CTIS 165 – FUNDAMENTALS OF INFORMATION SYSTEMS

Gottfried Wilhelm Leibniz

Abstract

Lab Guide 2 – Word Processing

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Gottfried Wilhelm Leibniz (1646 – 1716)

Gottfried Wilhelm (von) Leibniz was a German polymath and philosopher (Philosophy) who occupies a prominent place in the history of mathematics (Mathematician) and the history of philosophy, having developed differential and integral calculus independently of Isaac Newton (Russell). Leibniz's notation has been widely used ever since it was published. It was only in the 20th century that his Law of Continuity and Transcendental Law of Homogeneity found mathematical implementation (by means of non-standard analysis). He became one of the most prolific inventors in the field of mechanical calculators. While working on adding automatic multiplication and division to Pascal's calculator, he was the first to describe a pinwheel calculator in 1685 and invented the Leibniz wheel, used in the arithmometer, the first mass-produced mechanical calculator. He also refined the binary number system, which is the foundation of virtually all digital computers.

In philosophy, Leibniz is most noted for his optimism, i.e. his conclusion that our Universe is, in a restricted sense, the best possible one that God could have created, an idea that was often lampooned by others such as Voltaire. Leibniz, along with René Descartes and Baruch Spinoza, was one of the three great 17th-century advocates of rationalism. The work of Leibniz anticipated modern logic and analytic philosophy, but his philosophy also looks back to the scholastic tradition, in which conclusions are produced by applying reason to first principles or prior definitions rather than to empirical evidence.

Leibniz made major contributions to physics and technology, and anticipated notions that surfaced much later in philosophy, probability theory, biology, medicine, geology, psychology, linguistics, and computer science. He wrote works on philosophy, politics, law, ethics, theology, history, and philology. Leibniz's contributions to this vast array of subjects were scattered in various learned journals, in tens of thousands of letters, and in unpublished manuscripts. He wrote in several languages, but primarily in Latin, French, and German. There is no complete gathering of the writings of Leibniz.

Gottfried Leibniz was born on July 1, 1646, toward the end of the Thirty Years' War, in Leipzig, Saxony, to Friedrich Leibniz and Catharina Schmuck. Leibniz's father had been a Professor of Moral Philosophy at the University of Leipzig, and the boy later inherited his father's personal library. He was given free access to it from the age of seven. While Leibniz's schoolwork was largely confined to the study of a small canon of authorities, his father's library enabled him to study a wide variety of advanced philosophical and theological works—ones that he would not have otherwise been able to read until his college years.

1. Philosophy

Leibniz's philosophical thinking appears fragmented, because his philosophical writings consist mainly of a multitude of short pieces: journal articles, manuscripts published long after his death, and many letters to many correspondents. He wrote only two book-length philosophical treatises, of which only the *Théodicée* of 1710 was published in his lifetime.

Leibniz dated his beginning as a philosopher to his *Discourse on Metaphysics*, which he composed in 1686 as a commentary on a running dispute between Nicolas Malebranche and Antoine Arnauld. This led to an extensive and valuable correspondence with Arnauld; it and the *Discourse* were not published until the 19th century. In 1695, Leibniz made his public entrée into European philosophy with a journal article titled "New System of the Nature and Communication of Substances". Between 1695 and 1705, he composed his *New Essays on Human Understanding*, a lengthy commentary on John Locke's 1690 *An Essay Concerning Human Understanding*, but upon learning of Locke's 1704 death, lost the desire to publish it, so that the *New Essays* were not published until 1765. The *Monadologie*, composed in 1714 and published posthumously, consists of 90 aphorisms.

Leibniz met Spinoza in 1676, read some of his unpublished writings, and has since been suspected of appropriating some of Spinoza's ideas. While Leibniz admired Spinoza's powerful intellect, he was also forthrightly dismayed by Spinoza's conclusions, especially when these were inconsistent with Christian orthodoxy.

Unlike Descartes and Spinoza, Leibniz had a thorough university education in philosophy. He was influenced by his Leipzig professor Jakob Thomasius, who also supervised his BA thesis in philosophy. Leibniz also eagerly read Francisco Suárez, a Spanish Jesuit respected even in Lutheran universities. Leibniz was deeply interested in the new methods and conclusions of Descartes, Huygens, Newton, and Boyle, but viewed their work through a lens heavily tinted by scholastic notions. Yet it remains the case that Leibniz's methods and concerns often anticipate the logic, and analytic and linguistic philosophy of the 20th century.

