II.3 Time

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The heyday of the republic of letters during the sixteenth, seventeenth, and eighteenth centuries witnessed a profound and protracted upheaval in European timekeeping. The centrepiece of this upheaval was the transition between two calendars (1.1): the Julian calendar – devised under the Roman statesman Julius Caesar and in use throughout the Christian world during the Middle Ages – and the modern Gregorian calendar – devised under the Roman pontiff Gregory XIII and propagated in October 1582, but only adopted in Protestant Europe by fits and starts thereafter, in some cases as late as the mid-eighteenth century. Simultaneously, a number of factors further complicated this calendrical change (1.2). For one thing, the Julian calendar was interpreted and expressed in several different ways. At the same time, alternative chronologies were employed based on the Christian ecclesiastical calendar, and on papal or on regnal years. Still further calendars were in use among non-Christian communities in various times and places. Within such a complicated landscape, inferring calendar usage is a difficult problem in its own right (1.3). Even more intractable is the problem of how to handle dates that are incomplete, uncertain, or lacking altogether (1.4).

The simultaneous use of so many different ways of expressing dates has caused confusion to contemporaries and headaches for historians. These problems are aggravated for anyone attempting to assemble a union catalogue of correspond-

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[1] With thanks to Anna Skolimowska for her helpful examples regarding the dates used in the correspondence of Ioannes Dantiscus, and to Jeannine de Landtsheer for her comments.

ence embracing the whole of Europe during this period of tumultuous chronological transition. An individual correspondence, if brief in duration and local in scope, poses relatively few problems of this kind, and those that do occur can be resolved on a case-by-case basis in free-text annotations. However, a union catalogue encompassing early modern Europe in its entirety needs to confront the problem of the simultaneous use of multiple timekeeping systems in all its complexity. More specifically, a digital catalogue must overcome three interrelated problems if the data emerging from it are to be precise enough to satisfy scholars and unambiguous enough to be analysed and visualized computationally. First, rigorous means must be developed for reconciling all these forms of timekeeping to a baseline standard (2.1). Secondly, computational methods must be devised to determine when individual territories transitioned from one calendar to the next (2.2). Thirdly, in order to pre-process large new sets of incoming raw data, methods are needed to assign calendars to individual letters in a provisional fashion, pending closer editorial scrutiny (2.3). Fourthly, means must be developed for expressing, analysing, and visualizing the chronology of letters that remain uncertain or incomplete (2.4). The first section of this chapter addresses each of these four problems in turn, and the second section proposes solutions to them.

1 Problems

1.1 The Simultaneous Use of Julian and Gregorian Calendars

Miranda Lewis and Dirk van Miert

Prior to the mid-sixteenth century, Europeans shared a calendar sanctioned by ancient pedigree and long usage. The Julian calendar was the result of a reform of the Roman calendrical system instituted by Julius Caesar shortly after his conquest of Egypt. On the advice of the astronomer Sosigenes of Alexandria, Julius's reform prescribed a common year of 365 days divided into twelve months. Since ancient astronomers reckoned the actual solar year to be 365 and one-quarter days, the calendar was synchronized with the sun by adding one extra day every fourth year, known then as an *annus bissextilis* and now as a 'leap year'.[2]

Although an improvement on previous reckonings, this ancient measurement of the year was still slightly inaccurate: rather than 365 days and 6 hours, the average tropical year is in fact 365 days, 5 hours, 48 minutes, and 45 seconds. Whilst imperceptible initially, this difference of 11 minutes and 15 seconds accumulated gradually over time. Each 128 years, the Julian year moved out of step with the

[2] The solar year is the time that the sun takes to return to the same position in the cycle of seasons, for example, from vernal equinox to vernal equinox, or from winter or summer solstice to its equivalent.

solar year by one additional day.[3] As centuries passed, the annual cycle of spring and autumn equinoxes and the summer and winter solstices began to shift across the calendar, wreaking havoc with the seasons and the ecclesiastical calendar. By the sixteenth century, the vernal equinox was occurring around 11 March rather than 21 March, Easter was sliding towards summer, and Christmas towards spring.[4]

The displacement of liturgical festivals within the established calendar was of particular concern to the Catholic Church. During the pontificates of Pope Paul III (d. 1549) and his successors, leading Italian astronomers considered the problem, among them Aloysius Lilius (c. 1510–1576). Recommendations for a solution continued under Pope Gregory XIII (d. 1585), led by the German Jesuit astronomer and mathematician Christopher Clavius (1538–1612). Clavius's work produced a more precise measurement of the length of the average year as 365 $^{97}/_{400}$ or 365.2425 mean solar days; and on this basis he advised that the calendar could be kept synchronized with the seasons simply by skipping three Julian leap days in every 400 years.[5] In addition, to resynchronize the solstices and equinoxes with the seasons, ten days needed to be removed from the year in which the new calendar was instituted. The result of this work is the most widely employed civil calendar in use today, and is known as 'Gregorian' after its patron. Announced on 24 February 1582 in the papal bull *Inter gravissimas*, the transition from the Julian to the Gregorian was mandated to take place in October 1582, with Thursday, 4 October (Julian) to be followed immediately by Friday, 15 October (Gregorian).[6]

Even within the Catholic world, the adoption of the new calendar was not instantaneous. While a number of Catholic countries – including some Italian states,

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[3] To make matters worse, the lunar calendar, used for calculating the date of Easter, was even more inaccurate. Bonnie Blackburn and Leofranc Holford-Strevens, *The Oxford Companion to the Year. An Exploration of Calendar Customs and Time-reckoning* (Oxford: Oxford University Press, 1999), 682, explain: 'whereas after 76 years the solar calendar was about three-quarters of an hour behind the sun, the lunar calendar was nearly 6 hours behind the moon'.

[4] Martin Luther noted that, in 1538, Easter should not have been celebrated on 21 April but rather five weeks earlier on 17 March. He considered reform to be the concern of the Christian princes, who should act in a united fashion to prevent confusion arising both in everyday events, such as traditional markets, and secular business. See Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 632.

[5] See August Ziggelaar, 'The Papal Bull of 1582 Promulgating a Reform of the Calendar', in George V. Coyne, Michael A. Hoskin, and Olaf Pedersen, eds., *Gregorian Reform of the Calendar. Proceedings of the Vatican Conference to Commemorate Its 400th Anniversary, 1582–1982* (Vatican, 1983), 201–39, and P. Kenneth Seidelmann, ed., *Explanatory Supplement to the Astronomical Almanac* (Sausalito, CA: University Science Books, 1992). The approximation of 365 $^{97}/_{400}$ is achieved by having ninety-seven leap years every 400 years. The papal bull stipulated that a year should become a leap year if its number were divisible by four or by 400 but not by 100 unless it may also be divided by 400. The position of the extra day in the leap year was moved from the day before 25 February to the day after 28 February. In addition, new rules for the calculation of Easter were adopted.

