

Medieval Information Visualization

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Abstract—This paper reviews some of the visualizations employed to represent information during the Middle Ages. It discusses four kinds of visualizations: *rotae*, arc diagrams, tables and trees. It considers the historical context underlying early medieval scholarship and how these visualizations were used.

Index Terms—Visualization, history, medieval manuscripts, visual analytics.

INTRODUCTION

This paper explores examples of medieval information visualization that may be found from the Carolingian Renaissance [1] onward. Early medieval scholars, struggling with information both religious and secular in nature, invented charts and diagrams to bestow visual form to abstract concepts. Begun as a few incidental charts created to help communicate concepts within their manuscripts, these graphical representations had evolved by the twelfth century into routine formats for rendering scientific, philosophical, and theological truths.

It draws upon our earlier research in this area [2- 4] to review medieval information visualization's origins, and to discuss four kinds of visualization modalities: *rotae*, arc diagrams, trees, and tables. It expands this work by providing supplementary visualization examples, and discusses the use of these visualizations as part of a visual analytic process. For an examination of the historical context underlying early medieval scholarship, a discussion of the kinds of texts available to visualizers during the early medieval period, and the problems of visualization see [2]. Finally, the reader is invited to explore the differences between visualizations found herein and in [2 - 4].

1 MEDIEVAL VISUALIZATION

Most early examples of information visualization are found in Carolingian manuscripts associated with the quadrivium, the segment of Carolingian education focused on arithmetic, geometry, music, and astronomy; with the great preponderance of charts and diagrams being astronomical or cosmological in nature (c.f. Eastwood [5] for a complete discussion). What is significant about these works from an information visualization perspective is they contain diagrams explicitly created to elucidate concepts within their respective texts. In some cases the diagrams that appeared in manuscripts needed to be invented by medieval readers, because none were specified in the original. In other cases, diagrams that were in an original manuscript did not survive uncorrupted into the ninth century, necessitating either their reconstitution or invention anew. And finally there were manuscripts in which the original author explicitly stated how these diagrams were to be constructed. But even precisely defined procedures were misinterpreted. As Eastwood has observed, Carolingian students and teachers alike were challenged by the process of transforming text into visualizations. Thus, given their insufficient knowledge of geometry, and their difficulty in assessing a

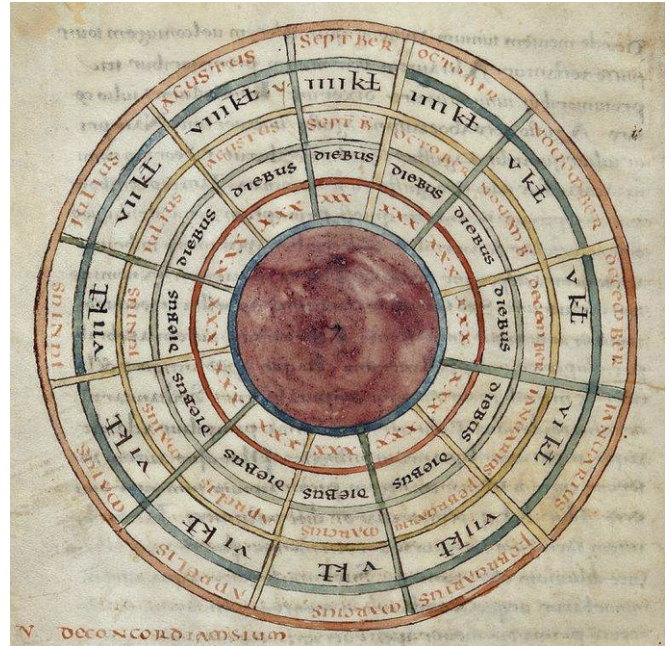


Fig. 1. Calendar, *De natura rerum*, Isidore of Seville, c. 9th C. (MS 422, fol. 3v, Laon, Bibliothèque Nationale).

diagram's correctness, the design, construction, validation, standardization, and integration of these diagrams into pedagogical practice evolved into a protracted process that formally did not abate until the infusion of scholarly Greco-Arabic texts into Western Europe by the twelfth century [6].

2 ROTA

Isidore of Seville (c. 560 – 636) is associated with the appearance of the *rota*, a circular diagram. He is considered one of the greatest scholars of late antiquity who is best known as the first encyclopedist of the Middle Ages [7]. *Etymologiae* [8] and *De natura rerum* [9] are two of his works that are of interest to the history of information visualization, because they contain diagrams that he considered useful for communication of ideas. In particular, *De natura rerum* contains seven figures, six of which are *rotae* that Isidore devises and employs for conveying a variety of concepts including cartography, computus, the elements, and the relation of man to the cosmos.