1.1. The Principles

Leibniz variously invoked one or another of seven fundamental philosophical Principles:

- Identity/contradiction. If a proposition is true, then its negation is false and vice versa.
- Identity of indiscernible. Two distinct things cannot have all their properties in common. If every predicate possessed by x is also possessed by y and vice versa, then entities x and y are identical; to suppose two things indiscernible is to suppose the same thing under two names. Frequently invoked in modern logic and philosophy, the "identity of indiscernible" is often referred to as Leibniz's Law. It has attracted the most controversy and criticism, especially from corpuscular philosophy and quantum mechanics.
- Sufficient reason. "There must be a sufficient reason for anything to exist, for any event to occur, for any truth to obtain."
- Pre-established harmony. "[T]he appropriate nature of each substance brings it about that what happens to one corresponds to what happens to all the others, without, however, their acting upon one another directly." (Discourse on Metaphysics, XIV) A dropped glass shatters because it "knows" it has hit the ground, and not because the impact with the ground "compels" the glass to split.

- Law of Continuity. Natura non facit saltus (literally, "Nature does not make jumps").
- Optimism. "God assuredly always chooses the best."
- Plenitude. Leibniz believed that the best of all possible worlds would actualize every genuine possibility, and argued in Théodicée that this best of all possible worlds will contain all possibilities, with our finite experience of eternity giving no reason to dispute nature's perfection.

Leibniz would on occasion give a rational defense of a specific principle, but more often took them for granted.

1.2. Symbolic Thought

Leibniz believed that much of human reasoning could be reduced to calculations of a sort, and that such calculations could resolve many differences of opinion:

> **"The only way to rectify our reasoning is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate, without further ado, to see who is right."**

Leibniz's calculus ratiocinator, which resembles symbolic logic, can be viewed as a way of making such calculations feasible. Leibniz wrote memoranda that can now be read as groping attempts to get symbolic logic—and thus his calculus—off the ground. But Gerhard and Couturat did not publish these writings until modern formal logic had emerged in Frege's Begriffsschrift and in writings by Charles Sanders Peirce and his students in the 1880s, and hence well after Boole and De Morgan began that logic in 1847.

Leibniz thought symbols were important for human understanding. He attached so much importance to the development of good notations that he attributed all his discoveries in mathematics to this. His notation for calculus is an example of his skill in this regard. C.S. Peirce, a 19th-century pioneer of semiotics, shared Leibniz's passion for symbols and notation, and his belief that these are essential to a well-running logic and mathematics.

But Leibniz took his speculations much further. Defining a character as any written sign, he then defined a "real" character as one that represents an idea directly and not simply as the word embodying the idea. Some real characters, such as the notation of logic, serve only to facilitate reasoning. Many characters well known in his day, including Egyptian hieroglyphics, Chinese characters, and the symbols of astronomy and chemistry, he deemed not real. Instead, he proposed the creation of acharacteristica universalis or "universal characteristic", built on an alphabet of human thought in which each fundamental concept would be represented by a unique "real" character:

> **"It is obvious that if we could find characters or signs suited for expressing all our thoughts as clearly and as exactly as arithmetic expresses numbers or geometry expresses lines, we could do in all matters insofar as they are subject to reasoning all that we can do in arithmetic and geometry. For all investigations which depend on reasoning would be carried out by transposing these characters and by a species of calculus."**

Complex thoughts would be represented by combining characters for simpler thoughts. Leibniz saw that the uniqueness of prime factorization suggests a central role forprime numbers in the universal characteristic, a striking anticipation of Gödel numbering. Granted, there is no intuitive or mnemonic way to number any set of elementary concepts using the prime numbers. Leibniz's idea of reasoning through a universal language of symbols and calculations however remarkably foreshadows great 20th century developments in formal systems, such as Turing completeness, where computation was used to define equivalent universal languages (see Turing degree).

Because Leibniz was a mathematical novice when he first wrote about the characteristic, at first he did not conceive it as an algebra but rather as a universal languageor script. Only in 1676 did he conceive of a kind of "algebra of thought", modeled on and including conventional algebra and its notation. The resulting characteristic included a logical calculus, some combinatorics, algebra, his analysis situs (geometry of situation), a universal concept language, and more.

What Leibniz actually intended by his characteristica universalis and calculus ratiocinator, and the extent to which modern formal logic does justice to calculus, may never be established.