[6] The bull was displayed on the doors of St Peter's on 1 March 1582. For the full text, see Christoph Clavius, *Romani calendarii a Gregorio XIII. P. M. restituti explicatio S. D. N. Clementis VIII. P. M. iussu edita. Accessit confutatio eorum, qui calendarium aliter instaurandum esse contenderunt* (Rome: apud Aloysium Zannettum, 1603), 13–5.

Spain, Portugal, and Catholic parts of Poland – followed the papal instructions immediately, removing ten days from October 1582, France, delayed by objections in the Paris *parlement*, removed the ten days between 9 December and 20 December 1582. However, with only months to make arrangements, and with calendars for 1583 already compiled and printed, not all countries made the change as requested. Many, especially those at a distance from Rome, were slow to introduce reform. In the Germanic lands, this new calendar was adopted at varying points in the 1580s, with Catholic states leading the way between 1583 and 1585. Prague arranged adjustments in January 1584, as did the Catholic cantons of Switzerland. Some states of mixed confession took longer: Transylvania removed the days 15–24 December 1590. In addition, a number of Catholic countries or states chose not to follow Rome's directive to the letter: Tuscany adopted the calendar but did not move the start of the year to 1 January until 1700.[7]

Inevitably, in the religious climate of the sixteenth century, Protestant countries and principalities refused to heed a mandate from the pope. A few accepted reform, notably the Duchy of Prussia, where 22 August was followed by 2 September 1612.[8] In the Low Countries, broadly speaking, the Catholic provinces switched calendars in 1582 or 1583. The northern provinces were split: in Holland and Zeeland, 1 January 1583 Julian was followed by 12 January 1583 Gregorian; but the other Protestant provinces chose to employ the Julian until 1700, and Friesland retained the Julian calendar until 1701. To complicate matters further, Groningen adopted the Gregorian calendar in 1583, reinstated the Julian calendar in 1594, and finally returned to the Gregorian reckoning at the time of its adoption by much of Protestant Europe around 1700.[9] In the Swiss Confederation, the Catholic cantons changed in 1583, 1584, or 1597; but the Protestant cantons retained the Julian calendar by and large until 1700. England did not adopt the Gregorian calendar until 1752.[10]

In short, the attempt to impose a new calendar on a confessionally polarized Europe fragmented the continent's timekeeping for 170 years. For well over a century after the papal bull, most Protestant and Catholic communities operated in

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[7] Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 785. Florentine and Pisan styles began the year on 25 March. Florence counted years from the 25 March following the Nativity; Pisa counted years from the 25 March preceding Christ's birth, which resulted in Pisa being one year ahead.

[8] See: Owen Gingerich, 'The Civil Reception of the Gregorian Calendar', in George V. Coyne, Michael A. Hoskin, and Olaf Pedersen, eds., *Gregorian Reform of the Calendar*, 266; Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 685; Friderich Karl Ginzel, *Handbuch der mathematischen und technischen Chronologie* (Leipzig: Hinrichs, 1914; fasc. Repr. Munich, 2015), vol. 3, ch. XIV, 266–79, esp. 271; Paul Botley and Dirk van Miert, eds., *The Correspondence of Joseph Justus Scaliger,* 8 vols. (Geneva: Droz, 2012), vol. 1, lvi–lvii; and Roger Kuin, ed., *The Correspondence of Sir Philip Sidney*, 2 vols. (Oxford: Oxford University Press, 2012), lxv–lxvi, and note. See also Christopher Robert Cheney, ed., *A Handbook of Dates for Students of British History* (Cambridge: Cambridge University Press, 2000), 236–41.

[9] See Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 384.

[10] For this overview, see Walter E. van Wijk, *De Gregoriaansche kalender: een technisch-tijdrekenkundige studie* (Maastricht: Stols, 1932), 56–65.

different time zones, divided not by hours but by ten days, which by the eighteenth century grew to eleven. Expanding the geographical scope to include the Greek and Russian Orthodox worlds extends calendrical discord into the early twentieth century: Russia converted from Julian to Gregorian in 1918,[11] and the Greek Orthodox Church adopted the revised Julian calendar in 1923.[12]

Understandably, there was resistance to change on the part of many Christians who complained that, whilst church feast days remained on the correct numerical date, following removal of the ten days, the feast would be celebrated on the incorrect day.[13] This, in turn, affected traditional fairs and markets.[14] Those who communicated across confessional boundaries faced additional problems: a letter dispatched from Paris on 5 January 1650 might be reckoned by its recipient in London to have been written on 26 December 1649. Confronted by these problems, some writers clarified their dates by marking them as 'new style' or 'n.s.' (Gregorian) or 'old style' or 'o.s.' (Julian). Others removed ambiguity by double dating letters and providing the date in both calendars, for example as "26 December/5 January'. But few adopted such conventions consistently. In consequence, letters might appear to have been received before they were written; and people moving across international borders appear to time-travel: William of Orange left the United Provinces, which used the Gregorian calendar, on 11 November 1688 but arrived in England, which used the Julian, on 5 November.

[11] Russia continued to employ the Julian calendar and, after 28 February 1800, its difference from the Gregorian calendar grew to twelve days. This continued to cause problems into the early twentieth century: In 1908, for instance, the Imperial team arrived in London twelve days too late for the opening of the Olympic Games. See Edward G. Richards, *Mapping Time: The Calendar and Its History* (Oxford: Oxford University Press, 1999), 247. The Gregorian calendar was implemented in Russia on 14 February 1918 with the elimination of the Julian dates of 1–13 February 1918 by order of a Sovnarkom decree signed by Vladimir Lenin on 24 January 1918 (Julian). Subsequent plans called for the abolition of the Christian week altogether and its replacement with a ten-day week, in the manner of the French Revolutionary calendar, but these plans were not realized (Richards, *Mapping Time*, 277).

[12] The Greek Orthodox Church adopted the Revised Julian calendar in 1923. See Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 687.