Fig. 1 displays the first *rota* that appears in a copy of *De natura rerum*, dated to the beginning of the ninth century (MS 422, fol. 3v, Laon, Bibliothèque Nationale), that was designed to communicate the concordance between the Roman (Julian) and Egyptian calendars [10]. Egyptian calendars were composed of twelve 30 day months, with five days remaining at the end of the year. This *rota* serves to express the number of days that the start of each Egyptian month precedes the onset of each Roman month. Beginning in this figure at four o'clock, the labels of the outer ring are read as the months

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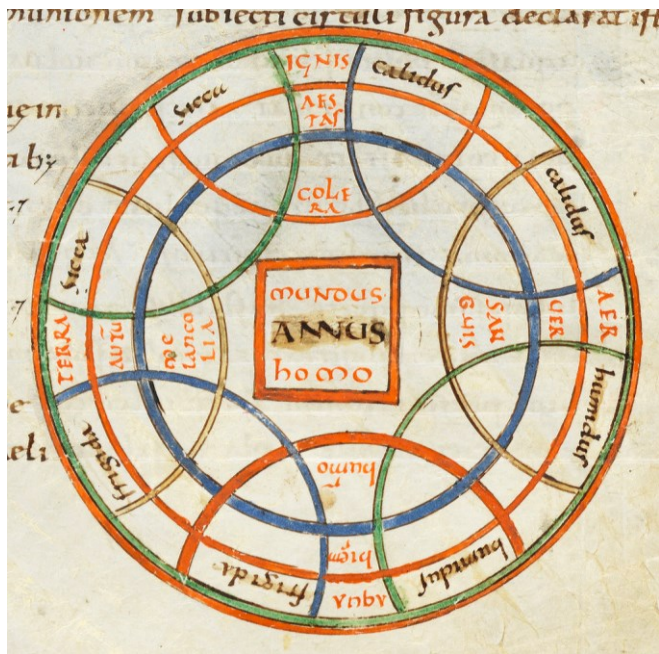


Fig. 2. *Annus - Mundus - Homo* diagram, Isidore of Seville (MS Pa. 32, fol. 62r, Zofingen, Stiftsbibliothek).

January through December, for the twelve radial divisions of the circle. The second ring inward contains Roman numerals followed by the letters *KL*, which specify the number of days that the beginning of the Egyptian month precedes the kalends (*KL*), the first day of the Roman month. The three inner rings may be read from the central roundel outward in the following way to give the number of days in each month in the Julian calendar: *Roman numerals – diebus (days) – month name*. Isidore's *rota* carries with it a less explicitly communicated layer of meaning related to the Roman-Egyptian calendars. Roman calendars represented a computational approach to fixing time, based on a government's authority at preordaining important dates for its population to observe; while Egyptian calendars represented time as a natural phenomenon, experienced as a progression of the sun's movements through the seasons. The Church would eventually take a computational approach [10][11] to accommodate both methods for measuring the passage of time in its calculation of important feast days, and thus affirm its magisterial authority over its followers.

The second *rota* from Isidore's *De natura rerum* is shown in Fig. 2. It is an *Annus-Mundus-Homo* diagram from a manuscript produced at St. Gallen during the second third of the 9th century (MS Pa. 32, fol. 62r, Zofingen, Stiftsbibliothek). This diagram expresses a combination of Greek thought on the nature of the universe and the state of mankind.

The ancient Greek cosmology of Empedocles, Pythagoras, and Plato begins with two properties of matter and their oppositions – hotness and coldness, moistness and dryness. When taken in combination, these properties form the four basic elements (earth (*terra*), air (*aer*), fire (*ignis*), and water (*aqua*)) displayed in logical opposition along the cardinal directions of Fig 2. Fire and water are opposites, as are earth and air. These elements are linked by shared properties. For example, fire and air share the property hotness (*calidus*); water and air share the property moistness (*humidus*), and so on.

Two additional sets of relationships are layered upon the diagram. The first set contains the four seasons: *aestas* (summer), *autumnus* (autumn), *hiems* (winter), and *ver* (spring) displayed as rational opposites around the *rota* in counterclockwise order. The second set is related to the concept of the four humors of Hippocratic medicine used to describe the human temperament. These are exhibited clockwise within the innermost ring of the *rota* as *colera* (bile),