1.3. Formal Logic

Leibniz is one of the most important logicians between Aristotle and 1847, when George Boole and Augustus De Morgan each published books that began modern formal logic. Leibniz enunciated the principal properties of what we now call conjunction, disjunction, negation, identity, set inclusion, and the empty set. The principles of Leibniz's logic and, arguably, of his whole philosophy, reduce to two:

All our ideas are compounded from a very small number of simple ideas, which form the alphabet of human thought.

Complex ideas proceed from these simple ideas by a uniform and symmetrical combination, analogous to arithmetical multiplication.

The formal logic that emerged early in the 20th century also requires, at minimum, unary negation and quantified variables ranging over some universe of discourse.

Leibniz published nothing on formal logic in his lifetime; most of what he wrote on the subject consists of working drafts. In his book History of Western Philosophy, Bertrand Russell went so far as to claim that Leibniz had developed logic in his unpublished writings to a level which was reached only 200 years later.

2. Mathematician

Although the mathematical notion of function was implicit in trigonometric and logarithmic tables, which existed in his day, Leibniz was the first, in 1692 and 1694, to employ it explicitly, to denote any of several geometric concepts derived from a curve, such as abscissa, ordinate, tangent, chord, and the perpendicular. In the 18th century, "function" lost these geometrical associations.

Leibniz was the first to see that the coefficients of a system of linear equations could be arranged into an array, now called a matrix, which can be manipulated to find the solution of the system, if any. This method was later called Gaussian elimination. Leibniz's discoveries of Boolean algebra and of symbolic logic, also relevant to mathematics, are discussed in the preceding section. The best overview of Leibniz's writings on calculus may be found in Bos (1974) (Jesseph).

1.4. Calculus

Leibniz is credited, along with Sir Isaac Newton, with the discovery of calculus (differential and integral calculus). According to Leibniz's notebooks, a critical breakthrough occurred on November 11, 1675, when he employed integral calculus for the first time to find the area under the graph of a function y = f(x). He introduced several notations used to this day, for instance the integral sign ∫, representing an elongated S, from the Latin word summa, and the d used for differentials, from the Latin word differentia. This cleverly suggestive notation for calculus is probably his most enduring mathematical legacy. Leibniz did not publish anything about his calculus until 1684. The product rule of differential calculus is still called "Leibniz's law". In addition, the theorem that tells how and when to differentiate under the integral sign is called the Leibniz integral rule.

Leibniz exploited infinitesimals in developing calculus, manipulating them in ways suggesting that they had paradoxical algebraic properties. George Berkeley, in a tract called The Analyst and also in De Motu, criticized these. A recent study argues that Leibnizian calculus was free of contradictions, and was better grounded than Berkeley's empiricist criticisms.

From 1711 until his death, Leibniz was engaged in a dispute with John Keill, Newton and others, over whether Leibniz had invented calculus independently of Newton. This subject is treated at length in the article Leibniz-Newton controversy.

The use of infinitesimals in mathematics was frowned upon by followers of Karl Weierstrass, but survived in science and engineering, and even in rigorous mathematics, via the fundamental computational device known as the differential. Beginning in 1960, Abraham Robinson worked out a rigorous foundation for Leibniz's infinitesimals, using model theory, in the context of a field of hyperreal numbers. The resulting non-standard analysis can be seen as a belated vindication of Leibniz's mathematical reasoning. Robinson's transfer principle is a mathematical implementation of Leibniz's heuristic law of continuity, while the standard part function implements the Leibnizian transcendental law of homogeneity.

1.5. Topology

Leibniz was the first to use the term analysis situs, later used in the 19th century to refer to what is now known as topology. There are two takes on this situation. On the one hand, Mates, citing a 1954 paper in German by Jacob Freudenthal, argues:

> **“Although for Leibniz the situs of a sequence of points is completely determined by the distance between them and is altered if those distances are altered, his admirer Euler, in the famous 1736 paper solving the Königsberg Bridge Problem and its generalizations, used the term geometria situs in such a sense that the situs remains unchanged under topological deformations. He mistakenly credits Leibniz with originating this concept. ... [It] is sometimes not realized that Leibniz used the term in an entirely different sense and hence can hardly be considered the founder of that part of mathematics.”**

But Hideaki Hirano argues differently, quoting Mandelbrot:

> **“To sample Leibniz' scientific works is a sobering experience. Next to calculus, and to other thoughts that have been carried out to completion, the number and variety of premonitory thrusts is overwhelming. We saw examples in "packing” ... My Leibniz mania is further reinforced by finding that for one moment its hero attached importance to geometric scaling. In Euclidis Prota ..., which is an attempt to tighten Euclid's axioms, he states ...: "I have diverse definitions for the straight line. The straight line is a curve, any part of which is similar to the whole, and it alone has this property, not only among curves but among sets." This claim can be proved today.”**

