MODELLING EAST ASIAN CALENDARS IN AN OPEN SOURCE AUTHORITY DATABASE

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Abstract *This paper discusses issues concerning the creation of conversion tables for East Asian (Chinese, Japanese, Korean) and European calendars and describes the development of an open source calendar database as part of the history of converting East Asian calendars. East Asian calendars encode both astronomical and political cycles. As a result, date conversion must in practice rely on complex look-up tables and cannot be done merely algorithmically. We provide a detailed overview of the history of such conversion tables and find that the modelling of these tables into the digital follows a trend of increasingly detailed computation of chronological time. The Buddhist Studies Time Authority Database was designed to allow computational conversion of the Chinese, the Japanese and the Korean Calendar, between each other, as well as with the Gregorian, proleptic Gregorian and Julian calendar. It relies on the Julian Day Number (JDN) as common referent for all conversions.*

Keywords: Chinese calendar, Japanese calendar, Korean calendar, calendar conversion, database, Buddhist Studies

"We are sketching out some little diatribes to add to the little *Computus*"
J. Scaliger[1]

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1. INTRODUCTION: MAPPING THE MODEL

In one of the most penetrating meditations on the nature of what is currently called the 'Digital Humanities' Willard McCarty has emphasized the crucial role that the 'iterative, perfective process' of modelling has for the field.[2] McCarty envisions 'modelling' as part of the hermeneutic practice for which the Humanities are responsible. As we translate analogue information into the digital, new operations become possible. Like with translations from one language to another, however, in modelling there is considerable leeway, as phenomena can be modelled in quite different designs. Michael Mahoney defines 'design' as 'about modelling the world in the computer [...] about translating a portion of the world into terms a computer can "understand".'[3] This understanding, in turn, is in various ways limited and pre-conditioned by the design of the dataset. Designs are guided by the intended use of a product, and often by the desire to improve over previous solutions within a framework of current standards and practices. In the following we will sketch the development of how East Asian calendars have been mapped to their European equivalents and the design of a dataset that allows to compute the mapping process in a digital environment.

Calendars are attempts to map time with the day as primary unit. They are models that, in their design, combine culture-independent astronomical time with a number of culture-specific concerns such as religion and politics. Calendars have a genetic, historical relationship with computing.[4] It is well known that before the term 'computer' became associated with the electronic device it was used for persons who performed calculations, often with the help of particular methods and tables of some sort. Next to economics and book-keeping one major impetus to design computational methods and datasets was the pan-cultural endeavour to solve the problem of how to keep track of time. All civilizations have developed calendar systems within the limit of their observational and computational skills and there is some evidence for calendars even in prehistoric societies.[5] The results were encoded in calculation aids, often in the form of look-up tables that were and are indispensable for the *praxis* of computation.[6] These look-up tables are the direct ancestors of the dataset described below.

Historically, most calendars have attempted to tie the day to other recurring astronomical phenomena, especially the lunar cycle, and/or the solar cycle marked by equinoxes and solstices. These calendar types all had to solve the same design problem: days, months and years are incommensurable. The fact that the number of days in a month, and the number of days and months in a year are not integers, requires careful calculation with fractions to keep the cycles in sync. The problem was dealt with in various ways. Most often the accumulating fractions were balanced out in a calendar by intercalation or (less frequently) extracalation, the insertion or removal of extra days in a month or a year, or extra months in a year.

However, traditional calendars were not merely looking towards the planetary cycles above; they also encoded cultural concerns related to religion, agriculture and politics. Rulers often decided the creation and standardization of calendars, and promotion by a strong government was generally the decisive factor in their adoption. In cases where political and religious rulership coincided as with the Roman and Chinese emperors, or the popes, the standardization of time reinforced the secular-religious union of their rule. In East Asia Confucianism promoted a worldview in which the central government alone decides on all issues of standardization and legislation. As the control over the calendar was directly related to the symbolic power and the legitimacy of the rulers, there was little room for mistakes. One of the earliest Chinese texts contains a speech in preparation of a punitive expedition to kill two astronomers who had neglected their duties: 'The statutes of government say: 'When [their calculations] run ahead of the [actual] time, let them be put to death without mercy. When their [their calculations] are later than the [actual] time, let them be put to death without mercy.' (adapted from Legge 1865, 166).