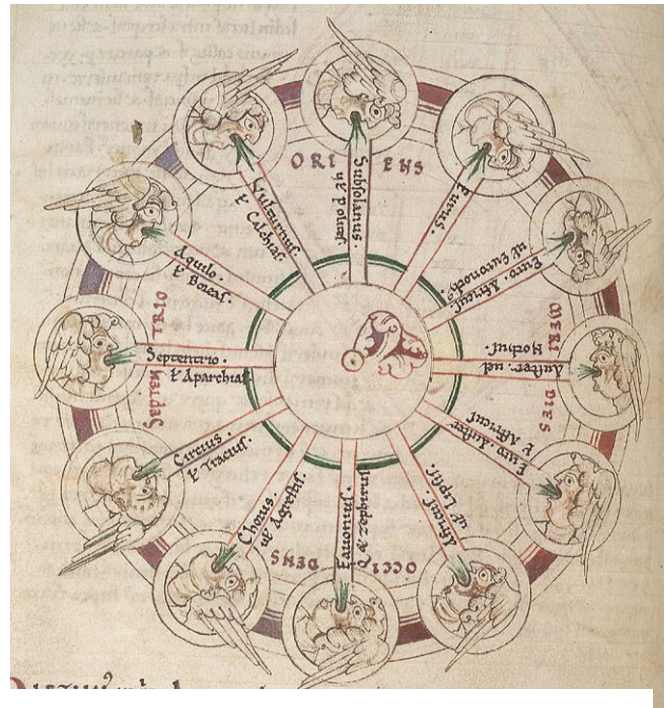


Fig. 3. Twelve Aristotelian Winds (MS Harley 3667, fol. 5v, British Library).

sanguis (sanguine), phlegmatic (here incorrectly given as *humor* instead of *pituuta*), and melancholia (melancholy).

This *rota* aligns the cosmic with the human, promulgating both the ancient Greek notion and Isidore's thesis that man is a small scale (microcosm) parallel of the universe (macrocosm) [12]. It is also a visual schema for guiding multilevel thought. The *rota*'s center points to three levels of engagement: the observer (*homo*), the world (*mundus*), and the year (*annus*). The concentric rings of information underscore the dynamic relationships therein, such as the mobility of elements from *ignis* to *aer* to *aqua* to *terra*; the cycles of the seasons; or the transitions in qualities from *calidus* (hot) to *humida* (humid) to *frigida* (cold) to *sicca* (dry).

The schema's generality lends it to be used for displaying the direction of the winds, temperatures, and more. For example, Fig. 3 shows a *rota* used to display a diagram of the personifications of the 12 Aristotelian winds from a manuscript created during the second quarter of the 12th century (MS Harley 3667, fol. 5v, British Library). In all, *rotae* became the standard means for visualizing a multiplicity of concepts through the fourteenth century.

3 ARC DIAGRAMS

Boëthius, Anicius Manlius Severinus Boëthius (480 – c. 524), along with Augustine and Aristotle, is considered to be the fundamental philosophical author of late antiquity. His treatises on arithmetic, geometry, and music were not only essential contributions to the quadrivium, but also contain a wealth of visualizations. Boëthius believed that visual representation of information was an important pedagogical tool for clarifying concepts. As a result, his works on arithmetic and music are filled with illustrations. Fig. 4 shows a diagram from Book 1 of Boëthius's *De institutione arithmetica* taken from a tenth century manuscript (MS Cod. 358(610), fol. 56, Einsiedeln, Stiftsbibliothek) which he uses as part of a discussion of "the nature of the odd times the even."

At the core of this diagram is a 4 x 4 square array consisting of even numbers that are related through multiplication. Boëthius uses latitude and longitude to designate rows and columns, respectively, and connects these with arcs, each of which is labeled with a number that is the product of two numbers that anchor each arc. For example, the multiplication of far left (12) and right (96) numbers of the top row produces 1152 (*icLii*), the numbers viewed along the apical arc.

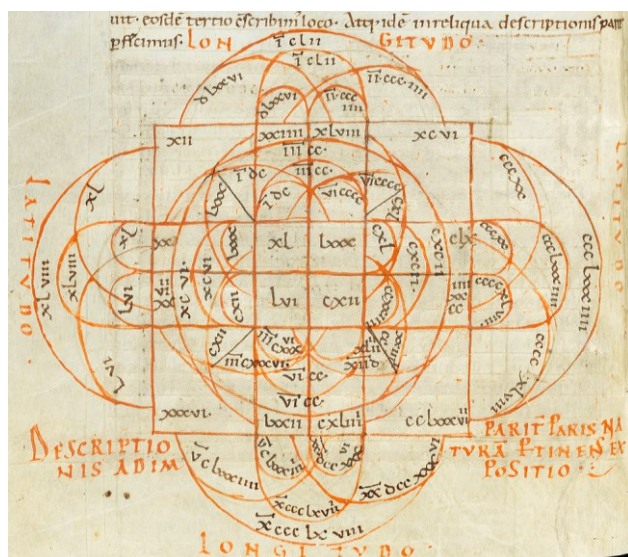


Fig. 4. Arithmetic diagram from Boëthius's *De Arithmetica* (MS Cod. 358(610), fol. 56, Einsiedeln, Stiftsbibliothek).