[13] See Heribert M. Nobis, 'The Reaction of the Astronomers to the Gregorian Calendar', in George V. Coyne, Michael A. Hoskin, and Olaf Pedersen, eds., *Gregorian Reform of the Calendar*, 243–54; Michael A. Hoskin, 'The Reception of the Calendar by Other Churches', in George V. Coyne, Michael A. Hoskin, and Olaf Pedersen, eds., *Gregorian Reform of the Calendar*, 255–64; Gingerich, 'The Civil Reception of the Gregorian Calendar', 266ff; and Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 684.

[14] Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 684–5. For the fairs and festival days affected in England, see also Robert Poole, '"Give Us Our Eleven Days!": Calendar Reform in Eighteenth-Century England', *Past & Present* 149:1 (November 1995): 95–139, esp. 121–9. See https://doi.org/10.1093/past/149.1.95.

1.2 Additional Calendars and Dating Conventions

Miranda Lewis and Dirk van Miert

The disparity between Julian and Gregorian calendars was not the only source of confusion. Further complexity was created by varying conventions within the Julian calendar itself, especially regarding the day on which a new year commenced. The Roman calendar began on 1 January, but in medieval Europe the Church moved the start of the year to 25 March, the Feast of the Annunciation also known as Lady Day, perhaps in an attempt to differentiate itself from the calendar of its pagan predecessors. Thus 24 March 1581 would be followed by 25 March 1582.

By today's reckoning (proleptic Gregorian), the year has always started on 1 January.[15] At the time, however, depending on where you lived, it might not. In Venice, the new year began on 1 March, and this practice was retained in official documents until the Republic fell to French forces under Napoleon in 1797.[16] In England, Florence, Naples, Pisa, or Scotland, the year began on 25 March. Elsewhere, the new year fell on Easter Day, or 24 or 29 September (respectively the equinox or Michaelmas, the Feast of Michael and All Angels). In certain German and Italian states, 25 December (Christmas Day) was when the year turned. Within France alone, the year began on one of these four different days depending on the region. From the sixteenth century onwards, however, some countries – although by no means all – moved the day the year changed to 1 January; others, including England, continued to use 25 March. By the time the Gregorian calendar was introduced in 1582, a handful of countries (both Catholic and Protestant) had made this change already: for example, France had begun to count the year from 1 January in 1564. Simultaneously, other countries persevered with a different start of the year: England did not begin the year on 1 January until it made the switch to the Gregorian system in 1752. Scotland, by contrast, switched the start of the year in 1600 but retained – with England – the use of the Julian calendar. Thus, a man in Paris might date his letter 30 January 1650 and upon receipt this might be recorded in London as having been dated 20 January 1649, or in Edinburgh as 20 January 1650.[17]

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[15] Working back in this manner is called proleptic Gregorian; see Richards, *Mapping Time*, 251; and *Data Elements and Interchange Formats – Information Interchange – Representation of Dates and Times ISO 8601*, 3rd edn. (2004), 8.

[16] Leofranc Holford-Strevens, *The History of Time: A Very Short Introduction* (Oxford: Oxford University Press, 2005), 128.

[17] Ironically, the bull issued by Gregory is itself a casualty of these confusions. It was signed and dated: 'Datum Tusculi, anno Incarnationis dominicæ MDLXXXI, sexto Kalendas Martii, pontificatus nostri anno X'. Converting from the Roman calendar, 'MDLXXXI, sexto Kalendas Martii' is 24 February 1581 in the Julian calendar, using the year start of 25 March; it is 24 February 1582 when using the Julian calendar using the 1 January year; and in the proleptic Gregorian calendar the date is 6 March 1582.

These complications were compounded still further by classically trained scholars keen to show off their erudition. Many of the citizens of the republic of letters continued to date their letters by the Roman calendar. To some, no doubt, using the Roman systems was merely a consequence of a desire to write in consistently classical Latin; but the practice was not confined to humanist epistles or even to those written in Latin, and many instances survive of letters that use the Roman calendar having been written in the vernacular.[18] To navigate the chronological labyrinth of early modern epistolography, the scholar must also understand how to convert Roman dates into Julian or Gregorian.

The Roman calendar differed from the form of Julian adopted in the Middle Ages in a number of important respects. By the time of Julius Caesar, it was divided into twelve months, beginning with January (Janus, to whom this month was dedicated, was the god of transitions), and the months were subdivided further into an arrangement based originally on the phases of the moon.[19] The kalends, the nones, and the ides made up the three distinctive sections: kalends set the first day of a month (it had once marked the new moon); ides (which had been based on the full moon) fell in the middle of the month, namely the 13th or the 15th, depending on the month; nones occurred nine days before the ides, but it is important to remember that Roman practice was to count inclusively and thus nones (which means 'nine') is actually eight days before the ides.[20]

Within each section of the month, days in the Roman calendar were named by counting backwards (once again, counting inclusively). Those between *Kalendae* and *Nonae* were called: 'the day before *Nonae*'; 'the 3rd day before *Nonae*' (with no '2nd day before *Nonae*' because *Nonae* itself was the first day, and thus 'the 2nd day before' and 'the day before' were one and the same); 'the 4th day before *Nonae*'; and 'the 5th day before *Nonae*'. Days between *Nonae* and *Idus* were numbered similarly to 'before *Idus*', while days after *Idus* were counted inclusively to before the *Kalendae* of the following month. In leap years, the *dies bissextus*, or extra day, was inserted before 'VI Kal. Mar'.[21]

Given the complexities across Europe associated with the date selected as the start of the year, it is unsurprising that, in the Roman calendar, scholars of the early modern period today encounter problems associated with the dates in the latter

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18 See, for example, the letter from William Stukeley to Edward Wilson, 25 July 1725, written in English with the date recorded as '8 Calend. Aug. 1725' (Bodleian Library, University of Oxford: MS Don. d. 90 p. 132 [no. 44]).

19 January and February as months had been added on 500 years previous to Julius Caesar's reform; until then there had only been ten months in each year. Under the Julian reforms, while the names of the months were retained, the number of days in most of them were changed, and an additional day was inserted every four years. Additionally, the year 46 BC was adjusted and the year contained 445 days. See Richards, *Mapping Time*, 214.

20 Inclusive counting reckons the day from which you are counting as day one (rather than taking the day before as day one).