2. ON THE HISTORY OF CONVERSION TABLES FOR EAST ASIAN CALENDARS

Our need to construct a calendar authority database arose because of several ongoing markup projects at the Dharma Drum Institute of Liberal Arts (DILA)[7], where Chinese Buddhist texts were converted into computable XML/TEI datasets. The projects were mainly concerned with historiographical texts which contain a large number of dates of varying precision. Mapping the dates to a common register allows the computational analysis of certain features of the text as well as improved interfaces to study the texts. Biographies, for instance, usually mention dates in conjunction with geographical data.[8] This information can be used to discover who was active at the same time in the same geographic region, even if the texts do not mention a explicit connection. We can thus gain new prosopographic data on Buddhist history in East Asia. Next to Chinese, the texts contain Korean and Japanese dates, and it was decided to include these calendars as well. Both the Korean and the Japanese calendar systems were closely modelled on the Chinese and therefore did not require a different data model.[9]

East Asian calendars combine a lunisolar calculation of months and years with two naming systems specific to East Asia. First, Chinese, Korean and Japanese calendars count days and years in a recurring sexagesimal (60-year) cycle.[10] Each year is identified by two characters, its cyclical sign (*ganzhi* 干支), the first of which is taken from a set of ten characters, the 'Heavenly Stems' (*tiangan* 天干). The second is one of twelve 'Earthly Branches' (*dizhi* 地支).[11]

The year 692 CE, for instance, had the cyclical signs *renchen* 壬辰 marking it as the 29th year of its 60-year cycle. In the current 60-year cycle that started in 1984 the *renchen* year was 2012.

Since the 60-year cycles themselves are not counted, another register was needed to point to past events. Therefore, a second system was provided by 'era names' (*nianhao* 年號). These were auspicious terms promulgated by the court, generally soon after the enthronement of a new ruler.[12] While the 60-year cycle was generally shared and in sync between China, Korea and Japan, era names were specific to each ruler. Unfortunately era names are not unique. Several were used by more than one dynasty, and when writing of the more distant past it was often necessary to indicate the dynasty.[13]

Thus, any year might be dated fully as '*dynasty name, era name, year no. X, cyclical signs YZ*'. Thus 692 CE was in China the 'first year of the era Wish-Fulfillment of the Tang dynasty, with the cyclical signs *renchen*' (*tang ruyi yuannian renchen* 唐如意元年壬辰). This format could be abbreviated freely and a source might, for instance, give only a reign period, or, especially if referring to the recent past, only the cyclical signs. Using two independent systems (the 60-year cycle and era names) to date a year, provides at times a double-check, but on the other hand increases the possibility of mistakes as especially the *ganzhi* notation is error-prone.[14]

Calendar conversion between East Asian calendars as well as between them and the Julian or Gregorian calendar (or proleptic versions of these) can be a challenging task. The many different dynasties, the arbitrary start and end points of era names, and the irregular intercalation of months make it difficult to produce tables that account for all possible dates that appear in the sources.

For the year 400 CE, for instance, when many dynasties co-existed in East Asia, the Buddhist Studies Time Authority database counts no fewer than nine Chinese and three Korean era names. All have the cyclical signs *jihai* 己亥.

Chinese era names in 400-01 CE:

1. 1st year of the era Tianxi of the rule of Duan Ye[15] of the Northern Liang dynasty 北涼 段業 天璽 元年
2. 2nd year of the era Tianxing of the rule of Daowudi of the Northern Wei dynasty 北魏 道武帝 天興 二年
3. 3rd year of the Taichu era of the rule of Liezu of the Southern Liang dynasty 南涼 烈祖 太初 三年
4. 2nd year of the Jianping era of the rule of Shizong of the Southern Yan dynasty 南燕 世宗 建平 二年
5. 4th year of the Feilong era of the rule of Taizu of the Later Liang dynasty 後涼 太祖 龍飛 四年
6. 1st year of the Changle era of the rule of Zhongzong of the Later Yan dynasty 後燕 中宗 長樂 元年

7. 1st year of the Hongshi era of the rule of Gaozu of the Later Qin dynasty 後秦 高祖 弘始 元年
8. 12th year of the Taichu era of the rule of Gaozu of the Western Qin dynasty 西秦 高祖 太初 十二年
9. 3rd year of the Longan era of the rule of Andi of the Eastern Jin dynasty 東晉 安帝 隆安 三年

Korean era names in 400-01 BCE:

1. 9th year in the era Yongrak 영락 of the reign of King Gwanggaeto 광개토 of Goguryeo 高句麗 廣開土王 永樂 九年
2. 44th year in the reign of King Naemul 내물 of Silla 新羅 奈勿尼師今（王年） 四十四年）
3. 8th year in the reign of King Asin 아신 of Baekje 百濟 阿莘王（王年） 八年

Obviously the usage of era names requires extensive look-up tables.[16] These tables in turn require thorough historical research to understand exactly when era names changed, and where dating conventions differed and overlapped. Anomalies such as calendar reforms[17], political manipulation,[18] and ideally even regional differences[19] must be taken into account.

Further challenges arise when we move from the year to the month and the day. Lunar months are generally counted one to twelve. Intercalated months (*runyue* 閏月) that were necessary every 3–5 years[20] during most periods could be inserted after any regular month, and in a date expression '閏*n* 月' denotes a month intercalated after the n^{th} lunar month. Days in Chinese sources are often simply numbered, but can also be expressed in the *ganzhi* notation.

