The history of calendar

RUC 3rd semester project

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Abstract:

Calendars are the products which belong to astronomic development and results of human chronically observing nature phenomena. In the 3rd semester project, we are interested in researching history of the calendars and this project focuses on the Chinese calendar and the Gregorian calendar which are two different kinds of calendar: Astronomical calendar and Arithmetical calendar.

The project is through the different developing processes of two calendars in order to investigate the Chinese calendar and Gregorian calendar’s historical background, besides convert between each other by mathematic functions. In the project, it is possible to convert from a Chinese date to a R.D. day number (one kind of intergradation) and changing the R.D. number into Gregorian date by functions from literature studying. In addition, the project contains the perspective of some calendars in the future.

Content:

Introduction

Calendar as a necessary is used widely in human’s daily life. Making a work plan or study schedule, you need calendar; celebrating a special day, you need calendar. On the other hand, country’s festivals cannot be confirmed without calendar; farmers cannot work without calendar to know farming season; historian or archaeologists doing the research are also not without calendar. It is not difficult to find that we all cannot away from calendar from begin to dead.

Difference calendars system

Do you know how to calculate calendar and what the calendar according by?

In science field, most calendars are always divided into Arithmetical Calendar or Astronomical Calendar. They use the different ways of calculating and setting the date to form calendar.

1. Arithmetical calendar:

Arithmetical calendar is calculated by following a kind of fixed mode which means set days or month by using different of mathematic formulas, no influence by any other outside factors. The advantage of arithmetical calendar is easily working out when has a particular day. The disadvantage of it is this kind calendar normally not very accurate.

2. Astronomical calendar:

However, the computation of Astronomical calendar is attended to consider the natural phenomena and environment changing such as seasonal changing and weather those are main factor of setting of calendar. So this kind of calendar is changeful. The advantage is more accurately with astronomical events, but calendar is more diversification.

The establishments of calendars have a large relationship with the movement of celestial bodies. Day, Month and Year are the basic units of calendar. The Day is because of the rotation of the Earth. The Month is based on the revolution of the moon around the earth. The Year is a unit according as the revolution of the Earth around the Sun. The tropical year is the interval between the Sun passes through the vernal equinox twice. It is about 365.24219 days. The synodic month is the time that elapses between successive new moons, equal to 29 days 12 hours 44 minutes and also called the lunar month. What you call plenilune, it is the time we can see the whole moon on the earth. It is about on each 15th or 16th of a month. Therefore, to be convenient, the one year is approximate 365 or 366 days, and because of the requirement of the lunar movement, one month is about 29 or 30 days. So one year is about 12 synodic months, or 354.36707days. That is the source of original calendar. [R6]

In astronomic events, moon phase is an important natural phenomenon. Full moon and New moon both are two special moon phase. The different of moon phase is caused by the relative of the moon, sun and earth. As well-known, the earth goes round the sun and the moon surrounds the earth around 27 and half days. At night, the moon light comes from the sun light reflection on the moon.

The sun light is always covered the half of the moon facing the sun, except during the lunar eclipses while the moon goes through the earth's shadow. When the earth and sun are on two opposite sides of the moon, the moon appears dark and it calls "New". When the earth is the moon and sun of opposite sides, the moon become bright and round and it calls "Full". During the new moon and full moon, the illuminated moon surface from dark growing wax to Full moon, and then decreases to wane until come back dark (New moon), when human observed the moon from the earth. This is a cycle from New moon to Full moon and back to next New moon. (See Figure)

Figure 1 [R7]

From the literature, it shows that is about forty calendars used in the world now. [R6] The Gregorian calendar is used mostly now. It divides the year into 12 months and confirms seven days a week, the number of the days in each month and leap year.

Generally, this kind of calendar is easy for people to remember and calculate the date. But actually, in many countries, without Gregorian calendar, they still use their own traditional calendars now. Those calendars are always made by different natural phenomena. Compared with the Gregorian calendar, they are all more detailed and complicated. We all know the orbit that earth surrounds the sun is an ellipse approximated round. The number of days in a year is always not fixed. It is changing every year. That is why the calendars always have the many difference with each other.

At first, because of the history, the fixed dates are different and the epochs for the calendars are different, too. The fixed date must be affect the whole calendar, because day's number every year is changed, the more cycle, the more difference for each calendar. Secondly, the number of days a week is different, four days a week, five days a week, eight days a week or ten days a week. Imaginably, the day's number in a month is not the same, too. Some calendar even divides one year just into 10 months. But in order to make sure the number of days in one year, these calendars used different ways, such as plus the extra days after the twelfth month. Leap year is also an instrument to balance the year error. In Gregorian calendar, in the leap year the February will change 28 days to 29 days. Each 4-year is a leap year but century years should be divided by 400, for example, 100 is not a leap year. In leap year, you just need to plus one day in the end of February. In some other calendars are not so easy to calculate. Some are add one day every four-year; some are add one month; some others are made intricately. For example, Chinese calendar divides one year into 24 solar terms: 12 zhongqi and 12 jieqi. Because it is a lunisolar calendar, the number of days is always changed among 364, 365 and 366. The moon changed changes the number of month days and the arrangement of those months depends on the sun's course through the twelve zodiacal signs. The way to calculate the leap year is more difficult. Not only using plus, minus or multiply, divide, but also need to use some high mathematics such as differential coefficient or integral to calculate the exact of calendar. Besides leap year, Chinese calendar also has leap month. Leap month strongly differ from leap year. This year has leap month, maybe next year still has leap month. It has the relationship with the changing of the solar term and can appear any time of year. When a year has a leap month, that year in Chinese calendar will have thirteen months. Obviously, leap month must be taking more problems in calendars conversion. [R2]

Problem formulation:

China is an old-line country in the east of the world, and technology and science were developed in the middle Ages, (famous invention: paper making, powder, compass, and printing)

The history of Gregorian calendar in China

China has there own calendar called Chinese calendar, because of feudal reign for long times. In 19th century, some western missionaries came to China communicated with Chinese astronomers and Gregorian calendar was first time bringing into china as a kind of communication produce, because at that period, Chinese astronomy is very development and attracted foreign astronomers.