21 For a more detailed explanation, see Richards, *Mapping Time*, 210–11, and Cheney, ed., *A Handbook of Dates*, 145.

part of December. When a letter is dated in the Roman calendar 'VIII Kal. Jan. 1642', this could be 25 December 1642, or it could be 25 December 1643, depending upon which Julian year start was being employed. While some early modern individuals believed that the year given in the Roman kalends of January was the one in which they were writing, others maintained it specified the following year (that is, the new year in which the kalends of January fell and from which they were counting backwards, and assuming they were in a country that used 1 January as the start of the year).[22]

These three distinctions – between Julian and Gregorian calendars; between the various beginnings of the new year; and between Roman and Julian/Gregorian dating styles – are the most common chronological complications to confront the student of early modern learned letters. But they are not the only ones. Within Christian Europe, dates are sometimes expressed with reference to liturgical calendars,[23] saints' days,[24] or papal or regnal years.[25] Outside the Christian community, specialists encounter dates expressed in the Islamic[26] or Jewish calendars.[27] There were dating systems such as the French Republican calendar imposed by political regimes,[28] or others, for example the Masonic calendar, employed solely by members of a specific organization.[29] These are just a few instances of the dating systems in use in the period.

[22] For specific examples and further clarification, see Botley and van Miert, eds., *The Correspondence of Joseph Justus Scaliger*, vol. 1, lviii. But early modern writers themselves were not consistent, and Botley and van Miert cite the example of letters written and dated by Scaliger on the same day and caution scholars to 'flag as uncertain the year of every Roman date between the 14th and the 30th of December (that is, from XIX Kal. Jan. to III Kal. Jan.) unless it can be dated securely by other evidence'.

[23] See Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 757–9.

[24] For example, the letter from Ioannes Secundus to Ioannes Dantiscus of 21 February [1532] is dated 'pridie Petri Vincti' (see *Corpus of Ioannes Dantiscus' Texts & Correspondence*, http://dantiscus.al.uw.edu.pl/?f=letterSummary&letter=756, accessed 20/03/2019). When calculating a date from a saint's day, a scholarly eye is often required. Which St John, for example, is being referenced: St John the Evangelist or St John the Baptist? Identification often depends upon the region in which the letter originates.

[25] Regnal years (calculated from an accession date) are not always as straightforward as might be imagined. For example, there is problem with Charles II, who counted his reign from 30 January 1649 (or 30 January 1648 by the Julian English calendar), when his father was executed, while others count it from the Restoration of the monarchy in May 1660.

[26] See Richards, *Mapping Time*, 232–5; and Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 731–5.

[27] See Richards, *Mapping Time*, 220–30; and Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 722–30.

[28] See Blackburn and Holford-Strevens, *The Oxford Companion to the Year*, 742–5.

[29] Although a number of Masonic dating systems exist, that of the *Anno Lucis* is used most widely in documentation. *Anno Lucis* is based on the chronology calculated by Archbishop James Ussher (1581–1656) that dates the creation to 23 October 4004 BC and involves adding 4004 to the year.

1.3 The Difficulty of Inferring Calendar Usage

Miranda Lewis and Dirk van Miert

The problems arising from the simultaneous use of multiple calendars are not confined to the technical difficulty of reconciling them with one another. As we shall see, reconciliation of this kind is a purely technical issue, to which definitive solutions exist. More intractable is a secondary difficulty, arising from the fact that letter-writers normally fail to indicate which calendar they are using.

In the absence of this information, previously it has been left to the scholar to deduce which calendar is employed in any particular letter. In relatively localized exchanges – between people in the same country sharing confession and homeland with one another – this is often unproblematic: the calendar employed can be safely assumed to be the one in official use at the time and place in which the letter was written.

When corresponding across national and confessional boundaries, however, letter-writers may decide, for a number of reasons, *not* to adopt the calendrical norms of the place from which they write. Travellers writing home, for instance, might adopt the conventions of their home country rather than those of the country from which they write. Diplomats or merchants might decide to adopt the calendar of their home country even when writing to countrymen who are also abroad. Early modern individuals clearly associated the two calendars with the two main confessional blocks: a letter from one Pieter Corneleszn in Alkmaar to the ministers of the Dutch Church in London is marked with the date 'desen 11 May 1586 stilo papali'.[30] Learned writers might adopt the calendars used by their addressee's confession as a courtesy. A vivid example of the resulting difficulties can be found in the correspondence of the early seventeenth century's foremost chronologer, J. J. Scaliger.

On 13 August 1602, Scaliger wrote two letters to two of his regular correspondents. Both resided in Augsburg. Both letters may be assumed to have been consigned to the same courier. The letter to David Hoeschelius, who was a Protestant, Scaliger dated 'III Non. Augusti Iuliani'. The letter to Marcus Welser, who was a Catholic, he dated 'Idib. Augusti', adopting the Gregorian calendar. Augsburg was an imperial free city inhabited by Catholics and Protestants alike; and Scaliger evidently expected these two confessional communities to use different calendars, and dated his letters accordingly. The ease with which he slipped between these two calendars should serve as a warning to editors to tread very carefully in this area.[31]

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[30] See Jan H. Hessels, ed., *Epistulae et tractatus cum reformationis tum ecclesiae Londino-Batavae historiam illustrantes: Ecclesiae Londino-Batavae archivum*, vol. 3, pt. 1 (Cambridge, 1897), 819, letter 1016.

[31] Botley and van Miert, eds., *The Correspondence of Joseph Justus Scaliger*, vol. 1, lvii.

In circumstances such as these, inferring calendar use is a speculative problem, and different scholars have employed very different methods of addressing it. One logical possibility is to convert all the dates of their letter headers into the Julian calendar.[32] The opposite procedure is to convert everything to Gregorian.[33] A third approach is consistently agnostic: simply to record the date as marked and not attempt to guess which calendar was used.[34] Within the domain staked out by these three logical options, a number of hybrid solutions exist. A fourth practice is to adjust to Gregorian whenever possible, while leaving dates as marked in doubtful cases.[35] A fifth alternative is to give both calendar dates in the letter header whenever possible and to infer from the place of sending which calendar has been used in any specific instance, again leaving the date as marked wherever there is doubt.[36]

This diversity of practice raises a third set of issues for anyone attempting to assemble a union catalogue from multiple scholarly editions and inventories. If a union catalogue is to be created by merging all of these inventories and many more, a common standard must be developed. Moreover, if the data in such a union catalogue is to be subjected to automated analysis and visualization, agnosticism regarding calendar use must be minimized. The reason for this is that large-scale digital analysis and visualization accommodates less ambiguity than traditional textual scholarship. In print editions, delicate issues of judgement can be handled in detailed prose annotations, which then inform the reading of relatively small numbers of letters. When doubts persist, the safe option is simply to mark the calendar, and therefore the date, as unknown. But when analyzing and visualizing large corpora of letters computationally, free-text discussion cannot be reliably parsed, and sidestepping uncertainty causes more problems than it solves. In most cases, there are grounds for regarding the use of one calendar as more probable than another; and the analytical distortion caused by incorrectly inferring calendar use in some cases is far smaller than that caused by setting aside all letter records for which the calendar cannot be identified with certainty.