Arcs are an important part of Boëthius's graphical schema. He uses them in his discussions of arithmetic and geometric ratios, and they are integral to his treatise on music which has its foundation in ancient Greek musical theory. In Fig. 5 Boëthius charts three tetrachord genera for the monochord. The monochord is a single stringed musical instrument invented by Pythagoras to study ratios that eventually became an integral part of medieval music education. A tetrachord is a four note series having a specific pattern of whole and half steps, that served as a basis for Greek and Medieval melodic construction. Here, the three monochord genera are plotted from top to bottom: the diatonic genus (e.g. whole, whole, half steps), chromatic genus, and enharmonic genus. What is immediately noticeable from this image is its overall complexity. It is probably the most complex visualization of early medieval times, and concomitantly the most difficult to craft and understand, even with direct reference to the associated text. Yet, this visualization and nearly all other illustrations in Boëthius' manuscript were copied and disseminated throughout the Middle Ages, making *De institutione musica* the standard musical textbook for over 400 years. Clearly, these illustrations were an important part of musical pedagogy that justified the investment of significant skill and effort required for their reproduction.

4 TABLES

Most early medieval tables were related to physical or natural phenomena that exhibited robust temporal attributes (e.g. astronomical measurements). They were used as well to organize all manner of information, including eclipses, urine samples, regnal lists, etc. (c.f. [3] for a discussion). However, they could be conceptual in nature as well, helping communicate philosophical or theological theories. The Tower of Wisdom is one such example.

The Tower of Wisdom (Fig. 6) from the *De Lisle Psalter* (MS. Arundel 83 II, fol. 135, British Library) is a tabular arrangement of information that appeared in c. 1310. Its design was meant to play an essential role in the medieval art of memory – the utilization of a collection of mnemonic principles and techniques to organize memory, improve its recall, and to enrich the thinking process as a whole [13].

The original concept and design for the Tower of Wisdom came from the Franciscan cleric John of Metz, who created it as a visual aid and object of meditation on moral teaching [14]. Anchored within an architectural frame, the table is meant to be read from bottom-to-top by following an alphabetical sequence of labels. "Humility" is the tower's foundation. Resting upon it are four pillars

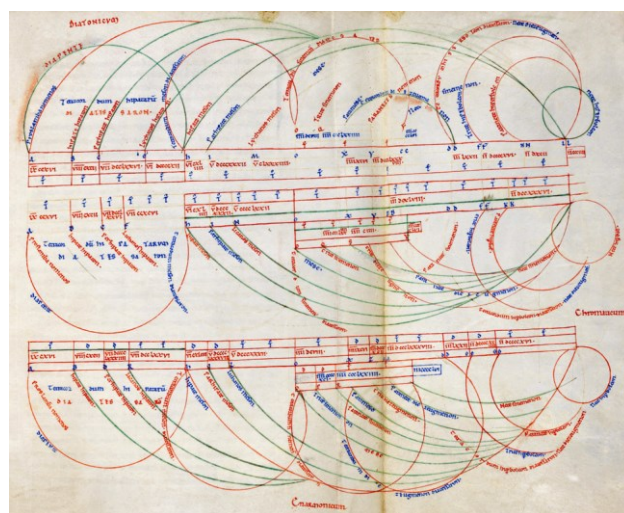


Fig. 5. Musical arc diagrams for the monochord from Boëthius's *De institutione musica* (MS VadSlg. 296, fol. 96r, St. Gallen, Kantonsbibliothek, Vadianische Sammlung).



Fig. 6. Tower of Wisdom (MS. Arundel 83 II, fol. 135, British Library)

representing the cardinal virtues (prudence, justice, fortitude, and temperance) that rise to support the tower. The faithful climb a set of stairs to reach "charity," the underlying truth to all the moral teachings compiled within the tower, and enter it through a doorway labeled "obedience" and "patience." They then ascend the tower