After 1911 Chinese Xin hai revolution, feudality ended in China, the Gregorian calendar is formally adopted on 1st January 1912 by the Republic of China leader Sun Zhong-shan in order to adopt the western advanced science culture and improve international relationship. 1912~1929 there is the period of warlordism in China and different warlords used different calendars following the feudal old tradition. So Gregorian was not introduced in public. [R18]

Until 1929, China unified by the Republic of China government and decreed the Gregorian calendar effective on 1st January 1929. Upon its foundation, in 1949, the people's republic of china continued to adopt the Gregorian calendar without too much changing in mainland. [R18]

Nowadays, the Gregorian calendar and Chinese calendar both are used in China. Following the two calendars are adopted in a long period, the two calendars' name are changed by Chinese people called the Gregorian calendar that is Western solar calendar and Chinese calendar is the Chinese lunar calendar, because the new names could be easily remember by Chinese people, but the Chinese calendar is not official adopted.

Chinese calendar is based on the astronomical events, and defined by the celestial bodies' movement. It includes much mathematic knowledge by human's wisdom. (We will make a literature for the Chinese calendar to expatiate exactly)

We choose the Calendar as subject and focus on the Chinese calendar and Gregorian calendar and our problem formulation is:

1. **<u>What are the histories of the Chinese calendar and the Gregorian calendar?</u>**

2. **<u>How to convert between the Gregorian calendar and the Chinese calendar by mathematics?</u>**

We want to through our project to understand the history knowledge of both two calendars and learn the mathematic relationship between the Gregorian calendar and Chinese calendar.

The Gregorian Calendar：

The history of Julian Calendar

In 45 B.C., Julius Caesar depended the seasons added 90 days in to the calendar to make the months of the Roman calendar back to the traditional place. Considered the length of the tropical year [R10] and an Alexandrine astronomer's advice, Julius Caesar created Julian calendar as a solar calendar with twelve fixed different length months and add an intercalary day every fourth year instead of the old calendar, which was made as a lunisolar calendar in inspiration, not follow the lunar phases and lost the step with the cycle of seasons. After Caesar's death, the rule of the leap year was not realized well, and authorities made a serious mistake on the leap year's establishment. They mistook it will has one leap year after three years for each three years have one leap year. And also some details was lacking. Historians always describe that period is “year of confusion”. [R1] So Emperor Augustus corrected the calendar from the Julian years 8 B.C. through 4 A.D. It was the time that Julian calendar became to be a function as planned. [R1]

Originally, people used three division points to count the day within the month. They are so-called **Kalends**, which is the first day of month; **Nones**, which is the ninth day before the ides of a month. In the ancient Roman calendar, the seventh day of March, May, July, or October and the fifth day of the other months; and **Ides**, which is the 15th day of March, May, July, or October or the 13th day of the other months in the ancient Roman calendar. Days between the division points were counted by the coming division points. For example, they called February 23 is VII Kalends March and February 24 is VI Kalends March. [R1, 12]

After that, Julian calendar was developing in nearly 15 centuries. In the Middle Ages, the initial epoch for counting years, the date for beginning the year, and the method to make sure the day of the month had varied with the time and place even purpose. Besides that, the first day of the beginning year also is changed many times, from January 1 to March 1, March 25 or December 25. [R1]

In other hand, Julian calendar created and developed laid a foundation for the Gregorian calendar.

History of Gregorian Calendar

Gregorian calendar was appeared because of calculating the date of Easter. Before the Gregorian calendar, when they still used Julian calendar, the date of Easter was fixed.

They used March 21 as the Easter date, means that spring is start. But until thirteenth century, they found the spring starting date was not fixed. It changed from March 21 to an earlier date in the month. Because of that, people realized Easter is not the time of spring beginning and had no relation with Jewish Passover (A holiday beginning on the 14th of Nisan—the seventh month in Judaism, and traditionally continuing for eight days, commemorating the exodus of the Jews from Egypt)[R3]. In the next four centuries, scholar had tried to find correct time for Easter by calendar.