For all of these reasons, the compilation of a union catalogue of correspondence requires a consistent method for making clear and defensible inferences regarding calendar use from the available data. Such a method should mirror the inferences made by scholars themselves. It should also be capable of distinguishing between more and less certain inferences, and should record the security of its

[32] As, for example, in A. Rupert Hall and Marie B. Hall, eds., *The Correspondence of Henry Oldenburg*, 13 vols. (Madison, WI: University of Wisconsin Press; London: Mansel; London: Taylor & Francis, 1965–86).

[33] See, for example, in G. Anton C. van der Lem and Cornelis S. M. Rademaker, *Inventory of the Correspondence of Gerardus Joannes Vossius (1577–1649)* (Assen and Maastricht: Van Gorcum, 1993).

[34] See the example of Roger Kuin, ed., *The Correspondence of Sir Philip Sidney*, 2 vols. (Oxford: Oxford University Press, 2012).

[35] As has been done in the Scaliger edition, see Botley and van Miert, eds., *The Correspondence of Joseph Justus Scaliger*.

[36] See the dating policy adopted in Noel Malcolm, ed., *The Correspondence of Thomas Hobbes*, 2 vols., The Clarendon Edition of the Works of Thomas Hobbes (Oxford: Oxford University Press, 1994).

inferences in a manner readable by both humans and machines. Although capable of being manually overruled by scholarly editors, such a method must also be capable of computational treatment for two reasons. On the one hand, some degree of automation will be necessary in order to standardize retrospectively tens of thousands of records already accumulated. On the other, distributed infrastructure will make automation even more necessary. The capacity to pool the results of multiple catalogues, inventories, digital archives, and libraries of printed and manuscript correspondence will generate letter records for curation on a vast scale; and these will only be processed efficiently if preliminary standardization is undertaken computationally, pending further refinement by scholars.

1.4 Incomplete and Uncertain Dates

Thomas Wallnig, Arno Bosse, and Miranda Lewis

The problems that arise when contemporaries fail to indicate which calendar they are using are a subset of the far larger problem of incomplete dates. When a letter includes a complete date but fails to specify the calendar used, then the data is incomplete, and systems need to be developed to complete it. Once the missing data is supplied (that is, once the calendar is tentatively identified), a separate tool can establish automatically the unique, unambiguous, and precise relationship between a date as given and a date in the proleptic (modern) Gregorian calendar.

Analogous but far more intractable difficulties arise when the date provided is itself incomplete, whether or not a calendar is specified. For instance, in some letters, a day and month is specified but not a year. In others, reference is made only to a day of the week, without day, month, or year. On other occasions, a feast day and year are provided, without mentioning day or month. Written notes that are part of a local communication system, within a town or a court for example, may only record an hour or a part of the day. Further chronological difficulties arise for letters that were not, in fact, written on one particular day. For example, a precise date might be recorded for the drafting of a letter, but not for the production of the final copy as sent. In other cases, letters could be composed over several days, thus requiring a 'date range' rather than a single date.

Still more awkward are the numerous letters in which no date of any kind is provided, whether because the writer failed to include it, or because it was left out by a copyist, or because part (or indeed all) of the letter has been lost. In such cases, dating must be inferred speculatively with varying degrees of certainty in many different ways: from the date of receipt; from the date at which a response was written; from the place of a specific letter in a sequence; from references to the letter or its content in other documents; or from dateable details of the content of the letter itself.

These problems and many more bedevil the ascription of precise and certain dates to innumerable early modern learned letters. Since uncertainty arises from many different sources, many different patterns of inference are needed to date undated letters and many different degrees of uncertainty arise from these inferences. In a traditional hard-copy edition or inventory, these inferences can be articulated at length one at a time. In order to analyse and visualize large quantities of correspondence metadata, however, standard means are required for representing both uncertain and incomplete dates and for the inferences involved in attempting to clarify or complete them.

2 Solutions

Arno Bosse and Howard Hotson

The complexities of competing calendrical systems encumber the proper dating of letters by the lone scholar. The problems posed by these complexities are greater still when a union catalogue is being compiled from multiple sources and huge numbers of letter records need to be processed. Before proposing solutions to these problems, we first need to divide these complexities into manageable parts.

In essence, three different problems are entangled together. The first problem is that of converting dates from one known calendar to another. For this procedure, reliable solutions are available (2.1). The second problem is to determine which calendars are in use in individual places at specific times. For this purpose, new resources are needed, such as the gazetteer proposed below, which indicates when specific places transitioned from one calendar to another (2.2). The third and hardest problem is to develop procedures for provisionally inferring the calendar employed in any individual letter and for assigning a degree of certainty to the inference (2.3). Each of these three components will now be discussed in turn.

2.1 Converting between Calendars

Arno Bosse

Individual tools for converting dates from one known calendar to another already exist. For converting between Julian and Gregorian dates, resources are readily available. These include tools both for developers seeking to create their own applications and for researchers, editors, and other users employing free conversion utilities on the web. Other tools can handle the Roman and Latin versions of the

Julian calendar, including those using Roman numerals.[37] Individual tools likewise exist for calculating the date of the Jewish Passover, Easter Sunday, and the other dates of the ecclesiastical calendar dependent on them,[38] and for handling the Hebrew, Islamic, French Revolutionary, and other calendars as well.[39] For developers, online resources such as *World of Science*,[40], and print references such as Reingold and Dershowitz's *Calendrical Calculations*,[41] explain the historical and mathematical context and provide the algorithms for converting dates between a wide range of calendrical systems. Open-source software libraries and applications implementing these conversion routines can readily be found on *GitHub* and other public-code repositories.

There is thus no lack of individual software solutions for converting dates between calendars. What is currently lacking is a well-maintained, centrally accessible resource providing facilities for three sets of uses: (1) a webform for converting dates while individual letter records are input by scholars; (2) a facility, based on spreadsheets, for converting calendrical data when large numbers of letter records are ingested by a catalogue data editor; and (3) the well-documented API and data exchange format needed by developers. As a starting point, such a resource would need to be capable of dealing with all widely used early modern calendar dates, that is, Julian, with year starting 25 March; Julian, with year starting 1 January; Gregorian; Roman; Hebrew; and Ottoman. Subsequent extension could include more complicated conversions, for instance, from the liturgical calendar.

