fix Documentation for Requirements Outside Project Scope

**Chapter Five – Conclusions**

Analog development is a mechanism that was engineered for the purpose of assisting the software developer. The process acknowledges the human nature of the developer and accordingly attempts to harness a natural human strength by reflecting upon the manner in which the conceptual mind works. As a result, the mechanism allows for a form of intelligent discovery. By measuring the discrepancy between the current status and the desired behavior, the developer is able to map a course to the endgame. This chapter revisits the evolution of ADD and its benefits. Also, it discusses potential considerations for the future of ADD.

*5.1 – In Summary*

Analog Driven Development was born out of need. Locating the boundaries and vertices of a shape without a map proved difficult. Evaluating impulse from collisions using velocity vectors would have been impractical without some form of pre-emptive test design. I chose to draw the scenarios. I wanted to see them. I wanted to see all the points of interaction. I wanted something I could trust. So I built it.

Initially, ADD existed only for a single test case. I needed to know where a couple things were in the simulation space. It was immediately apparent how simple the transition from the sketch to the test suite was. The sketch was comprised of the pieces I already had, but as a whole it represented what I was building next. I had found a design tool.

The analog process as it currently stands is a result of the benefits I found inherent to sketching my designs: isolation of support logic from a greater function, coagulation of similar class features allowing for normalization and hierarchy design, creation flexible test scenarios using relative mathematics, and the value of self-reconnaissance.

These benefits come from the different ways I have molded a use for the process. Because ADD requires only an initial visual solution, it is easily adaptable to various conceptual problems. Not shown in the examples herein are analog designs other adaptations of this process, including: a customized linked-list for queuing members of a collision and the design of algorithms for reversing an object’s trajectory.

Aside from the direct benefits of ADD, there are also positive side effects to the process. Firstly, familiarizing another developer with the backend code for FutureLab has proven to be a simpler process if I can show what is happening. Reading through an algorithm in Java is not as easy as looking at a picture of how the code resolves a collision event. Secondly, I have found a significant increase in my confidence regarding written code. The analog process forces a deep understanding of the artifact itself. The test scenarios provide a robust exercise of the code. This combination allows me to be confident in my product. Thirdly, when asked in a design meeting how a proposed feature might impact the backend, I can simply open my sketchbook and see exactly how that feature is going to impact what FutureLab already has.

Analog development is a test-first development practice by definition. The test code is written before the source. But before a test is written, the entire scenario is resolved. This process is not for every design decision as there is associated overhead. For difficult problems, I have found benefit in the disciplined nature of this process. When solving any engineering problem, discipline is important. “As you sow, so too shall you reap.”

*5.2 – Considerations for the Future*

The known advantages of ADD are listed above. However, there may be a plurality of other benefits to this process that will require more exploration to derive. I doubt I’ve found the very best way to sketch the physics of FutureLab. I continue to find new applications. Also, there may be venue specific benefits to the process. Further use of this process is required in order to understand what potential it might have.

The full design of a database will likely take a different visual form that FutureLab did. Instead of depicting a grid system for collisions, one could map table relationships. A visual representation of a database’s keying structure might facilitate the logic behind query designs or optimization. If an engineer could see the key structure, mapping a query might take less effort. Or perhaps queries could be built as aggregation functions. Analog design found the ability to isolate support logic within a simulated physical environment. Perhaps in an object relationally mapped database with the same would be applicable in the creation of modular sub-queries.

It is also plausible that ADD may be beneficial in academic scenarios. Perhaps it has uses in the classroom. Might an inexperienced student benefit from being able to ‘see’ the code about to be scripted? Might an advanced student benefit from an additional design tool? Might we all benefit from further harnessing our greatest human tool, our conceptual minds.

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**Appendix Alpha**

**Appendix Beta**

**Appendix Gamma**