Until sixteenth century, the date of spring starting was changed nearly ten days and astronomical new moon was four days before ecclesiastical new moon. So Pope Pius V introduce a new Breviary (A book containing the hymns, offices, and prayers for the canonical hours) in 1568 and Missal (Roman Catholic Church A book containing all the prayers and responses necessary for celebrating the Mass throughout the year) in 1570. They mentioned about lunar movement and the leap year. After that, Pope Gregory XIII succeeded Pope Pius and considered the ten days were out of the calendar. So he changed the date October 4, 1582 to October 15, 1582. Then Easter was determined by the new calendar of new moon and full moon. But the new calendar was not accepted immediately. At first, the new calendar was only accepted in the Roman-Catholic world. Over the coming centuries, Protestant states gradually accepted it. But because of the cycle of Christian holidays, the Eastern Orthodox churches still used their old calendar, Julian calendar and kept the old way to calculating Easter. In the non-Christian world, we do not have this problem. But as international communications developed, Gregorian calendar was gradually accepted in the whole world. [R1, 11]

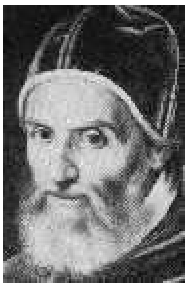

Figure 2: Pope Gregory XIII [R8]

The Gregorian calendar is the standard calendar in present times in most of countries. People have already used this calendar for more than 400 years in Europe. Actually, calendars can be divided into astronomical and arithmetical two kinds, and the Gregorian calendar belongs to the latter one.

The Gregorian calendar based on the Julian calendar, corrected the error by used mathematical calculation. [R16] So some people thought the Gregorian calendar is still a sort of the Julian calendar. Therefore, the Gregorian calendar is same as the Caesar Julian calendar consisted of that 12 months: 11 months of 30 or 31 days and February is 28 days (extended to 29 days every fourth year of leap year) according to solar circulate:

January	31 days
February	28(29) days
March	31 days
April	30 days
May	31 days
June	30 days
July	31 days
August	31 days
September	30 days
October	31 days
November	30 days
December	31 days

And the staring point of the fixed counting of days in Gregorian calendar was defined as:

gregorian_epoch = 1 [R2]

Depending to Pope Gregory XIII 10 years investigated, the leap year of the Gregorian calendar could be divisible by 4 and is not a century multiple of 100, unless they are divisible by 400. It means in Julian calendar 1600, 1700, 1800, 1900 and 2000 all are leap years, but in new the Gregorian calendar only 1600 and 2000 are leap year [R9, R13] :

1600/400=4

2000/400=5

The total number of days in 400, 100 and 4 years are:

400 * 365 + 100 - 3 = 146097 days

100 * 365 + 25 –1 = 36524 days

4 * 365 + 1 =1461 days

Also the week number per 400 years a cycle is:

146097 / 7 = 20871 weeks

The leap year and common year is both included in the Gregorian calendar. A leap year has 366 days with an extra day (leap day) as February 29 instead of usual 28 days, but a common year has 365 days. The leap year happens in each 4 years in order to synchronize the calendar year with the solar year and made the time of one year is same with earth use for surrounding the sun completely in its orbit which is 365 and 1/4 days. [R9, R12] As we know the tropical year is the earth to make one complete revolution around the sun, measured from one vernal equinox to the next and equal to 365 days, 5 hours, 48 minutes, 45.51 seconds or 365.24219 days. If we calculate each year by 365 days, that we will miss 0.24219 days each year; 0.96876 days each 4 years; 96.876 days each 400 years. So we need about 97 leap years in 400 years. The way to calculate the leap year by Gregorian calendar is very exact. It will be one-day error in 3333 years.

Total evolvement for Gregorian calendar:

Period	Country	Maker	The length of year	Month	Comparison	Result
713 B.C.	Old Rome	Numa Pompilius	354 days	12	11days more than tropical year	Establish the base of calendar
59 B.C.	Old Rome	Julius Caesar	365 days	12	Each 3 years has one leap year, 366days	"year of confusion", Bad influence
8 B.C.	Old Rome	Augustus	365 days	12		Resumed each fourth year have one leap year. Almost the same like Gregorian calendar
1582	Rome	Pope Gregory XIII	356.2425 days	12	0.0003 days error comparing tropical year	Make a exacter way to calculate leap year

Table 1 [R5]

Gregorian calendar carried out in non-Christian countries

On October 15th, 1582, only Italy, Poland, Spain and Portugal started to use the Gregorian calendar. [R4]

Until 18 century, Great Britain includes: England and Scotland, and U.S.A began to use Gregorian calendar. In Alaska, the next day after the Friday October 6th, 1867 is Friday October 18th. Because of the time of day in Alaska from Asia time change to North America time. [R4]

Sweden from 1699 began to change the old calendar to Gregorian calendar. At first, they want to cancel 11 leap days (Feb. 29th) between 1700 and 1740 in order to change to Gregorian calendar gradually. At that period, Sweden calendar was different between the old one and Gregorian calendar. Actually, from 1704 to 1708, the leap days were still used. So there are 10 days later than Gregorian calendar. So king of Sweden Carl XII went back to use the old calendar, add one day after Feb.29th, 1712. At last, in 1753, Sweden changed Feb.18th in old calendar to March 1st in Gregorian calendar.

The last changed county is Greece, 1923. But national church still did not use it.

China used it from 1912, Jan. 1st.

Japan used it from 1873, Jan 1st.