As with the era names, in order to ascertain the exact dates of lunations in a historical year, and to determine exactly when extra months or days were intercalated, one can only rely on historical records. Fortunately, East Asia has produced these in abundance and the official annals of each dynasty contains a section on the calendar. The need to convert East Asian dates into European ones arose at the very beginning of Western sinology when Jesuit missionaries first studied Chinese history and culture. The Jesuits earned their privileged position at the imperial court first due to their proficiency in performing astronomical calculations, especially the prediction of solar eclipses.[21] In the 16th and 17th centuries Jesuits held important positions in the Chinese Bureau of Astronomy, which was in charge of producing the official calendar for each year. In 1732 Antoine Gaubil, S.J. (1689–1759) published an extensive history of astronomy in China, an account which was only superseded in 1959 by Joseph Needham's volume on astronomy in *Science and Civilisation in China*.[22] More central to our purpose here, the missionaries produced ever more comprehensive conversion tables that mapped East Asian dates to the European Calendar. The first such tables, e.g. the ones by Couplet (1687), were concerned only with aligning the years. Later the chronological table produced by Jean-François Foucquet

(1665–1741) (*Tabula chronologica historiae Sinicae connexa cum cyclo qui vulgo kia tse dicitur* 1729), that included the 60-year cycle, was widely discussed by the small scholarly community in Europe that was interested in issues of comparative chronology.[23] After those first forays the interest in conversion tables slackened, and in 1839 Pauthier's history of China had to include tables produced by Jean Joseph Amiot (1718–1793) that had been created some 70 years earlier.[24] The tables sent by Amiot from China to Paris around 1770, were rough and started their year count in the legendary past long before we have a reliable chronology for China. They did not attempt to solve the difficult problems posed by those periods in Chinese history when more than one dynasty devised era-names, and the exact mapping of months and days between different calendars was not tackled until later.

The tables devised by John Williams (1871) and William F. Mayers (1874) try to map era names for most dynasties while still bothering to include 'The Legendary Period' of the Five Rulers, the Xia, and the Shang dynasties, for which a reliable year-by-year dating is not possible.[25] Williams even went one step further. By making use of Chinese encyclopedias[26] he was able to expand the record of observations of comets that Édouard Biot (1803–1850) had begun.[27] Since these observations were dated to the day in the Chinese annals, the records could be used to align the calendar's on the level of months and days. Williams does attempt to convert the dates for his 372 comet sightings to the Julian calendar, but his lunation tables are only approximated and not based on the Chinese records.[28] Williams did not compare the records with the astronomical historical record and the mapping of the sightings to the Western calendar is questionable, because the exact position of the lunations in the Chinese year had not yet been established.

In 1905 the extensive *Synchronismes Chinois* by Mathias Tchang, S.J. (1852–1929) was the first work to provide conversion tables with era names for all dynasties of China, Japan, Korea, Vietnam and (where applicable) Mongolia. In his preface Tchang remarks that such an overview had been attempted neither by European nor by Chinese authors before.[29]

His very thorough effort was soon carried further by a fellow Jesuit, Pierre Hoang, S.J. (1830–1909), whose posthumous work *Concordance des Chronologies Néoméniques Chinoise et Européenne* were the first comprehensive and astronomically exact conversion tables for the Chinese calendar that allow conversions to the level of months and days.[30] The reason conversion tables to the month and day appeared relatively late was that they had to be based on an exact record of new moons, intercalary months and solstices for all dynasties in Chinese history. This kind of information is difficult to collate especially for earlier periods when, as we have seen, there existed several parallel dynasties in China and Korea, for many of which the historical record is but rudimentary. Nevertheless such a record was provided by Wang Yuezhen

王曰楨 who in 1877 published the 'Summary of the Chronology of the Historical Dynasties' *Lidai changshu jiyao* 歷代長術輯要, himself building on a long line of Chinese historiographers.[31] For the period between 841 BCE to 1670 CE, Hoang's tables are based on the *Lidai changshu jiyao*, for dates after 1670 CE the Qing 'Perpetual Imperial Calendar' *Qinding wannian shu* 欽定萬年書 (Hoang 1968 [1910], XI–XII) was used.

Hoang's tables provide the user with the epact (the day difference of the solar and lunar year) for both the (proleptic) Gregorian and the (proleptic) Julian calendar (s.b.) thereby allowing for unambiguous conversion into either European calendar notation. By his use of brackets he even carefully indicates what calendar should be used for each period (proleptic Gregorian 841 BCE to 1 BCE, Julian 1 CE to 1582 CE, and Gregorian since 1582).