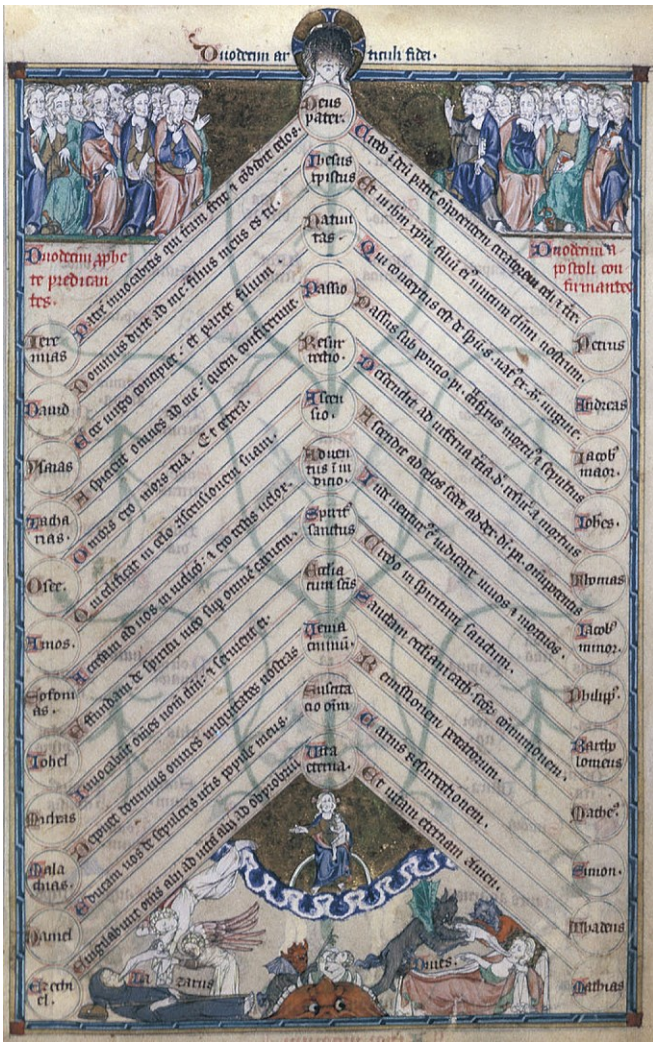


Fig. 7. Articles of Faith, (MS. Arundel 83 II, fol. 128, British Library)

stone-by-stone to ponder the lessons contained within it. The left-most stone in each course renders a guiding principle, such as honesty, compassion, and mercy; each is followed by nine actions related to its guiding principle. One action directs an individual to "be upstanding." Another declares "flee vainglory." Yet another, "reject gluttony."

John of Metz employed the mnemonic "method of loci" as the foundation for his tower. Known sometimes as "memory palace" or "memory walk," this technique relies on memorization of spatial relationships to absorb, organize, and re-call information [14]. The "method of loci" is a memory technique that originated with the ancient Greeks, was exploited by Roman orators such as Cicero [13], and was later revived and taught to medieval clerics, becoming an important part of medieval monastic education. In it, an individual associates the concepts to be remembered with discrete locations within an architectural plan, such as the rooms in a building, binding them with distinguishing locational features or landmarks. The result is a mental image, by definition a visualization, which may be invoked for information recall by having the individual simply conjure up a walk through the building's layout; in John of Metz's case, a walk up the stairs through the doors into the tower.

A second example of a table which organizes concepts is the table of the Twelve Articles of Faith from the *De Lisle Psalter* (MS. Arundel 83 II, fol. 128, British Library) in Fig 7. There are twelve fundamental truths which must be endorsed for someone to be considered a Christian. These truths are laid out in the Apostles Creed. The table arranges this information, linking it to the twelve

apostles and twelve Old Testament prophets. The central column of nodes lists the articles of faith. At its left is a column of Old Testament prophets, and at its right, a column of the twelve Apostles. The central column is connected to each by bands containing supplemental information. For the Apostles, the bands are inscribed with portions of the Apostles' Creed; for the prophets, there are prophesies. The head of Christ resides at the table's head, bounded on the left and right by prophets and Apostles, respectively. At the table's base is a symbolic representation of the story of Dives and Lazarus (Luke 16: 19-34).

The table's angular arrangement of rows is reminiscent of tree structures, such as the tree of life. Indeed, similar arrangements may be found in the *De Lisle Psalter*, such as the tables of the Ten Commandments (f. 127v) and the Seven Works of the Passion (fol. 131). The flexibility of such a design made it useful for three-way information correlations, particularly allowing for the addition of intervening text to create a narrative structure. Yet, "true" tree structures were required for hierarchical ordering.