Timeline

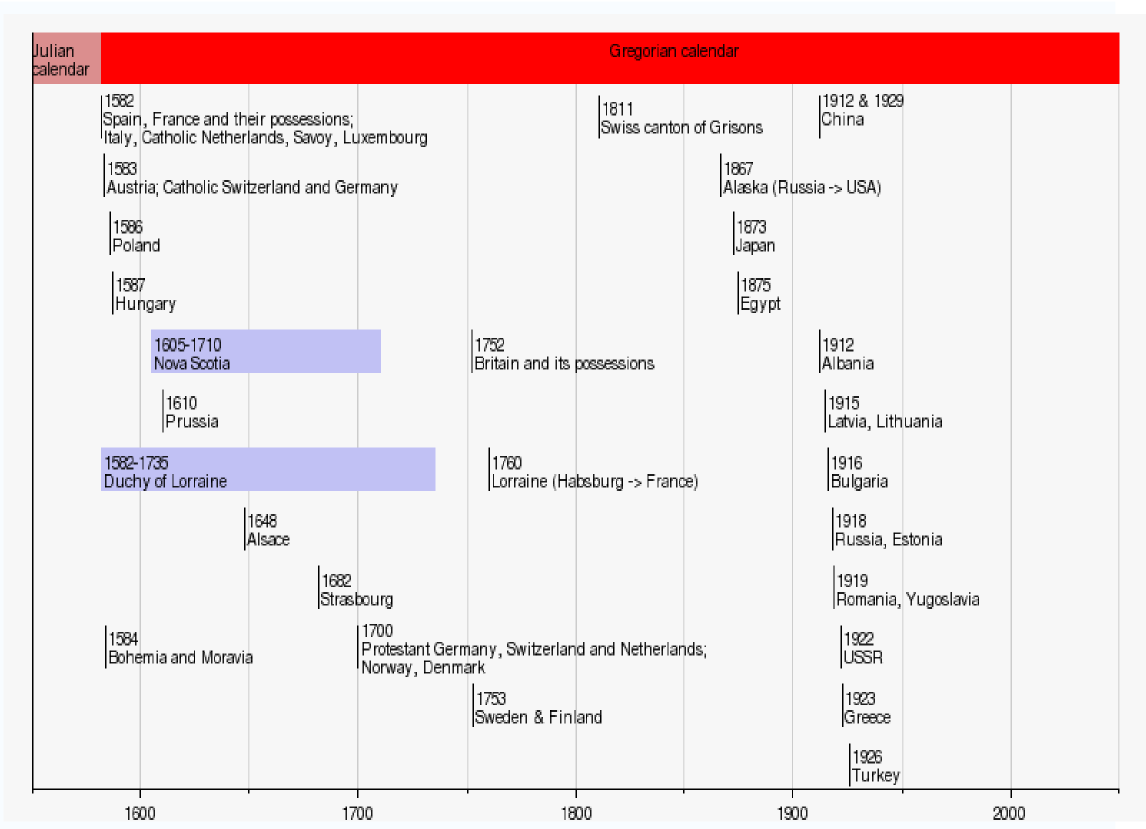

Table 2 [R4]

From Middle Ages, Jan.1st was defined as the first day of New Year. But some countries still kept their own traditional consuetude, using Dec.25th or March.25th, even Easter and so on as the first day of New Year. So determined Jan. 1st as the first day of New Year is the first step of revolution for the Gregorian Calendar.

It has got a very important signification in the history of calendar. [R4]

Adoption of January 1 as beginning of numbered year versus Gregorian Calendar adoption year [R4]		
Country	**1 Jan NY**	**Greg Cal**
Venice	1522	1582
Germany	1544	from 1583
Spain, Portugal, and Roman Catholic Netherlands	1556	from 1582
Prussia	1559	1700
Denmark	Early 14th century	1700
Sweden	?	1753
France	1564	1582

Lorraine	1579	1682
Protestant Netherlands	1583	from 1700
Scotland	1600	1752
Russia	1700	1918
Tuscany	1721	1750
England	1752	1752

Table 3 [R4]

Formulas explain:

1. Counting the current fixed date from the Gregorian date by counting the number of days in prior years and months of the current year, and counting the days in the current year:

fixed_from_gregorian (month, day, year) =

gregorian_epoch-1+365*(year-1)

$$+\left\lfloor \frac{year-1}{4} \right\rfloor - \left\lfloor \frac{year-1}{100} \right\rfloor + \left\lfloor \frac{year-1}{400} \right\rfloor + \left\lfloor \frac{367*month-362}{12} \right\rfloor$$

$$+\begin{cases} 0 & if \quad month \le 2 \\ -1 \quad if \quad month > 2 & and \quad gregorian\_leap\_year?(year) \\ -2 & otherwise \end{cases} + day \qquad \text{[R2e2.17]}$$

This formula explanation is as follows. When we count the total days in the Gregorian calendar, first 365 days times over years (all years number -1) and add one fourth of leap year number because the leap year can be divisible by 4, but the century year is not leap year except the century year is divisible by 400. And further calculation is for counting the previously days in that year. The formula is designed February-30 days, if the current year have not passed first two months, it need not consider 28 days in Feb. add 0 in the end. If over first two month and the current year is leap year, it need reduce 1 day (30-1=29, leap year Feb. 29 days). If currently year is common year, the answer reduces 2 and equals 28.

