A history of diagrams – Turning points in the spatial representation of ideas and information

[This is an abstract of a forthcoming book to be published by Palgrave McMillan.]

In his autobiographical *Via coaetanea* (ca 1311), the Catalan scholar Raymond Llull wrote that "because of the weakness of human intellect" which he had witnessed at the university in Paris, he had to simplify his diagrammatic system considerably. However, the cognitive limitations which he observed were not particular to Paris, the medieval era, or even academic institutions, but are a general human trait. Together with other characteristics of our cognition, they have contributed in shaping the development of diagrams throughout history.

When diagrams first appeared in their fully developed form, more than two millennia ago, they already built on a long development. Their oldest roots are found in evolutionary history, which developed the biological foundations of the spatial cognition that enables diagrammatic thinking. It has been suggested that the capacity to orientate spatially in the landscape developed first, where after the same neural system for spatial reference frames was first reused to map the locations of parts of objects, and later, through analogy, to represent abstract concepts. Then followed a prehistory of diagrams, when humans used various spatial aids to enhance their cognition. Although gestures leave no archaeological evidence, they have a role in speech similar to that of diagrams in text, and they are probably older than vocal speech. Oral cultures used physical locations in terrain and architecture as memory loci that indexed songs containing their entire cultural knowledge. Similar mnemonic functions could also be performed by portable objects. The most advanced of them, such as the Inca quipus, are a mix of proto-writing and proto-infographics. The invention of complete systems of writing meant that the figurative, diagrammatic and symbolic aspects of communication became separated, after having been closely intertwined in proto-writing systems. This paved the way for the emergence of diagrams as a distinct form of illustrations.

The history of diagrams is characterized by several periods of intensive diagram construction, followed by long periods dominated by reuse of earlier established forms. Golden Ages of diagram creation seem to occur when large amounts of new knowledge need to be systematized and explained, or when old knowledge needs to be explained to large new groups. Since diagrams help humans structure information, it is not surprising that during periods where the rate of accumulation of new information has been particularly high, new forms of diagrams have also been invented. For example, during the twelfth and thirteenth centuries, the Latin scholars of Europe were inundated with translations of rediscovered Greek texts, which forced them to develop diagrammatic tools for structuring textual information.

However, this was only part of a larger pattern, since both the western and eastern parts of the Eurasian landmass saw a new great flowering of diagrams in the period from approximately 800 to 1300 AD, characterized by an increase in the use of diagrams and in the development of new forms.

Another wave followed from the 1700s, with the introduction of data visualizations. Although scholars such as Nicholas Oresme in the 1300s made theoretical advances that could have been used to represent data in diagrams, they were not used for this purpose until the 1700s. Then, data visualization took off as the data amassed by modern societies became object of human spatial thinking. This wave culminated in the second half of the 1800s. It has been described as a golden age of data visualization, when nation-building statistical agencies experimented with new diagrammatic forms. The first half of the 1900s was a period with fewer inventions, but for the first time, statistical graphics now reached the majority of the population through popular media, such as newspapers and school textbooks. A revival for development of diagrammatic forms began in the 1960s, this time accompanied by computerized methods for visualization and data analysis.

In order to fully understand such periods of intense diagram creation we need to reflect on the relationship between the cognitive and historical aspects of diagramming. Cognitive anthropology has shown that humans everywhere tends to classify knowledge into hierarchical systems, folk taxonomies. These have a limited number of levels and branches at each node, a structure adapted to human working memory capacity. Undoubtedly, this phenomenon also underlies the ubiquitous attempts by scholars to construct, for example, tree diagrams. However, while universal principles of cognition can explain these similarities, they cannot explain the differences and changes. Although the tendency to classify is found everywhere, it is not always made the center of science and philosophy, such as in the European high Middle Ages, when classificatory subdivisions permeated scholasticism. Instead, we can understand such periods as a response to a particularly severe overload of new knowledge, such as translations of texts in twelfth century Europe or some centuries earlier in the Arab World, or of newly described plants in the sixteenth to eighteenth centuries.

Bar charts, time series diagrams and other data visualizations rest on cognitive principles such as the analogy between line length and number, that are either innate or primary metaphors, acquired by everyone early in life. However, it was only in the 1700s, when waves of numerical data flooded the world as a result of improved measurement techniques and changed scientific ideals, that the need for externalization and oversight spurred the invention of diagrams for data visualization.

An intriguing question is why golden ages for diagram creation in geographically distant civilizations have coincided in time, such as the 800s to 1300s in the Arab, Latin and Chinese worlds. That these periods were characterized by information overload does not suffice as an explanation, since we still need to explain why this overload would take place across the globe simultaneously. Its primary cause might be the long cycles in traditional agricultural societies. Periods of good harvest increased the population and enabled more to engage in other activities than food production. A new larger class of literate people became educated in complicated theories earlier reserved for a smaller intellectual elite, and this called for diagrammatic simplification. The influx of information in the form of translations was also enabled by growing literate groups; texts don't just flow between cultures unless someone is there to read and translate them. The periods of diagram development in Europe in the Middle Age and the late 1700s to 1800s took place after inflection points in population increase around the years 1100 and 1700. In Asia, the Medieval inflection point took place earlier, as did the period of diagram development. This synchronicity is not unique to diagrams, but form part of a general strong development of culture and science during the periods. Although historic climate trends have not coincided all over the world, both Europe and China experienced medieval warm periods, which through increased harvests might explain their simultaneous population growth.