5 TREES

The use of trees as visualization schema was pervasive throughout the Middle Ages. They were exploited for organizing and representing lists of useful facts such as virtues and vices, books of the Bible, or lineages, so as to make them more amenable to learning [15]. The first example is a tree of vices (Fig. 8). The concepts of virtues and vices have a long history which took hold visually in the High and Late Middle Ages as part of the education of religious and laity into moral and theological concepts important to Christian education. The tree of vices shown here is one of a matched pair, the other being virtues, taken from the Beinecke library's *Speculum theologiae*. Pride is at its root, shown at the tree's base. There are

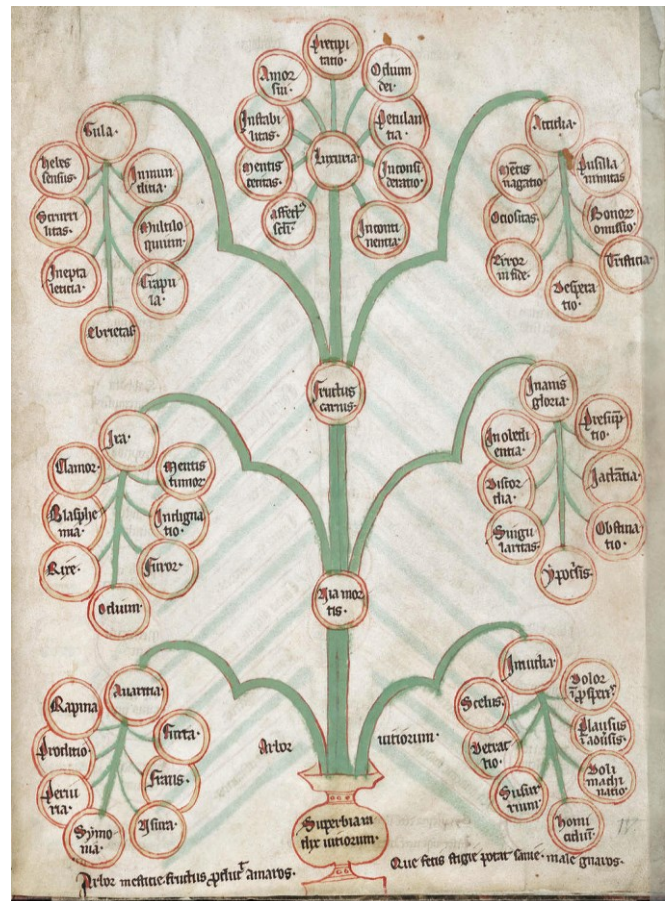


Fig. 8. Tree of Vices (Beinecke MS 416, fol. 4r, Beinecke Rare Book and Manuscript Library, Yale University)

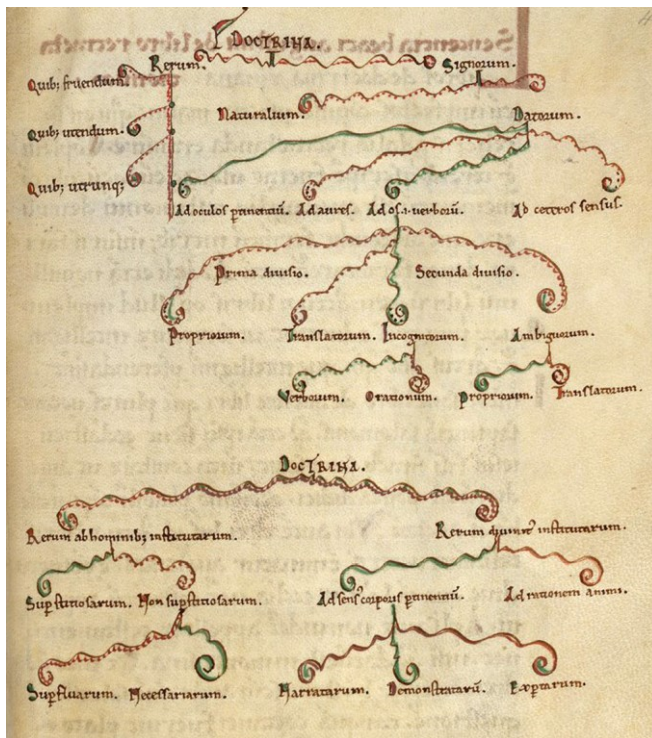


Fig. 9 On Christian Doctrine (1202) (Royal 5 B XII, Part 2, fol. 4. British Library).

seven branches culminating in circular clusters (fruit). Moving up the tree's trunk the reader passes two nodes labeled: "way toward death" and "fruits of flesh," arriving at the apex node of lust, we find it situated between the vices gluttony and sloth. Each major vice is connected to secondary decadent attributes. For example, under gluttony are sensuality, vulgarity, silliness, drunkenness, inebriation, talkativeness, and uncleanness [16]. The organization of vices within the tree is shaped by a number of issues. Avarice became an important vice with late medieval monks, who were acutely critical of the morals of merchants. As a result, it became a foundational vice. Lust was exceptionally problematic for monks, given their vow of celibacy and isolation, so it was placed at the tree's pinnacle [17, p. 67].