Example

We give a date 2005-11-21. How many days have passed?

fixed_from_gregorian(11,21,2005)=1(**gregorian_epoch**)-1+365*(2005-1)+

$$\left\lfloor \frac{2005-1}{4} \right\rfloor - \left\lfloor \frac{2005-1}{100} \right\rfloor + \left\lfloor \frac{2005-1}{400} \right\rfloor + \left\lfloor \frac{367*11-362}{12} \right\rfloor \text{-2+21}$$

=0+731460+501-20+5+306-2+21

=732271

2. Counting the Gregorian date from the current any days by counting year number:

gregorian_year_from_fixed (date) =

$$\begin{cases} year & if \ \ n_{100} = 4 or n_1 = 4 \\ year+1 & otherwise \end{cases}$$

Where

$$
\begin{aligned}
&d_0 = date - \text{gregorian\_epoch} \\
&n_{400} = \left\lfloor \frac{d_0}{146097} \right\rfloor \\
&d_1 = d_0 \bmod 146097 \\
&n_{100} = \left\lfloor \frac{d_1}{36524} \right\rfloor \\
&d_2 = d_1 \bmod 36524 \\
&n_4 = \left\lfloor \frac{d_2}{1461} \right\rfloor \\
&d_3 = d_2 \bmod 1461 \\
&n_1 = \left\lfloor \frac{d_3}{365} \right\rfloor \\
&d_4 = (d_3 \bmod 365) + 1 \\
&year = 400 * n_{400} + 100 * n_{100} + 4 * n_4 + n_1
\end{aligned}
\qquad \text{[R2e2.18]}
$$

The second formula: d_0 is the total day's number from the new epoch. 400 years has 146097 days; 100 years is 36524 days; one cycle of 4 years has 1641 days; so n_{400} is number 400 year cycle, n_{100} is number of 100 years from the Gregorian epoch. Therefore, the formula changes the counting date into calculation number of year and adds all cycles of years to know how many years from current to Gregorian epoch:

year = 400 * number of 400 years a cycle + 100 * number of 100years per cycle + 4 * number of 4 years of one cycle + number of single years

month = $\left\lfloor \frac{12n + 373}{367} \right\rfloor$ (n is the passed days number in the year)

(The formula is to calculate the day of the year falls in month number) [R2]

day = n – [(m –1) * 30+

$$\begin{Bmatrix} 0 & & if \quad month \le 2 \\ -1 & if \quad month > 2 & and \quad gregorian\_leap\_year?(year) \\ -2 & & otherwise \end{Bmatrix} + \left\lfloor \frac{7m-2}{12} \right\rfloor \qquad \text{[R2]}$$

Example:

We give a number of days is 732271; we use it to calculate the Gregorian date.

$d_0 = 732271 - 1(\text{gregorian\_epoch}) = 732270$

$n_{400} = \left\lfloor \frac{d_0}{146097} \right\rfloor = \left\lfloor \frac{732270}{146097} \right\rfloor = 5$

$d_1 = d_0 \bmod 146097 = 1785$

$n_{100} = \left\lfloor \frac{d_1}{36524} \right\rfloor = \left\lfloor \frac{1785}{36524} \right\rfloor = 0$

$d_2 = d_1 \bmod 36524 = 1785$

$n_4 = \left\lfloor \frac{d_2}{1461} \right\rfloor = \left\lfloor \frac{1785}{1461} \right\rfloor = 1$

$d_3 = d_2 \bmod 1461 = 324$

$n_1 = \left\lfloor \frac{d_3}{365} \right\rfloor = \left\lfloor \frac{324}{365} \right\rfloor = 0$

$d_4 = (d_3 \bmod 365) + 1 = 325$

$year = 400 * n_{400} + 100 * n_{100} + 4 * n_4 + n_1 = 400*5 + 100*0 + 4*1 + 0 = 2004$

732271days=2004 years + 325 days

$\left\lfloor \frac{12n+373}{367} \right\rfloor = \left\lfloor \frac{12*325+373}{367} \right\rfloor$=11month

$d_5 = d_4 - [(11-1)*30 - 2 + 6] = $ 325-304=21days

So we find 732271 days is 2005-11-21 in Gregorian date.

The third formula is one of the defined functions in the Chinese calendar part.

gregorian-date-difference(*g-date2*, *g-date1*)= [R2e2.20]

(**fixed-from-gregorian**(*g-date2*)–**fixed-from-gregorian**(*g-date1*))

where

g-date2 and *g-date1* are two different the Gregorian dates and has been transformed into R.D. day number.

The Chinese calendar

History of Chinese calendar

The Chinese calendar is a kind of calendar which is based on the astronomical events. And the main point is moon, sun and planet Jupiter. It is one kind of lunisolar calendar. Lunisolar calendar are used for most part of Asia in ancient time which based on the moon phase and the solar year.

- Moon phase: people had seen the aspects of the moon from Earth.
- Solar year: The time of one cycle that the Earth moves around the Sun.

There are two calendars at the present years in China, one is the Gregorian calendar which is used in the world and another one is a traditional Chinese calendar.

Chinese calendar has a special function to exist in China although people do not use that on normally days. In China, time is one of the points to determined Fortune's wheel and the geomantic omen which counted with Chinese calendar. Further more the time of the traditional festival and birthday (In China, people's birthday is counted with Chinese calendar) are counted with Chinese calendar.

In ancient time, China came into being two kinds of calendars (Solar calendar, lunar calendar) which invented by the different growth of crops needed. And the legend indicates that the first Chinese calendar was invented by Yellow Emperor. We do not know the exactly time that when the Chinese calendar (lunisolar calendar) invented. But from the knowledge of archaeology we can consider that it came from Shang Dynasty. (1600 BC to 1046 BC) Totally from Yellow Emperor to Qing dynasty have 102 calendars more. (Around 4000 BC to 1911) Even though some of calendars were not been used, but these calendars also can reflect the Chinese civilization, for example physic, astronomy and mathematics.