2.2 Tracking Calendar Usage in Specific Places

Arno Bosse

As well as these tools for converting between calendars, resources are needed for determining which calendars were in use in specific times and places.

The background functionality for such a tool will be provided by *EM Places*, the historical gazetteer for the early modern period currently under development at *Cultures of Knowledge*.[42] As discussed in more detail in the previous chapter, *EM Places* will offer a database of political-administrative place entities or 'polities' containing data on when these polities existed historically and where they were situated at any given time within hierarchies of larger and smaller polities. Every specific

[37] See http://www.csgnetwork.com/julianmanycalconv.html; http://www.softhawkway.com/rcalc.htm, and the electronical version of the classic Grotefend, http://bilder.manuscripta-mediaevalia.de/gaeste/grotefend/grotefend.htm, both accessed 20/03/2019.

[38] See https://www.staff.science.uu.nl/~gent0113/easter/easter_text2a.htm, accessed 20/03/2019.

[39] See http://www.fourmilab.ch/documents/calendar/, accessed 20/03/2019.

[40] See Edward M. Reingold and Nachum Dershowitz, *Calendrical Calculations. The Ultimate Edition.* 4th edn. (Cambridge: Cambridge University Press, 2018).

[41] See https://doi.org/10.1017/9781107415058.

[42] See https://github.com/culturesofknowledge/emplaces, accessed 20/03/2019.

place recorded in the gazetteer – for example, a city from which a letter may have been sent – will be situated within one of these political-administrative hierarchies.

In order to track calendar usage in individual times and places, *EM Places* will also record the dates at which individual polities transitioned from one calendar to another (specifically, between the Julian calendar with different dates for the start of the year, and from Julian to Gregorian). In this way, when metadata are inputted or uploaded indicating that a letter was sent on a particular date from a particular place, *EM Dates* will be able to draw on *EM Places* to determine which calendar was in use in that place at that time.

As noted in the previous chapter, it is not expected that *EM Places* will be populated with a comprehensive data set for all European places at the outset. For instance, the difficult task of generating a consensus on the shifting hierarchical relationships between geographical entities will only be accomplished gradually over time. Likewise, it will not be possible initially to supply comprehensive data on dates of calendrical transition for all regions of Europe. Instead, a first stage of work will prioritize large polities where political authority was well consolidated by the late sixteenth century (such as France and England) and regions containing towns and cities from which the largest numbers of letters were sent or received. In this way, data on the main centres of intellectual communication can be provided within a manageable initial data set. No less importantly, a structure will have been provided within which the scholarly community can pool its expertise to enhance this data to better serve its needs. In other words, this aspect of *EM Dates* and *EM Places* is not a ready made service, furnished with a comprehensive data set at launch: instead, like EMLO, it offers a framework within which the scholarly community can collaborate in creating the resources it needs. In the meantime, an incomplete set of calendrical data represents an improvement on the current situation, in which chronological data typically fails even to identify the calendars used, much less to reconcile dates in different calendars with one another.

A related challenge will be to decide how to handle places for which no reliable information on calendrical usage is readily available. In such cases, two general axioms will be applied in the absence of historical information to the contrary. The first is that, within polities in which political and ecclesiastical authority is well consolidated, subordinate polities transition between calendars at the time dictated by superordinate authorities. For instance, Munich, Ingolstadt, and all the other towns and cities of Bavaria transitioned from Julian to Gregorian at the same time as the duchy that governed them; and the same transition was affected in the Upper Palatinate when it was annexed to Bavaria during the Thirty Years' War. The second axiom is that, in the absence of any other information, it will be assumed that all Roman Catholic territories transition from Julian to Gregorian on 15 October 1582, and that all non-Roman Catholic territories do not. Although this is of course a gross oversimplification, it will still provide a more adequate starting point than making no claim at all. When data reveals that a specific historical polity (e.g. the 'Duchy of Opole') transitioned at a later date (in this case, January 1584), the first axiom implies that all the polities *below* it (e.g. the town of Opole) also transitioned at that date, while the second axiom implies that assumptions about calendrical usage in the polities *above* it in the hierarchy remain unchanged. As *EM Places* is populated with an increasingly comprehensive data set on calendrical usage, any anomalies initially arising from these assumptions will gradually disappear.

2.3 Inferring Calendar Usage in Individual Letters

Howard Hotson

The most difficult of these problems is that of identifying which of the two homologous calendars and their various interpretations was used in any individual letter. Detecting the use of the Roman, ecclesiastical, Jewish, or Islamic calendars is easy, since each records dates in a different fashion. However, Julian (irrespective of which day marks the start of the year) and Gregorian calendars all record their dates in the same way – that is, in terms of years ('anno Domini') and sequentially numbered days of the month – making it impossible to determine at first glance which is being used. Unless the letter explicitly indicates which calendar is used, which calendar was used must be inferred from the contextual data available, hence the need for a tool for provisionally inferring calendar use from contextual data, pending further scholarly scrutiny.

The purpose of such a tool is four-fold. First, it should aim to replicate the most simple and straightforward inferences made by scholars. Second, when the data is inadequate for confident scholarly assertion, it should supply a reproducible 'best guess'. Third, since not all of these inferences will be equally robust, the tool should also indicate the confidence of the inference in a manner legible to both computers and human users. Fourth, the tool should also be capable of provisionally assigning calendars to letters automatically when ingesting or retrospectively standardizing large quantities of unedited letter records.

How then to devise a tool capable of performing these functions? The starting point is the acknowledgement that an inference depends on the data available. When little data are available, the inference may be simple but insecure. When more data is available, the inference may be more complicated, but also more certain. The following discussion first treats the most basic pattern of inference employed by scholars and then considers how to render it computational.

In the simplest cases, the only data available for automatic analysis are the places and dates contained in the letter records themselves. When only date and place of sending are known, the inference is simple but insecure: the calendar employed is most probably the one standard at that place and time at which it is written, but the confidence level of this inference is relatively low. When the place of both sending and receipt are also known, a more complicated inference is required. If both places use the same calendar, the use of that calendar can be inferred with a higher degree of confidence. If the two places use different calendars, however, the calendar in use at the place of sending remains the more probable inference, but confidence in the inference is lower than in either of these two other cases.