Fig. 9 displays a second use of the tree motif. Here, a diagram related to Augustine's (354 –430) *On Christian Doctrine* (1202) (Royal 5 B XII, Part 2, fol. 4. British Library). The diagram was meant to aid the reader. One of the most important books for medieval theologians, it was a systematic theory for explaining in human terms - or interpreting - divine wisdom as communicated via scripture and the natural world. It was often presented in medieval copies with this diagram. 'Doctrine' is shown to have four main branches: things, signs, things instituted by men, and things divinely instituted. The branch below signs, given (or intended) signs, is the most complex because to Augustine it was the most important to interpretation, scripture itself being a series of signs -- given in the most important way, in words -- which had to be correctly and fully interpreted. His theory of signs still influences modern literary criticism.

6 VISUAL ANALYTICS

Prognostication was an important component of medieval visualization. Charts, tables, and infographics were utilized in concert to help predict the future. This process could be as complex as predicting the future date of a movable feast days, or the likelihood of survival of a medical patient. In both cases, visualizations were meant to enhance an individual's analytical reasoning skills. The former example is related to the computus, the

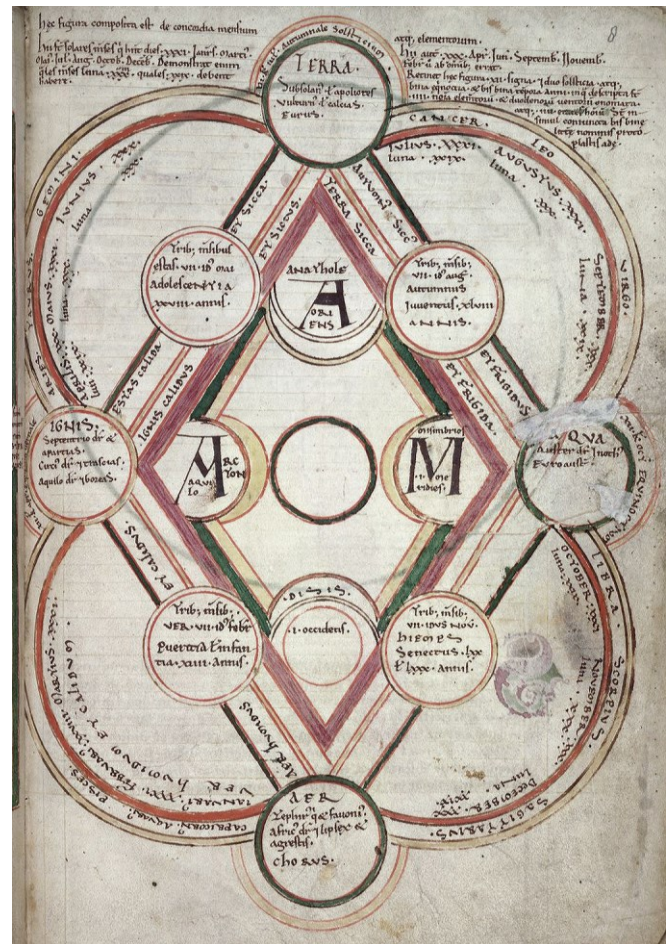


Fig. 10. "Byrhtferth's diagram" (Harley 3667, fol. 8, British Library)

medieval science of reckoning time and fixing the dates of ecclesiastical feasts, particularly Easter (c.f. [3] for a discussion). Although tables were the principal component of this process, charts were used as well. Fig. 10 displays a copy of a "Byrhtferth's diagram," created after 1122 (Harley 3667, fol. 8, British Library), the original being part of the *Thorney Computus* (MS 17, Saint John's College, Oxford). It expands upon the *Annus - Mundus - Homo* diagram of Fig. 2 by overlaying the twelve month zodiac cycle, number of days in each month, dates of solstices and equinoxes, names of the twelve winds, four ages of man, and months associated with either 29 or 30 day old moons. "Byrhtferth's diagram," is considered to be a visual meditation on the cosmic and religious significances of computus, communicating the concord between time and the physical world; which it is. But because its layered data is arranged systematically around the diagram to expose a yearly cycle of correlated information, the *Annus - Mundus - Homo* diagram is transformed into a useful visual tool for easily finding quantitative answers to questions about annual calendric events, without the need to resort to complex table look-up.