The old Chinese calendar that the time before the Han dynasty (before 202 BC) determined 366 days for one year, and already used day, month, xun and geng for time units. (The time units are not the same as the Gregorian calendar, I will introduce in the part of describe structure of Chinese calendar) In 2852 B.C the legendary emperor Fu-his, the astronomy came up into this country. Old Chinese calendar based on the pole star and the moving around it of circumpolar constellations (for example the Ursa Major that north in winter, south in summer and marked the twelve months of the Chinese) to calculate the length of a solar year. And astronomers found that each twelve years can be completed by the orbit of the planet Jupiter which called T'ai-sui in Chinese, and was taken into account in the Chinese division of periodic time (terrestrial branches). Because of the moon from dark to full are not fixed relation to the solar year, it had to be computed, so that months in the Chinese calendar could be regulated to fit the year.

After the 3000 BC, astronomers determined 24-solar 'nodes'. It is based on the solar longitude, each 15 degree per one node. The main nodes include two solstices and equinoxes. And it defined the beginnings of four seasons. All nodes consist one year.

Index	**Solar longitude.**	**Chinese Name**	**Gregorian Date (approx.)**	**English name**	**Remarks**
1	315°	Lichun	4 February	Beginning of spring	spring starts here according to the Chinese definition of a season
2	330°	Yushui	19 February	rain water	starting at this point, the temperature makes rain more likely than snow
3	345°	Jingzhe	5 March	waking of	when [hibernating]

				insects	insects awake
4	0°	Chunfen	21 March	Spring Equinox	lit. the central divide of spring (referring to the Chinese seasonal definition)
5	15°	Qingming	5 April	pure brightness	a Chinese festival where traditionally, ancestral graves are tended
6	30°	Quyu	20 April	grain rain	rain helps grain grow
7	45°	Lixia	6 May	beginning of summer	refers to the Chinese seasonal definition
8	60°	Xiaoman	21 May	grain full	grains are plump
9	75°	Mangzhong	6 June	grain in ear	lit. awns (beard of grain) grow
10	90°	Xiazhi	21 June	summer solstice	lit. summer extreme (of sun's height)
11	105°	Xiaoshu	7 July	minor heat	when heat starts to get unbearable
12	120°	Dashu	23 July	Great heat	the hottest time of the year
13	135°	Liqiu	7 August	beginning of autumn	uses the Chinese seasonal definition
14	150°	Chushu	23 August	limit of heat	lit. dwell in heat
15	165°	Bailu	8 September	White dew	condensed moisture makes dew white; a sign of autumn

16	180°	Qiufen	23 September	Autumnal equinox	lit. central divide of autumn (refers to the Chinese seasonal definition)
17	195°	Hanlu	8 October	cold dew	dew starts turning into frost
18	210°	Shuangjiang	23 October	descent of frost	appearance of frost and descent of temperature
19	225°	Lidong	7 November	beginning of winter	refers to the Chinese seasonal definition
20	240°	Xiaoxue	22 November	Slight snow	snow starts falling
21	255°	Daxue	7 December	Great snow	season of snowstorms in full swing
22	270°	Dongzhi	22 December	winter solstice	lit. winter extreme (of sun's height)
23	285°	Xiaohan	6 January	Slight cold	cold starts to become unbearable
24	300°	Dahan	20 January	Great cold	coldest time of year

Table 4 [R15]

As it can be seen from the above table, the meteorological cycle was the named by observing the weather during that period.

Each year has 12 months, and each month covered the number of the principal term.

Principal Terms

- Principal Term1: when the sun’s longitude is 330 degrees.

- Principal Term2: when the sun’s longitude is 0 degrees.
- Principal Term3: when the sun’s longitude is 30 degrees.
- Etc.
- Principal Term11: when the sun’s longitude is 270 degrees.
- Principal Term12: when the sun’s longitude is 300 degrees.

Chinese calendar was service by agriculture and 12 months are the joint with agriculture. And months also have a plant name.

- (First month): Latin "primus mensis".
- (Apricot month): apricot blossoms.
- (Peach month): peach blossoms.
- (Plum month): plum ripens.
- (Guava month): guava blossoms.
- (Lotus month): lotus blossoms.
- (Orchid month): orchid blossoms.
- (Osmanthus month): osmanthus blossoms.
- (Chrysanthemum month): chrysanthemum blossoms.
- (Good month): good month.
- (Hiemal month): hiemal month.
- (Last month): last month.

And then astronomers found the lunar months are not fixing to the solar year, some year has 13 lunar months and some year has 12 lunar months. It means one year has 13 full moons or 12 full moons. (Now we only discuss the 13 full moons, in the leap year part we will introduce all of them) So they determined a special month to regulate each year. This kind of special month is not fixed but depends on the solar system. As we mentioned, each month has a Principal Term, and cover a full moon. But it must have a month cover 2 full months, and this is that special month. And they also had a rule for determined this month that it should be the third full moon out in one of four seasons in a year.

In record of the lunar calendar also had a similar full moon called blue moon. But they determined differently. Because of the Chinese calendar are adjusted by human, but in lunar calendar it was determined by the nature way.