Thus the fractal geometry promoted by Mandelbrot drew on Leibniz's notions of self-similarity and the principle of continuity: Natura non facit saltus. We also see that when Leibniz wrote, in a metaphysical vein, that "the straight line is a curve, any part of which is similar to the whole", he was anticipating topology by more than two centuries. As for "packing", Leibniz told to his friend and correspondent Des Bosses to imagine a circle, then to inscribe within it three congruent circles with maximum radius; the latter smaller circles could be filled with three even smaller circles by the same procedure. This process can be continued infinitely, from which arises a good idea of self-similarity. Leibniz's improvement of Euclid's axiom contains the same concept.

3. Scientist and engineer

Leibniz's writings are currently discussed, not only for their anticipations and possible discoveries not yet recognized, but as ways of advancing present knowledge. Much of his writing on physics is included in Gerhardt's Mathematical Writings.

1.6. Physics

Leibniz contributed a fair amount to the statics and dynamics emerging around him, often disagreeing with Descartes and Newton. He devised a new theory of motion(dynamics) based on kinetic energy and potential energy, which posited space as relative, whereas Newton was thoroughly convinced that space was absolute. An important example of Leibniz's mature physical thinking is his Specimen Dynamicum of 1695.

Until the discovery of subatomic particles and the quantum mechanics governing them, many of Leibniz's speculative ideas about aspects of nature not reducible to statics and dynamics made little sense. For instance, he anticipated Albert Einstein by arguing, against Newton, that space, time and motion are relative, not absolute: "As for my own opinion, I have said more than once, that I hold space to be something merely relative, as time is, that I hold it to be an order of coexistences, as time is an order of successions."

Leibniz held a relationist notion of space and time, against Newton's substantivalist views. According to Newton's substantivalism, space and time are entities in their own right, existing independently of things. Leibniz's relationism, on the other hand, describes space and time as systems of relations that exist between objects. The rise of general relativity and subsequent work in the history of physics has put Leibniz's stance in a more favorable light.

One of Leibniz's projects was to recast Newton's theory as a vortex theory. However, his project went beyond vortex theory, since at its heart there was an attempt to explain one of the most difficult problems in physics, that of the origin of the cohesion of matter.

The principle of sufficient reason has been invoked in recent cosmology, and his identity of indiscernible in quantum mechanics, a field some even credit him with having anticipated in some sense. Those who advocate digital philosophy, a recent direction in cosmology, claim Leibniz as a precursor. In addition to his theories about the nature of reality, Leibniz's contributions to the development of calculus have also had a major impact on physics.

1.7. Social Science

Much of Leibniz's work went on to have a great impact on the field of psychology. His theory regarding consciousness in relation to the principle of continuity can be seen as an early theory regarding the stages of sleep. He believed that by the principle that phenomena found in nature were continuous by default, it was likely that the transition between conscious and unconscious states had intermediary steps. Though Leibniz's ideas regarding pre-established harmony were rejected by many, psychologists embraced his ideas of psychophysical parallelism. This idea refers to the mind–body problem, stating that the mind and brain do not act upon each other, but act alongside each other separately but in harmony.

Leibniz believed that the mind had a very active role in perception, and plays a much larger role in sensory input. He focused heavily on perception, distinguishing between the type of perception where we are conscious of a stimulus, and the other which is being aware of a distinct perception. He thought that there are many *petites perceptions*, or small perceptions of which we perceive but of which we are unaware. For example, when a bag of rice is spilled, we see the rice but are not necessarily aware of how many grains are in the pile. With this principle, there are an infinite number of perceptions within us at any given time of which we are unaware. For this to be true, there must also be a portion of the mind of which we are unaware at any given time. In this way, Leibniz's theory of perception can be viewed as one of many theories leading up to the idea of the unconscious. Additionally, the idea of subliminal stimuli can be traced back to his theory of small perceptions. Leibniz was a direct influence on Ernst Platner, who is credited with originally coining the term *Unbewußtseyn* (unconscious).

Leibniz's ideas regarding music and tonal perception went on to influence the laboratory studies of Wilhelm Wundt.

In public health, he advocated establishing a medical administrative authority, with powers over epidemiology and veterinary medicine. He worked to set up a coherent medical training program, oriented towards public health and preventive measures. In economic policy, he proposed tax reforms and a national insurance program, and discussed the balance of trade. He even proposed something akin to what much later emerged as game theory. In sociology he laid the ground for communication theory.

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