Assessing the outcome of an illness was a computistical problem that could involve a calendar, the Sphere of Life and Death, eclipse tables, urine table, additional tables for predicting movable feast days, the altitude of the sun at noon in degrees and minutes, the year in the Paschal lunar cycle, the time of lunar conjunction, in hours, and the location of the sun at sunrise in degrees of the relevant zodiacal sign; a liturgical calendar; lunar tables for determining which sign of the zodiac the moon was in for any day of any month, and which planet ruled over the hours; and correlated tables used to find the degree of the moon in the zodiac signs [18].

Fig. 11 displays a Sphere of Life and Death used to ascertain the outcome of an illness along with its accompanying Latin prose, from

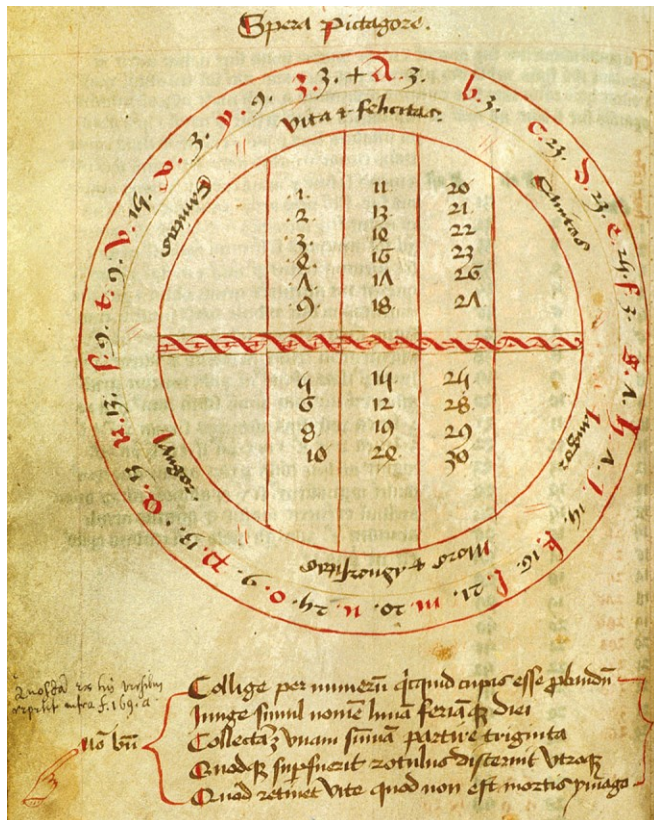


Fig. 11. Sphere of Life and Death (Harley 3719, fol. 175v, British Library).

a 14th century English miscellany of astronomical, calendric, medical, and philosophical texts (Harley 3719, fol. 175v, British Library). The diagram consists of a *rota* with an outer rim displaying number equivalents for each letter in the Latin alphabet. Upper and lower hemispheres comprise three columns that contain the numbers 1 to 30. To predict the outcome of an individual's illness, the number equivalents for the letters in a person's name are summed. To this is added astronomical and calendrical values, the age of the moon at the onset of the illness, and the number assigned to the weekday on which the onset occurred. This result is divided by 30, the number of days in a lunar cycle. Its remainder (modulo 30) is located within the columns. If the value is found in the upper hemisphere, the patient will live; otherwise the patient will die. The illness's duration may be assessed as well by determining which column the remainder is found – either short, intermediate, or long [19, p. 294].

By today's standards these predictions are numerology at best. But, from a visual analytics perspective they were cutting edge for their time. Charts and tables were used in concert with complex computations in attempts to make prognostications that literally could mean life or death. Similar capabilities and outcomes are expected from contemporary visualization systems as well.

7 DISCUSSION

The medieval visualizations discussed here and in [2 – 4] provide only a small snapshot of the kinds of visualizations that appeared during the Middle Ages. Yet, the question may be raised: can exploring the history of medieval information visualization address any contemporary information visualization concerns? One contemporary challenge, and a reason given by the early visualizers – Isidore, Macrobius, and Boëthius, for creating medieval diagrams is education. Their intent was not only to make information easier to understand, but to teach individuals how to use these methods themselves. Another challenge medieval visualizers addressed was the creation of a visualization that clearly represented its underlying

text or narrative, an open problem in contemporary information visualization. Fig. 6, The Tower of Wisdom, and Fig. 7, Articles of Faith, are examples of building narrative structure, here into a tabular visualization. In the latter case, nodes are connected with sufficient text to aide in narrative recall. In the former, the Tower of Wisdom is designed to capitalize on a conceptual representation and memorization scheme that creates a narrative, in this case the "method of loci." Finally, medieval visualizers employed metaphor and allegory as a method for transforming information and knowledge into visual form. The Tree of Vices shown in Fig. 8 is one example, others are found in [4]. The application of metaphor to contemporary information and knowledge visualization remains open territory, and an exploration of medieval manuscripts has the possibility of bearing much fruit.

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