Compared to the libraries of modern and even early modern times, the absolute number of books that entered Europe in the high Middle Ages was not impressive. However, considering the severe limitations of the knowledge infrastructure and information technology of the day, the relative load no doubt rivaled that of the Enlightenment and the present. Combined with an increasing number of students, this caused Europe to develop institutions such as universities, methods such as scholasticism, practices such as diagramming, materials such as paper, and technologies such as printing.

The number of diagrammatic forms is the highest in the beginning of the cycles of diagram innovation, where after they begin to plateau and decrease. After an initial period of experimentation when many new diagrams are created, some eventually come to dominate. Diagrams have an advantage in this “survival of the fittest” if they function as efficient analogies for concepts and information by being well adapted to cognitive principles, and if they are easy to reproduce given the technologies of the day. Thereafter follows periods of little innovation in abstract diagrams. For example, following the intense Middle Age innovation of diagrams, in the European renaissance and the scientific revolution scientific texts were either accompanied by images of naturalia and scientific equipment or tabulated data. The invention of print was not associated with any new diagrams, but reproduced medieval types with new means, primarily tree diagrams printed with bracket types. However, successful diagrams often also connect to pre-existing systems of knowledge, values and conventions. Entirely new diagrammatic forms are difficult to interpret, and often require long explanator at their first appearances, such as Priestley's timelines. When some diagrams become more common and recognized than others, they form schemas that can be reused with limited cognitive load. Thereby, they get an additional reproductive advantage over others forms, which eventually fade into the background.

The general development of philosophy and geometry has been closely intertwined with the development of diagrams. In classical Greece and in the later cultures that it inspired—the Byzantine, the Latin and the Arab—the deductive methods of geometry became an ideal for philosophy in general, and the diagrams of Euclidean geometry became models for diagrams in all fields. Ancient Indian and Chinese philosophy had less of a distrust of sense perception, which was also reflected in the diagrams produced in these cultures. For example, the Buddhist philosophical diagram Hetucakra was concerned with the conditions for correct inference from perception, rather than the deductive logic of the similar western square of opposition. Likewise, Chinese tree diagrams analyzed particular textual examples, and not general abstract principles such as many Medieval European tree diagrams. Still, that the spatial forms of the diagrams were similar across all cultural areas, such as the tree diagram, reflects that they were founded on the same universal cognitive principles.

The next large revolution in the history of diagrams, the development of statistical graphics in the 1700s, was not merely a result of improved measurement techniques that created increased amounts of data, but also of an intellectual revolution: Analytical geometry created the conception of a quantified space that could be used to illustrate measurements. The development of mathematical functions and the coordinate system endowed space with mathematical properties and provided a template for how to express quantitative data in diagrammatic form. This development was pioneered by Leonard Euler and Johann Heinrich Lambert, both attached to the Berlin academy in the mid-1700s. While Euler completed the mathematical development of the function concept, Lambert applied it to scientific data in time series diagrams of evaporation. Another inspiration for Lambert was musical notation, which he recognized as a form of time series diagram.

Another intellectual development important for the introduction of data visualizations was the emergence of a distinction between quantitative and qualitative properties. This originated in the 17th century discussion on primary and secondary qualities, which was influenced by Greek atomism. The primary qualities, such as size and shape, were considered more fundamental than the secondary qualities, which were perceived through the senses and were considered an effect of the primary qualities. When a property such as speed now could be considered quantitative, and thereby measurable, it made sense to plot it in the quantified space provided by analytical geometry.

That the field of music was so early in developing forerunners of modern diagrams for data visualization might be due to the fact that there the relationships between primary and secondary qualities, such as the length of a string and pitch, were relatively easy to untangle. What we today would describe as the quantitative aspects of music was therefore of direct relevance for ancient, medieval and renaissance thinkers in their search for its qualities, and they were represented in diagrams that anticipated the quantitative turn in diagramming that was to take place in the 1700s.

Technologies of image production have had some influence on what diagrams have been produced. For example, the bamboo strips used in Chinese chronological tables might have invited a tabular design. The facility with which bracketed diagrams could be reproduced with led types after the invention of printing in Europe probably favored this form of tree diagrams, although it had its origins in medieval manuscript culture. From the late 18th century, advances in copperplate printing made it easier to reproduce high quality diagrams. In the 20th century, computerization facilitated new forms of diagrams, and even enabled moving graphics. However, regardless of such changes, the basic construction of the diagrams has changed remarkably little. Good diagrams must be adapted to basic principles of human cognition, which have remained unchanged. Clearly delineated diagrams simple enough to be grasped by human consciousness look similar throughout the ages.