THE DIGITAL WORLD: DIGITAL AUDIO

We've come to understand something of the nature of the Digital World through a few foundational concepts:

- <u>Components</u>: Hardware, Software, Data.
- <u>Stages:</u> Entrance, Memory, Processing, Exit
- <u>Method:</u> The Digital Game in the Electric Shell via binary numbers.
- <u>Organization:</u> Hierarchical selection as the dominant logic.

We've also taken a first glimpse at MIDI, the system that popularized digital control of music and sound, continues to serve as a universal communications code, and influences interface design. This chapter will focus on the remaining foundational area: digital audio. Digital audio is the process of bringing sound itself into the domain of rules and numbers. As happens often in this book, in order to make sense of the issue at hand, we need first take a side trip…

Analog and Digital Measurement

This section is about two fundamental methods of gaining knowledge of the size of something. One method is to compare the object we are measuring to something else of similar size; the other method is to find a number that expresses the size of the object on some sort of scale. We use both methods every day, and neither is inherently more or less a reflection of the true size of the object.

Let's consider this book in your hand. How tall is it, top to bottom? There are several ways to answer that. I can raise my hands, hold them a little ways apart at a distance comparable to the book's height, and say, "It's this tall." That's convenient, but not too accurate, particularly if I go across the street (without the book) to inform my neighbor, who wants to fit the book into her display case (not a true story).

The hands or fingers method is, of course, well-adapted to expressing the size of something when you want a little leeway for poetic license: "The fish was this big!" or "I was this close to making the putt!"

For a more accurate measurement, I can take a piece of string, hold it flat against the book, and carefully mark each edge with a fine-lined pen. The string now has a marked length *analogous* to that of the book's height. If I marked carefully and the string doesn't stretch, this can be an extremely precise measurement—an *analog* measurement of the height of the book. You may have checked the width of a couch against the length of your arm or body (or the belt from your roommate's bathrobe) to see if it would fit through a door or under the picture window. The distance between my two hands, the marked piece of string, and the bathrobe belt are all analog measurements.

Another way to measure the height of this book is against a scale of some sort—say, a ruler. A ruler presents an <u>Entrance</u> stage to the Digital World in a very basic sense.

Way back in Chapter 1 I implied in passing that the Digital World has actually been with us for a long time. Measuring with a ruler is an example. In the most fundamental sense, any time we convert human information into the form of number, we have digitized it. Use of the term "Digital World"—here and in other places—is normally reserved for use of computers and their ilk, but the conversion process is conceptually the same.

This book as it sits in your hand is a physical, tangible thing; it's neither a mathematical nor a numerical concept. It's about this big, weighs about this much, and is this color. The Digital World (in a broad sense) aids us in describing it by assigning numbers to it. A ruler is also a physical thing, and it has a set of marks at equal distances, each given a number in increasing sequence. When we lay the ruler over the book, we can express the book's height by counting the marks height from top to bottom, to the nearest mark. Let's say the ruler I'm using now is a crude yardstick, with marks only at each foot: 0', 1', 2', 3'. The height of the book is closest to the 1' mark, so numerically, the book is one foot tall.

In earlier studies in math or general science, you may have encountered the difference between the terms "accuracy" and "precision." Well, the digital measurement we just made is very *accurate* (the height is definitely closest to the one-foot mark, no mistake there). That number "1" is exact. Further, all of the durability we noted earlier is here: "1" will not drift over time, you can go out in a lake and imagine it, it can be written "1 foot" or "one foot" or "1′". Advertisements for some gizmos boast "digital accuracy", and we could too in this case. Digital can be perfectly accurate. Therefore, this book is one foot tall (with digital accuracy!).

The problem is, our measurement is not very *precise* (this book is clearly less than one foot tall). The measurement is *approximated,* to the nearest foot in this case.

Big Concept**:** *Every digital measurement is an approximation.*

What we need here is a ruler that will measure with higher precision; that is, one marked with a greater number of smaller distances.

Let's try a yardstick with 36 markings between 0 yards and one yard (instead of only 3 markings), grouped and labeled as inches. Now we count 9 markings, or 9 inches, as closest to the height of the book. This not only remains perfectly accurate, but its precision is much more appropriate. *It is still an approximation, however.* If we need even greater precision, we could find a ruler or other device capable of measuring to the nearest thousandth of an inch, or millionth of a meter, or whatever. It may be perfectly accurate, and extremely precise, but it will *never* be a *perfect* measurement. The yardstick itself is a continuous piece of wood with potentially an infinite number of infinitely close marks on it. But the very act of separating a length into marks and counting them creates discrete chunks that are no longer continuous, and destroys the analogy in favor of expressing the measurement as a number. In other words, we **quantize** the measurement.

Along with space, time is another concept that has size. From a western philosophical perspective in the 21st century, time passes at a continuous (if relative) rate. A clock has a motor or mechanism that turns the hands continuously—an analog clock. At any moment, we can look at the hands and see *exactly* what time it is by referring to the continuous analogy. But as soon as we give it a number, we are approximating. "It's 8:15 and, uh… (33...34...) 35 seconds." This is, of course, what a digital clock does. There's an old joke passed around during the early days of VCRs: "I don't set my digital clock; that way it's correct twice a day." The implication is that the clock (flashing "12:00") is correct at noon and midnight, wrong the rest of the day. We now understand that this joke is the actual reality for any digital clock of any sort; it's only a matter of precision. Your alarm clock may be accurate on each minute, but it is *wrong* for all the times between minutes. This is OK for waking up in time for work, but inadequate for timing Olympic sprinting, or MIDI sequencing, or laser beam frequencies. Each of *those* clocks is (hopefully) accurate and appropriately precise, but each digital clock is still approximate, and incorrect for all the times between the markings.

To summarize:

- Digital measurement is all around us, and it is central to the particular Digital World we are studying; here, all information relating to measurement becomes numerical.

- Digital measurement consists of expressing a continuous, real-world phenomenon by finding an analogous dimension (i.e., yardstick), marking it in discrete chunks, then counting the chunks to convert the dimension to a number. The resulting number is a *quantization* of the original phenomenon.

- Every digital measurement is thus an approximation. One job for every person working in the Digital World is to decide the appropriate precision (the approximation or quantization level) and choose (or at least be aware of) the degrees of precision offered in any digital environment.

- There is nothing continuous in the Digital World. *Everything* is quantized.

These concepts are inherent to the MIDI code and systems. Some MIDI messages, called "continuous controller messages," sort of pretend to be analogous and precise—they relate to things such as modulation wheels, foot pedals, and other knobs and buttons that may be in your experience. We now know they all are actually divided into steps (often 128). Pitch is divided first into notes, 12 to the octave. For finer gradations, the pitch bend wheel messages are potentially capable of over 16,000 discrete pitches (few controllers actually do this), but even then, a *completely smooth* frequency sweep (which can be found on any cheap analog signal generator) is unavailable. However, the stair steps in most MIDI continuous controller messages are so many and so gradual that the approximation seems appropriate and reasonable.

Well, now we're ready to understand digital audio.

and continuing...

from *The Craft of Controlling Sound* by Stephen Solum

more info: www.thecraftofcontrollingsound.com