One might argue at this point that a day-to-day mapping of dates between China and Europe for the time before the two civilizations came into contact is not of great importance for macro-history. Indeed for most comparative purposes it is enough to understand roughly in what year events happened. There are, however, a number of historical questions which can only be dealt with via a computable, day-by-day model of the calendars. The Chinese records contain many sightings of astronomical events, which are usually dated to the day. These are invaluable data for the history of astronomy. Day-to-day mappings are most important wherever we have to interpret events that were recorded in different calendars. For the encounter between the peoples of Europe and East Asia this is only relevant since the 16th century, but for contacts between Chinese, Japanese, and Koreans parallel records extend back to the 7th century CE. The history of the Japanese embassies to China in the 7th century, e.g., is told in both Japanese and Chinese sources, and a comparison needs a reliable mapping between the two calendars. Computable day-to-day mappings also can solve duration-related questions within any given calendar, which are otherwise only difficult to address. Whenever Chinese sources mention time periods where differences on the day scale matter (i.e., for a prison term, a journey, or an illness) it might be important to be able to calculate the actual length of the duration in days. This can only be achieved if the exact number of days for each lunation is known and intercalary months are accounted for.

Since Hoang's breakthrough in day-to-day mapping between Chinese and European calendars, the numerous later conversion tables created in the 20th century generally follow him, while expanding the record in various way.

Both Wang et al. (1991) and Wang and Li (1996) expand the concordance to Muslim, Tibetan, Dai, Yi and other calendars of ethnic minorities in China. Wang et al. (1991) moreover includes Julian Day Numbers, the standard also used by the Buddhist Studies Time Authority (s.b.).

Even though Fang and Fang (1987) draw heavily on Wang Yuezhen, and their mapping gives three dates for each lunation (for the 1st, the 10th and the 20th day), it is in other respects less detailed than Hoang's work. First, no mapping to western dates is given for BCE dates. Also Fang and Fang do not address proleptic dates, and all dates between 1 CE and Sept. 1582 are converted to the Julian calendar, after that to the Gregorian calendar. The treatment of parallel dynasties and their era names is cursory. Many smaller dynasties and their era names are omitted,[32] and the exact dates of accession and era name change (listed by Hoang in his appendix 1) are not included.

Zhang Peiyu's (1997 [1990]) main concern is not conversion, but his tables do give Western dates for the period 722 BCE to 2050 CE. Making use of now widely available astronomical data, Zhang gives the lunations between 1500 BCE and 2000 CE to the minute. Zhang also has compiled a comprehensive list of all solar eclipses visible in China between 1499 BCE to 2051 CE, including the exact duration of their visibility from different locations in China. Appendices 2 to 4 contain important data on differences between the calendars of parallel dynasties in various periods, making Zhang's impressive work the most accurate and comprehensive tables in print so far.

3. THE BUDDHIST STUDIES TIME AUTHORITY DATABASE

Design Principles

The Buddhist Studies Time Authority Database was constructed to provide a digital, open source dataset for East Asian calendars to allow for conversion between these and the Gregorian calendar. Dharma Drum Institute of Liberal Arts maintains the database as a web service with an open API and provides distributables on its website and GitHub.[33] In principle there are two ways to approach the issue of calendrical conversion. One is to implement conversion algorithmically. The authoritative third edition of *Calendrical Calculations* by Derschowitz and Reingold (2008) provides a large number of tested formulas for calculating dates within and between calendar systems. Another way to convert dates is the use of lookup tables that share a common register. For our purpose, the identification and disambiguation of dates in classical texts, only the latter approach is viable. Although Derschowitz and Reingold devote considerable space to the Chinese Calendar they too admit 'It is not traditional to count cycles or years; years are generally given as regnal years [era names] and by sexagesimal name.'[34] The many functions they provide model only the Qing Dynasty calendar (instituted in 1645) exactly. In principle, purely algorithmic conversion cannot address the dating by era names and their politics. In order to identify and mark a date in a Chinese text one needs to access a library of era names. At times identifying a date involves disambiguating decisions, which cannot be modelled computationally, but depend on textual and historical context. The Time Authority Database thus allows for a standardized mapping of date references in East Asian sources.

3.1 Julian Day

It has long been recognized that calendar conversion is simplified if all calendars are mapped to a common register (Richards 1998, 287). A day-based register for astronomical calculations was first proposed by Joseph Scaliger (1540–1609), who was one of the first European historians to expand historical inquiry systematically beyond the confines of Greek and Roman history. During his research of Arabic and Jewish sources he became deeply interested in different traditions of astronomy and calendar lore. His *De emendatione temporum* (1583) 'marked a radical change in chronological studies' among other things by proposing the *Julian Period* as a calendar-independent framework for chronological calculations.[35] In the 19th century John Herschel refined the system to be used with days. The *Julian Day Number* (JDN) is the interval of time in days since January 1, 4713 BCE Greenwich noon, proleptic Julian calendar (i.e., November 24, 4714 BCE in the proleptic Gregorian calendar). Scaliger wanted to place the start of his calendar outside of history, before the beginning of clearly datable events, as 'an arbitrary framework within which different theorists could disagree about the date of the Creation or of Christ's birth and still agree about other dates established by clear synchronisms.'[36] His expressed aim was to 'to bring … home, with a method as his guide, the chronologer who journeys through all the world, and roams like a wandering stranger back through all ancient times and origins, so that when he reads the acts, annals, *fasti* of the ancients, he may sometimes know where he is, and need not always be a stranger'.[37] The JDN is widely used by astronomers and its use is recommended by the International Astronomical Union (IAU (1997) Resolution B1) as the standardized treatment of the content described in the following sections. Scaliger's and Herschel's JDN works for us as we are mapping the days of three different East Asian calendars to JDNs as the basis for all conversions. The Day_ID in the database is identical with the day's JDN.