A more sophisticated tool might also analyse data contained in the person records of each of the two correspondents. A basic person record contains dates and places of birth and death. Places of birth and death can help determine whether the countries from and to which a letter is written are the long-term places of residence of the two correspondents, and doing so is useful for inferring calendar usage. This possibility would produce six separate geographical reference points: the places of birth and death of the two correspondents and their places at the time of correspondence. If all six of these data place both correspondents in regions using the same calendar, then the probability that they are using that calendar is very high. If, on the other hand, these six geographical data points are mixed, their relative weight must be measured. Consider, for instance, a letter written from Utrecht to Venice in 1620. Judging from the places of sending and receipt alone, we might conclude (with a low level of confidence) that the letter uses the Julian calendar. However, if person records indicate that both sender and recipient were born and died in Venice, then the greater likelihood is that they are using the calendar in official use in their home city, that is, the Gregorian.

This discussion suggests a basic mechanism for inferring probable calendar usage and measuring the confidence of the inference. In a somewhat simplified version of this basic model, only four factors are in play (aside from the date of sending): these are the places of sending and receipt, and what might loosely be called the *patria* (or homeland) of the sender and recipient.[43] These four factors need to be weighted differently. The active party (the letter-writer) is more important in choosing which calendar to use than the passive party (the recipient); so the location and *patria* of the sender must count more than those of the recipient. The location (of writer and recipient) might also be treated as more important than their homeland (since the most convenient thing for any contemporary is to follow the timekeeping practices of one's locality).[44]

Precisely how these four factors would be weighted requires careful study. The first step in such a study would be to mock up a set of metrics and test the results against scholarly intuition and eventually empirical data. To begin this process:

[43] 'Nationalities', in turn, are indicated by places of birth and death, but these can be treated as unitary to simplify the initial construction of the model.

[44] In determining 'nationality', place of birth counts more than place of death.

- Location of sender (the most important datum) is assigned 4 points.
- Location of recipient (less important than location of sender) is assigned 3 points.
- Nationality of sender (the next most important factor) is assigned 2 points.
- Nationality of recipient (the least important of these four factors) is assigned 1 point.

The results of this exercise are displayed in figure 1.[45] The rows of the table indicate all the possible combinations of the four factors on which the calculation is based. The first factor (location of sender) is weighted 4, the second (location of recipient) 3, the third (nationality of sender) 2, and the fourth (nationality of recipient) 1. In columns 1 through 4, the letters 'A' and 'B' stand for the two calendars in contention. Column 5 then sums up the points registered in columns 1 through 4 in favour of calendar A. Column 6 then expresses this confidence level with colour rather than a number: colour is deployed here to avoid the impression that this is a precise calculation of probability, and to provide a code which can be used in visualizations.

The maximum confidence level (bright green) is reserved for row 40, where all four columns indicate that both correspondents are located in and indigenous to a *patria* using the same calendar. The minimum confidence level (bright red) is reserved for the two instances (rows 20 and 34) in which equal points are recorded for both calendars: for instance, row 20 describes a correspondent of unknown origin writing from a region using calendar A to a correspondent who is both located in and indigenous to a region which has adopted calendar B.[46] The two instances in which a negative number is returned in column 5 indicate that the preponderance of data suggests that calendar B might be used, despite the location of the letter-writer in a region using calendar A. Between these two extremes, the moderate levels of confidence (3–6) can be produced by many different combinations of factors. Row 4, for instance, totals 4 points because the only datum available is the location of the sender; and row 37 likewise registers the same moderate level of confidence because this is an instance of a letter written from the home country to a countryman travelling abroad.

[45] This chart simplifies the calculus in two important respects. First, it assumes that there are only two calendars at play in the calculation, whereas sometimes there may be three: old and new-style Julian as well as Gregorian. Second, it assumes that places of birth and death indicate the same 'nationality', whereas in fact these may differ. Removing these possibilities reduces the number of permutations dramatically, allowing the method employed here to be illustrated and studied. Once the basic principles are understood, this additional level of complexity could easily be entered into a computational version of this model.

[46] This is a very useful outcome, since it means that in all but two of these thirty-seven cases there is a balance of probability in favour of one calendar or the others, which helps to render the data analysable and visualizable computationally.

		1	2	3	4	5	6
	Data	**Location**		**Patria (homeland)**		**Confidence level**	
		of sender (weight: 4)	**of recipient** (weight: 3)	**of sender** (weight: 2)	**of recipient** (weight: 1)	**sum**	**colour code**
1	**A**				A	1	
2				A		2	
3			A			3	
4		A				4	
6	**AB**			A	B	1	
7			A	B		1	
8		A	B			1	
9			A		B	2	
10		A		B		2	
11		A			B	3	
12	**AA**			A	A	3	
13			A		A	4	
14			A	A		5	
15		A			A	5	
16		A		A		6	
17		A	A			7	
19	**ABB**	A	B	B		-1	
20		A	B		B	0	
21		A		B	B	1	
22	**AAB**	A	B		A	2	
23		A		B	A	3	
24		A	B	A		3	
25		A		A	B	5	
26		A	A	B		5	
27		A	A		B	6	
28	**AAA**		A	A	A	6	
29		A		A	A	7	
30		A	A		A	8	
31		A	A	A		9	
33	**ABBB**	A	B	B	B	-2	
34	**AABB**	A	B	B	A	0	
35		A	B	A	B	2	
36		A	A	B	B	4	
37	**AAAB**	A	B	A	A	4	
38		A	A	B	A	6	
39		A	A	A	B	7	
40	**AAAA**	A	A	A	A	10	

Figure 1: Table for inferring probable calendar usage

The purpose is not to calculate the mathematical probability of one calendar being used instead of another. Rather, the aim is to determine two things in a standardized fashion. The first is to infer which of two calendars is more likely to have been used in any given letter (based on the evidence available): this is necessary in order to analyse and visualize large data sets computationally. The second is to determine how much confidence should be attached to the previous inference: this is necessary to ensure that human users as well as computers do not treat all of these inferences as equally secure.

Despite its simplicity, this basic model appears to provide a surprisingly effective solution to this problem. Yet it need not be regarded as a finished product: it could be further developed in a variety of ways. In the first place, a formula for disaggregating *patria* into places of birth and death is needed: these might be weighted the same or differently. Second, confessional differences might be added to the model, to help resolve the problem of multi-confessional polities such as Augsburg, where more than one calendar is in use simultaneously. Third, where even richer prosopographical data is available, the relative social standing of the two correspondents at the specified point in time might be taken into account as well: in multi-confessional polities like the Holy Roman Empire, a lower-status sender might adopt the calendar preferred by the higher-status recipient as a sign of respect, irrespective of questions of origin and confession. Fourth, the weightings attached to individual factors could be adjusted, if this produced more satisfactory calculations.[47] Introducing weights which are not integers could be easily accommodated due to the fact that colour coding is the main means of communicating the confidence level, rather than precise numerical values.