Seasons	**Name of full moon**
Yule, Winter Solstice	Moon after Yule
	Wolf Moon
	Lenten Moon
First Day of Spring, Vernal Equinox	Egg Moon (Paschal Moon)
	Milk Moon
	Flower Moon
The Long Day, Summer Solstice	Hay Moon
	Grain Moon
	Fruit Moon
Summer's End, Autumnal Equinox	Harvest Moon
	Hunter's Moon
	Moon before Yule
The third full moon in any season	Blue Moon

Table 5

From the above figure, it shows that the different month covered the different name of the full moon, and it is fixed, but the blue moon is not fixed.

Based on the each special month astronomer determined the 4 seasons and Sui. In here I will insert the definition of the year and the Sui in Chinese calendar. Year means from the first month of the lunar year to the next the first month of the lunar year. Sui means from the midwinter to the next midwinter. So it means that they were different length in that time. And the end of that time, because of the war and China was divided by few countries, and each country had their own calendar which based on the old Chinese calendar.

Figure 3 [R14]

The words on the oracle bones proved that the Chinese calendar already been used in Shang dynasty and Chinese had already established the calendar at 365.25 days and the lunation at 29.5 days

From the beginning of Han dynasty Chinese calendar had an important changed. First of all, the emperor unified the many calendars to Chinese calendar. A man named Wan-nien created the ‘perpetual calendar’ during the Shang dynasty (1766-1123 B.C). He surveyed to the length of the shadows for the sun through the year with a gnomon template (see figure). In virtue of the longest and shortest days in the year he set solstices and in turn the two equinoxes, and concluded that the year has 365 + fraction days within a year’s time.

The astronomers defined the basis for the imperial calendar and almanac. The almanac fixed up the lengths of the months, defined the dates of spring and autumn equinoxes (a year that night’s length equal day’s length) and of the summer and winter solstices (night and day different most in length). And then they changed the days per one year from 366 to 365. For leap month they used the mathematics to calculate and defined instead to depend on the astronomic movement. It means that the leap month is the fixed in each year. So from that time Sui and year are the same length.

After these changed, Chinese calendar has a general structure, and be used until now days.

Describe the structure of Chinese calendar

Chinese calendar’s hour is not the same as others. Each day divide by 12 times called ‘Gen’. And it begins from 11 pm to 1 am.

Zi	Chou	Yi	Mao	Chen	Si
11pm-1am	1am-3am	3am-5am	5am-7am	7am-9am	9am-11am
Wu	Wei	Shen	You	Xu	hai
11am-1pm	1pm-3pm	3pm-5pm	5pm-7pm	7pm-9pm	9pm-11pm

Table 6 [R2]

The day in Chinese calendar begins at the midnight.

The period of the month was from the new moon (when the moon is in conjunction with the sun) to the next new moon.

Chinese calendar has not defined the ‘week’ but ‘xun’. Each 10 days called one ‘xun’. Each month has 3 ‘xun’. And be called ‘up xun’, ‘middle xun’ and ‘down xun’.

The period of the month was from the new moon (when the moon is in conjunction with the sun) to the next new moon.

A normal year has 12 months and 353, 354 or 355 days.
A leap year has 13 months and 383, 384 or 385 days.

Heavenly stems and earthly branches

The ancient time Chinese uses the system to determine the years which is named Sexagenery Cycle. There are two groups of names, one is so-called heavenly stems, and the other one is earthly branches. (Shown in the following picture)

Heavenly stems-element:

Heavenly stems-element was defined by 1-10 Chinese numbers. It is figure by the five elements as well. In ancient time people thought all things made from these 5 elements in China and each thing has their own Ying or Yang. We can apprehended by each things has positive or negative. We also can say that female are Ying and male are Yang.

Table 7

Jia	Yi	Bing	Ding	Wu	Ji	Geng	Xin	Ren	Gui
Wood Yang	Wood Ying	Fire Yang	Fire Ying	Earth Yang	Earth Ying	Metal Yang	Metal Ying	Water Yang	Water Ying

Earthly branches (animal):

Earthly branches were determined by the 12 direction points that the planet Jupiter move around the sun.

Zi	Chou	Yin	Mao	Chen	Si	Wu	Wei	Shen	You	Xu	hai
Rat	Ox	Tiger	Hare	Dragon	Snake	Horse	Sheep	Monkey	Fowl	Dog	Pig

Table 8

The year list:

1. jia-zi	16. ji-mao	31. jia-wu	46. ji-you
2. yi-chou	17. geng-chen	32. yi-wei	47. geng-xu
3. bing-yin	18. xin-si	33. bing-shen	48. xin-hai
4. ding-mao	19. ren-wu	34. ding-you	49. ren-zi
5. wu-chen	20. gui-wei	35. wu-xu	50. gui-chou
6. ji-si	21. jia-shen	36. ji-hai	51. jia-yin
7. geng-wu	22. yi-you	37. geng-zi	52. yi-mao
8. xin-wei	23. bing-xu	38. xin-chou	53. bing-chen
9. ren-shen	24. ding-hai	39. ren-yin	54. ding-si
10. gui-you	25. wu-zi	40. gui-mao	55. wu-wu
11. jia-xu	26. ji-chou	41. jia-chen	56. ji-wei
12. yi-hai	27. geng-yin	42. yi-si	57. geng-shen
13. bing-zi	28. xin-mao	43. bing-wu	58. xin-you
14. ding-chou	29. ren-chen	44. ding-wei	59. ren-xu
15. wu-yin	30. gui-si	45. wu-shen	60. gui-hai

Table 9

The cycle is running between these two groups. For instance, the first year in Chinese calendar was name Jia –Zi. However, when 60 cycles was finished, the cycles will start all over again. The sixty cycles was also used in order to name the days and the month in Shang dynasty. From Han dynasty, the Chinese begins to use Sexagesimal Cycle System to name years. In this case, people must be confuse that how to calculate the exactly years be done.