3.2 Issues in the Conversion to European Calendars

Since the East Asian calendars are aligned to JDNs conversions can be done algorithmically to either the Gregorian, the proleptic Gregorian, the Julian, or the proleptic Julian calendar.

As the Gregorian calendar was first adopted by some European states on October 15th 1582 (following the Julian date October 4th 1582), most conversions will want to give Gregorian dates after that and Julian dates before that.[38] For ease of use, therefore, both Julian dates and proleptic Gregorian dates are provided for the time between 8 CE and 1582 CE.[39] Any instantiation of the database as a website, API or stand-alone look-up tool should take care to inform its users which European date they are seeing as a result of a conversion.

This needs to be understood by historians, who need at times to compare historical events to the day, and have to take the difference into account.

As the difference between the proleptic Gregorian and the Julian calendar never exceeds ten days, chances are that it will not matter greatly for comparative historical studies, still, in cases where sources and conversion results seem to disagree the difference might be resolved by a further conversion between Julian and Gregorian dates.

Another issue liable to confuse users is whether to use a year zero in the conversion to European dates before the year 1 CE. In both the Julian and the Gregorian calendar, the year 1 CE follows directly on the year 1 BCE. However, two modern calendar systems, the Astronomical Year Numbering as well as the important ISO standard ISO 8601 (*Data elements and interchange formats – Information interchange – Representation of dates and times*),[40] do use the year zero. Astronomical year numbering and ISO 8601 were partly designed for easy computability, and calendars without a year zero do require an awkward exception whenever periods have to be calculated or compared across the BCE/CE divide.

The decision of whether or not to use the year zero in the conversion yields makes an immediate difference. The date for the unification of China under the first Emperor of the Qin dynasty converted to the proleptic Gregorian calendar *with* the year zero is 220, *without* the year zero it is 221 BCE as it usually appears in the history books.

Again due to the use of the JDN, the Time Authority Database can return BCE dates with or without the year zero and applications should take care to keep the user informed about which method is used for the conversion.

3.3 Eclipses and Other Transient Events

Eclipses and other transient astronomical events are often deemed important events and their observation was carefully recorded in China. The importance of eclipses for conversion tables is obvious. Together with some other astronomical phenomena that are recurring and observable (comets, planetary movements etc.) they can be clearly dated by modern astronomy and therefore allow to ascertain recorded dates beyond doubt.[41]

First attempts to publish the Chinese record of solar eclipses in a European language were made by John Chalmers (1865) and Alexander Wylie (1867) in the 1860s, and discussion of the earliest recorded eclipses attracted a lot of attention.[42] As mentioned above, the Chinese observations of comets were first comprehensively summarized for a Western audience by Biot (1846) and Williams (1871).[43]

Novae and *supernovae* are not recurrent and help to ascertain conversion tables only if there are two or more observation records in different calendars.

The first recorded *nova* (or *supernova*) was observed in China around 1300 BCE and duly noted on an oracle bone.[44] Lundmark (1921) has summarized the information on *novae* and *supernovae* from ancient Chinese sources.

As of 2012, the Time Authority does not contain comprehensive information on eclipses. More than 900 references to solar eclipses, however, are referenced to Korean historiographical sources and are included in the table *t_month_comment*.[45] While this part should be seen as work in progress, it is sizeable enough to be useful.

Further information on eclipses, as well as a record of comets, *novae* and other transient phenomena should be added to the database in the future.

3.4 The Chinese Calendar

The data covers Chinese calendar dates between 220 BCE and 1912 CE. Special attention had to to be paid to the problem of prolepsis in the context of the Chinese calendar, which is commonly manifest in two kinds of circumstances. The first occurs when historical sources refer to dates in their respective futures, specifying a year of an era (*nianhao* 年號), which subsequently never comes to pass. The second is where a historical source continues to use the dating system of an era, emperor or dynasty after that era, emperor or dynasty has ceased to exist.[46]

To be able to cope with this, our database contains records that cover, where appropriate, a range of dates before and/or after the actual historical period spanned by a given era, emperor or dynasty. A result of this is that the extent of these periods if queried directly from the database can seem to be inaccurate.