In any case, a fundamental principle of this system is that scholarly judgements can always override computationally generated inferences, provided that scholars are also willing to assign a confidence level to their judgements. The primary purpose of such an automated system would be to assign calendars *provisionally* to unedited data ingested in bulk. Whenever carefully curated data is ingested – for instance, from meticulously compiled inventories and editions – the scholarly judgement of the editors must conclusively override the computationally generated inferences. To be more specific, expert users will be able to override these automatic inferences, for instance, for individual letters (e.g. when the calendar used is explicitly stated), or for all the letters from a specific person (when their usage is consistent). On the other hand, in the not-too-distant future, distributed infrastructure will create the capacity to pool the results of multiple catalogues, inventories, and digital archives and libraries of printed and manuscript correspondence. At that point, it will be necessary to complement scholarly curation of individual data records with automatic data curation on a very large scale.

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[47] One might argue, for instance, that these initial weightings undervalue nationality relative to location. For instance, if two Spanish ambassadors correspond with one another from postings in London and St Petersburg, they may use the Gregorian calendar despite the continued use of Julian in the countries from which they write.

Finally, it should also be stressed that empirically derived rules could also be deployed to override these calculations systematically in specific cases. If, for instance, it is discovered that ambassadors from a given country are required to report home and to write to one another using the calendar of the home country, this can be implemented as a general rule. Likewise, if research determines that the religious minority in a given country normally adopts the calendar used by their co-religionists abroad, this might be introduced as a special rule which overrides the normal calculus of this system.

2.4 Handling Incomplete and Uncertain Dates

Thomas Wallnig, Arno Bosse, and Miranda Lewis

Given the great complexity of the inferences involved, there is no immediate prospect of automated inference providing precise dating for undated or partially dated letters. What a union resource does require, however, is a standard means of representing the various forms of unknown, uncertain, and incomplete dates in a manner which is accurate, consistent, and computationally tractable. Without such a standard, there is no prospect of including the huge numbers of imprecisely dated letters in automated analysis or visualization, or of undertaking semi-automated bulk conversions of calendrical data.

Among the available standards that might be adopted in response to this problem, two merit brief consideration here. Chapter 13.1.2 of the TEI guidelines provides a very basic set of tags to describe periods of time and *termini ante quem* as well as *post quem*.[48] Since it is already incorporated within the TEI guidelines, this system can facilitate broad interoperability (e.g. in the context of <correspDesc>, for which see chapter II.7); but its basic form is generic and does not address the variety of problems outlined above. In a similarly generic way, but with extended features, the conceptual reference model CIDOC CRM offers categories for the description of some kinds of temporal uncertainty under the heading 'E2 – temporal entity'.[49] Most of them – like, for example, 'time span', 'occurs during', 'overlaps with', 'meets in time', 'happens during', 'ongoing throughout', 'at some time within', 'minimum/maximum duration' – reflect CIDOC CRM's mission to relate cultural heritage artefacts to descriptive categories of complex semantic value (such as 'the Bronze age'). In that sense, a reuse of this model for correspondence metadata is not inconceivable, but would require adaptation.

[48] See http://www.tei-c.org/release/doc/tei-p5-doc/en/html/index.html, accessed 20/03/2019.

[49] See http://www.cidoc-crm.org/sites/default/files/cidoc_crm_version_5.0.4.pdf, accessed 20/03/2019.

Something similar can be said about means for measuring the closeness and overlap of query and annotation intervals,[50] or visualizing the overlap of time-spans while taking into account uncertain beginnings and endings.[51] These too have been framed primarily as solutions to a somewhat different problem: namely, the difficulty of assigning data to broad historical periods, rather than the uncertainty arising from the lack of precisely dating to year, month, and day. For example, an 'axial age', one of the test settings of *topotime*, overlays the lifespans of roughly a dozen ancient religious leaders and philosophers; uncertainties regarding their exact dates of birth and death are visualized by means of geometrical figures that become more acute the shorter the documented period of activity is. This solution provides a good overview of the simultaneous activity of ten to fifteen individuals with often considerable biographic uncertainty, but the visual concept will not be adequate for the visualization of uncertain dates of tens of thousands of letters.

The ISO standard for representing date and time digitally, ISO 8601:2004,[52] provides a means of avoiding ambiguities between different conventions for representing dates. A simple example is the conflict between the American month-day-year convention and European preference for day-month-year. In this case, ISO specifies the use of YYYY-MM-DD. ISO is currently silent on the problem of representing incomplete, uncertain, and unknown date data, but a new draft revision, ISO 8601-2 (due for adoption in 2019)[53] is intended to deal with this deficiency. It describes precise means for representing uncertain or approximate dates, and cases in which portions of dates are unspecified, as well as time intervals with uncertain, unknown, or open start and/or end dates. Adopting this standard is important, since tools such as *EM Dates* will get far more traction if contributors do not first have to convert their incomplete, uncertain, and unknown date metadata into a format that other software can understand. Bulk conversions of many dates can also be exported by *EM Dates* into the new standard so that other applications can automatically recognize uncertain or approximate conversions.

The employment of methods and tools ultimately depends on the purpose: if the goal is that of pointing the user of a union catalogue to the uncertainty of a letter date, basic tagging and intuitive colour coding may suffice. If, however, research questions can be formulated that relate to the different types of uncertainty outlined above, then it will be necessary to create more sophisticated semantic systems.

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[50] See Tomi Kaupinnen et al., 'Determining relevance of imprecise temporal intervals for cultural heritage information retrieval', *International Journal of Human-Computer Studies* 68:9 (2010): 549–60, see https://doi.org/10.1016/j.ijhcs.2010.03.002. This and the following resource have been recommended by Bruno Martins.

[51] See http://dh.stanford.edu/topotime/docs/TemporalGeometry.pdf; http://dh.stanford.edu/topotime/; https://github.com/kgeographer/topotime, both accessed 20/03/2019. See also http://perio.do.

[52] See https://www.iso.org/standard/40874.html, accessed 20/03/2019.

[53] See https://www.iso.org/standard/70908.html, accessed 20/03/2019.