3.5 The Japanese Calendar

The data covers Japanese calendar dates between 593 CE and 1872 CE. On January 1st 1873 Japan adopted the Gregorian calendar. The Japanese calendar closely followed developments in the Chinese calendar.[47] The data has been assembled at Dharma Drum Buddhist College[48] between 2008 and 2010, building on data provided by Mr. Takashi Suga 須賀隆 (with the help of Professor Michel Mohr) whose kind help is acknowledged.

3.6 The Korean Calendar

The data covers Korean calendar dates between 56 BCE and 1910 CE. The Korean calendar data should be understood as an extension to the Chinese dataset above. The Korean calendar has a special relationship to the Chinese calendar and, in a special form of calendric prolepsis, sometimes retained era names beyond their use in China. Certain proleptic dates used in Korean texts

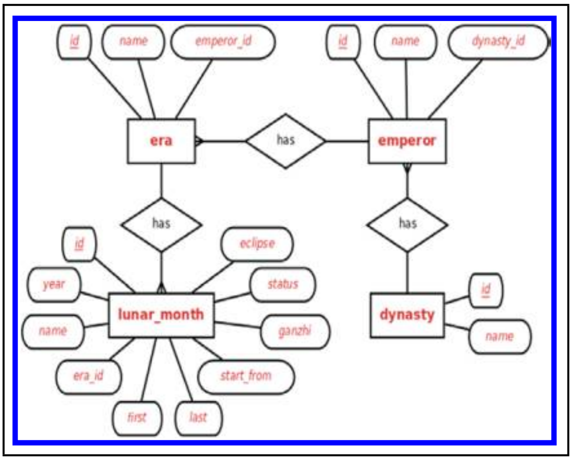

Figure 1. Entity Relationship Diagram of the Buddhist Studies Time Authority Database.

(e.g., 150th year of *chongzhen* 崇禎 (∼1777 CE)) are part of the Chinese calendar dataset.

3.7 Technical Specification and Database Structure

The services of the Buddhist Studies Time Authority Database are in the main built with MySQL 5.5 and PHP 5. PHP is used to provide the web-interface and to transform the Julian Day Number in the Gregorian, proleptic Gregorian, or Julian calendar. The Julian Day Number is linked to the calendars and stored in a MySQL database. Every query through the interface instantiates both a database query and a PHP script.

Database Structure

The basic structure of the Buddhist Studies Time Authority Database is to record dynasty, emperor, and reign era for each lunar month. Above is the Entity Relationship Diagram (ERD).

A *dynasty* entity represents a Chinese, Japanese, or Korean dynasty (*chaodai* 朝代). Each dynasty has a *name* and an *id*. A dynasty will usually encompass the reigns of several different emperors (*huangdi* 皇帝). Each *emperor* entity has three attributes: *name, id,* and a *dynasty_id* which refers to the parent dynasty. Each emperor's reign consists of one or more eras (*nianhao* 年號), represented as *era* entities in the database. An era entity also has *name* and *id* attributes, and the *emperor_id* of its parent entity. Finally, each era consists of one or more *lunar_month* entities (*yue* 月).

In the Buddhist Studies Time Authority Database, the lunar month is the smallest unit of data: i.e., the database does not store a record for each day. The details of an individual day are derived from its *lunar_month* entity. A lunar_month entity consists of nine attributes: *id* (its unique identifier); *year* (the ordinal number indicating the year of the era); *name* is the name of the month in Chinese; and *era_id* is the unique id of the parent era; *first* and *last* are Julian Day numbers specifying the first day and the last day of the month, and *start_from* indicates the ordinal day of the month from which this record is valid. This is usually Day 1, but where an era begins on another day of the month the record must take that into account. The *ganzhi* 干支, 'cyclical signs', field stores the sexagesimal designation of the solar year to which the lunar month belongs. *Status* is one of two values: 'S' for standard; or 'P' for proleptic. Finally, *eclipse* records whether the first day of this month corresponds to a solar eclipse.[49]

Web-Service API

In order to provide content from the Buddhist Studies Authority Databases to other web applications, a web-service API is available, which allows other web applications to query the database without connecting directly to the database server. The service is a PHP script, which accepts http-requests, and responds in JSON format. The service accepts and responds to well-formed http-requests from anywhere in the world. The API requires users to submit a date (in JND or ISO 8601) and the script will return all East Asian calendar dates in return.[50]

Distribution

The database is published under a Creative Common License (Attribution - Share Alike 2.5 Taiwan). It is made available on the college website (http://authority.ddbc.edu.tw/docs/open_content/download.php) and a GitHub repository (https://github.com/ddbc/Authority-Databases).

4. OUTLOOK

The above outlines the history of mapping East Asian calendar systems based on calculating dates with the help of ever more sophisticated datasets. The Buddhist Studies Time Authority Database provides the first open digital dataset to compute conversions from and to East Asian calendars. However, there is more to be done. The solar and lunar eclipses as recorded in Chinese sources should be added to the data and need to be double-checked against their actual astronomical date. The Vietnamese calendar – modelled on the Chinese calendar, but using Vietnamese era names since 1306 – deserves to be added, too. Also the time range of the dataset, that in the original project was limited to CE dates due to the focus on Buddhist sources, might be extended back to 841 BCE.

END NOTES

[1] Cited in Grafton 1975: 158.

[2] McCarty 2005: 20.

[3] Mahoney 2005: 128.

[4] The oldest analog computer, the Antikythera mechanism (c. 100 BCE), was used to calculate the synodic month (Henderson 2009: 13).

[5] Richards 1998: 130–144.

[6] Moon ephemerides, for instance, had to be consulted to calculate longitude before clocks that could withstand a sea-voyage became available in the 17th century.

[7] Between 2005 and 2014 known as Dharma Drum Buddhist College (DDBC).

[8] Some of these projects are described in Hung, Bingenheimer, Shiu (2011); Hung, Bingenheimer, Xu (2010); and Bingenheimer, Hung, Wiles (2009).

[9] The Japanese generally followed updates to the Chinese calendar, whenever the more precise calculations became available. See Bramsen (1880: 25) for a list of these changes.

[10] The cycle is generally aligned in the three calendars, but due to occasional differences in the date for the new year there are numerous exceptions. The cyclical sign are also, less commonly, used to count months and days.

[11] The set of 12 and 10 are combined in fixed arrays. Thus their total possible combinations is 120, but only the first 60 of these are used. Derschowitz and Reingold (2008: 261) suggest that this is because 60 is the "least common multiple" of 12 and 10.

[12] Era names were used in China after ca. 140 BCE, before that years were counted within a reign as "regal years" (*wangnian* 王年). Korea and Japan started to use era names (ko. *yeonho*, jp. *nengo*) on a regular basis only in the 7th century. In earlier dynasties era names were changed several times during the reign of an emperor, while in later imperial China generally only one era name is used per reign.

[13] The era name *yongping* 永平 "Eternal Peace", for instance, was used on four occasions. It was first chosen by Emperor Ming of the Eastern Han (58-02-11 to 75-09-02 CE) (then continued during the first 6 months of the reign of his successor Emperor Zhang (75-09-03 to 76-02-21 CE)). More than 200 years later it was adopted for two months (291-02-16 to 291-04-23 CE) during the long reign of the feeble-minded Emperor Hui of the Western Jin. In North China the "Eternal Peace" of Emperor Xuanwu of the Northern Wei lasted from 508-09-28 to 512-05-27 CE. Then again, four hundred years later in Sichuan, Emperor Gaozu of the Former Shu used *yongping* as era name from 911-02-07 to 916-02-10 CE. Non unique era names can easily lead to confusion. Even emperors at times got it wrong. Tchang (1905: X) recounts the story of Song Taizu (r. 960–976), who chose the era name *qiande* 乾德 (963–968). In its second year he noticed that one of his concubines was using a mirror with a date of *qiande* 4. He asked his Grand Councillor who had to remind him that *qiande* had already been used by the short-lived dynasty of the Former Shu (907–925) in Sichuan, the *qiande* of the Former Shu lasting from 919 to 925.

[14] *Wu* 戊 and *xu* 戌, and *ji* 己 and *si* 巳 especially are easily confused. Moreover the 10 "heavenly stems", from which the first characters is chosen, and the 12 "earthly branches", which provide the second, allow for 120 permutations. Of these only 60 are used in the 60-year cycle, the other 60, however, look like very natural cyclical signs even to Chinese authors. For example

there is no *jiahai* 甲亥 year (or day); the combination is not used, but only someone who remembers all 60 'legal' combinations extremely well would notice this at first glance.

15 No temple name is recorded for Duan Ye. All other Chinese rulers are listed by their temple names.

16 While the order of the 60-year cycle is relatively uncontroversial, the exact beginning of any year is irregular and might vary depending on the intercalations that at times happened independently in different dynasties.

17 E.g. the "long year" *Taichu* 1 of the Han Dynasty (c. 104 BCE) which lasted for 472 days (Hoang 1968 [1910]: 93).

18 Even within the same dynasty there are sometimes two dates for the same day. One extreme case is the attempted retroactive extirpation of the era name *jianwen* 建文 used from 1399 to 1402 by the Huidi 惠帝 emperor (r. 1398–1402). Huidi was defeated and presumably killed in a succession struggle by his uncle the Yongle 永樂 emperor (r. 1403–1425), who decided to add the *jianwen* years to the era of his father *hongwu* 洪武 the emperor (r. 1364–1398). Some 200 years later the Wanli emperor revised this decision with the result that the years 1399–1402 can appear either as *hongwu* or as *jianwen* in the sources.

19 It is known, e.g., that the calendar at Dunhuang, at the Western periphery of the Chinese empire was at times not in sync with the official calendar. For instance, the intercalated month of the year corresponding to 809 CE was inserted after the third month in the regular calendar, but after the fourth month in the Dunhuang region (Deng 1996: 704). For convenient tables listing the differences between parallel dynasties regarding the insertion of intercalary months between see the appendices 2 to 4 in Zhang (1997 [1990]).

20 This due to the civil year being based on 12 lunations, resulting in 354 or 355 days. The embolismic year lasted between 383 and 385 days, the legal year 360 days. (Havret et Chambeau and Hoang 1968 [1920]: 13).

21 The Jesuits were at the Chinese court from 1601, when Matteo Ricci became the first foreigner to be invited into the Forbidden City, until 1773 when Clement XIV dissolved the order and no new Jesuit missionaries could be sent to China.

22 Needham 1959.

23 See Sloane (1753) for the reaction of the Royal Society, London.

24 Pauthier 1839: 475–488.

25 Williams (1871: 95–123) and Mayers (1874: 361–390). The currently most advanced look-up tables by Zhang (1997 [1990]) start with 722 BCE (proleptic Gregorian without the year zero) from around which time we can reliably match the Chinese calendar with the record of solar eclipses.

26 Mostly the *Wenxin tongkao* 文獻通考 by Ma Duanlin 馬端臨 (1245–1322) and its supplement the *Xu wenxin tongkao* 續文獻通考 edited by Zhang Tingyu 張廷玉 (1672–1755).

27 Biot 1846.

28 Cf. Williams' explanation of his method of conversion (1871: xv-xx) and the title of his Table G "Approximate Table of the first day of each moon. . . " (Williams 1871: unnumbered).

29 Tchang 1905: II.

30 For Japan, the Japanese Home Department in the years 1874 to 1878 published a 3-volume set of conversion tables that map Western dates to the Japanese calendar. These were criticized by Bramsen (1880: prefatory remark), whose conversion tables map Japanese dates to Western dates and use the Julian calendar rather than the proleptic Gregorian.

31 According to Hoang, Wang used the 24 dynastic histories and a host other primary sources, but especially the chronological tables by Liu Xisou 劉羲叟 (1007–1072) contained in Sima Guang's 司馬光 *Zizhi tongjian* 資治通鑑 (1084) for the calendar between 206 BCE and 959 CE. Wang's standard for new moons and intercalary moons for the period between 960 CE and 1276 CE was Qian Daxin's 錢大昕 (1728–1804) *Song Liao Jin Yuan Sishi shuorun*

kao 宋遼金元四史朔閏考. Hoang points out that Wang was meticulous in correcting mistakes in his sources and double-checking the records with astronomical events. The calendars for the rest of the Yuan and the Ming Wang presumably worked out himself based on the official annals. These periods were less complicated, because there were no parallel dynasties within China and because the period was more recent and better documented.

32 E.g. the Later Qin 後秦 (384–417). On the other hand Fang & Fang include the Taiping calendar (1852–1868), which Hoang does not list.

33 https://github.com/ddbc/Authority-Databases (Sept. 2014).

34 Derschowitz and Reingold 2008: 263.

35 Grafton 1975: 157.

36 The start date of the Julian Period is derived by establishing the year of birth of Jesus Christ in three different registers (Solar cycle, Lunar Cycle, Indiction Cycle) and then counting backward (Grafton 1975: 162).

37 Quoted in Grafton (1975: 164).

38 This is bearing in mind that the Gregorian calendar was adopted only very slowly and fitfully. Japan (1873) and Korea (1896) adopted it before Russia (1918) or Greece (1923) for instance.

39 Between the first adoption of the Julian Calendar in 46 BCE and 8 CE intercalation was mismanaged by the pontifices left in charge of the calendar after Julius Caesar's assassination (Richards 1998: 215).

40 Latest revision is ISO 8601:2004.

41 See Eberhardt (1940) for an attempt to reconsider the dating of some astronomical texts in the the Buddhist canon, based on the astronomical and textual information.

42 See, e.g. Schlegel and Kühnert 1889.

43 See Lundmark (1921: 227) on the relationship between these two.

44 Needham 1959: 424.

45 We made use of the *Samguk Sagi* 三國史記 (1145), *Goryeosa* 高麗史 (1451), and the *Joseon Wangjo Sillok* 朝鮮王朝實錄 (1865).

46 Most persistently prolepsis was used during the Li Dynasty in Korea, which stayed true to its Ming suzerain by refusing to accept the era names of the Manchu dynasty, with the result that the era name *chongzhen* 崇禎, which lasted only from 1628 to 1644 in China, was used until 1895 in Korean sources.

47 Derschowitz and Reingold (2008: 268).

48 Since August 2014 called Dharma Drum Institute of Liberal Arts (DILA).

49 For more information on the schema of this database, see http://authority.ddbc.edu.tw/docs/open_content/table_schemas.php.

50 For more detail on the Web-Service API, see http://authority.ddbc.edu.tw/docs/services/date_query.php.

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