There was another method which is used to make the calendar in ancient times, because at that time the emperor of the kingdom was claimed by the son of the heaven. The ancestry want to prove that the heaven and the emperor were consentaneous, so when each of the new emperors was born, that year was considered the first year in the new Chinese calendar. Each new era was also established by the new emperor who was going to govern the whole empire. The era which is so-called epoch was the name of the year, because if the old emperor was dead or nature disaster happened, the new era was established by the next emperor. The new era was also established when there was new theory introduced.

Because of each time had own emperor, and emperor just can cover 1 or 2 cycle of Sexagesimal Cycle System. So when people calculate the years, also should use reference about the emperors' list.

Chinese Leap year

In Chinese calendar, each month starts on the middle night of the new moon, and counting months by the "principal term" (we already explain it in the history part). And the 11th month must fix with Principal Term11 it means that the month which includes midwinter has to be fixed.

Normally one solar year has 13 lunar months, but in some cases, one solar year only has 12 lunation months, but 11th month which includes midwinter has to be fixed, so it would insert an intercalary month as well. And we called this year is a leap year. In leap year at least one month can not cover any of principal Terms, and the first month which do not cover the principal Term called leap month. And this month has the same days with last month. In Chinese calendar has not the 13th month's name. And if last month called July, then leap month called leap July.

In Chinese calendar the leap year has a roughly cycle about 19 years according by Gregorian calendar. For example 27th May of 2001, 27th May of 1982 and 27th May of 1963 are the 5th of leap April.

In infrequent cases, the two months in a year cover each 2 numbers of Principal Terms, but it has 13 lunar months. It means even not a leap year; it may have a leap month also. For example year of 2034, January is a leap month, but 2034 is not the leap year.

The twelve animals as year designations

Each year in China has their animal representation. Totally they are twelve animals to describe the years. These descriptions are orderliness. It based on the Earthly branches which we mentioned before.

Why did ancestries choose these kinds of animals? Because of it based on the Ying and Yang system that we can easy to know 6 animals are wild 6 animals are domestically. In ancient time Chinese believe that all things have two attributes. (Ying and Yang) And they also assigned each of animals to accord with five elements. And they could use these kinds of information to do fortunetelling and geomantic omen. But actually in now days many people are not believe that, because it is superstition that we realized by science.

Different way to counting time in ancient time

1. “Biao and Gui”

A long time ago, Chinese people discovered buildings, trees and so on generated the shadows by sunlight below illuminating are able to be fling out the reflection, and these the reflections alternations possess the specified regular pattern.

The flat ground is going up straight making a bamboo pole either stone pillar to watch the reflection alternation and this erect rod either vertical column are known as “Biao“ which is a instrument as watch. In the way of length and the orientation that the ruler was surveyed the “Biao” image, piece may realize double-hour. Because in archaic time, Chinese people established 12 double-hours in one day.

Afterward, Chinese people discover the 11 a.m. to 1 p.m. the watch image always flings to the northern direction. The ruler made by flagstone, the store put on the surface of the earth, and form uprightness with “Biao”, the one end of ruler is joining the “Biao” foundation, and another piece is extended to the northern direction, and this ruler of flagstone make is called “Gui”. The 11 a.m. to 1 p.m. “Biao” image flings on flagstone. Chinese forefathers are able to direct reading “Biao” image length is worth.

Figure 4: “Biao” and “Gui” [R17]

Observes after over a long period of time, the our forefathers not merely comprehend the 11 a.m. to 1 p.m. cousin-hour's image of a day is the shortest at high noon time, but also obtains the inside the summer solstice--the 10th of the 24 solar terms day of 1 year, the high noon “Biao” image is the shortest in a year; the high noon image is the longest in a year when the day is winter solstice day coming.

Then, Chinese forefathers with upright the 11 a.m. to 1 p.m. the “Biao” image length come to fix solar term and 1 year length. For example, when successive twice of the “Biao” image is develop to be worth most, this twice is develop to be worth the fate being apart most, and time length that was 1 year is equaled 365 days. Chinese forefathers realized 1 year length by this way.

2. Sundial

The sundial (see figure) is Chinese country anciently utilizes the shadows length as one kind of counting of time apparatus. Consist of the needle of copper system indicator and stone disc usually. The indicator of copper system is known as “sundial needle”, vertically passes the disc heart, and is role as “Biao” action. So the sundial needle is called “Biao” once more, the disc is known as " the surface of sundial " , places at stone on stage , and presents that northern is lower and southern is higher, and causes the sundial parallel to the sky equatorial plane. The surface of sundial is divided into 12 great squares and the internal angle is 30 degree. Every one great squares formed by crossed lines stands for two hours. When the sunlight illuminates the sundial on, the sundial needle reflection is able to fling to the sundial surface, and when the sun moves from east to westward, flings to the sundial surface of the sundial needle reflection also slowly through western eastward removing such as the moving reflection of the sundial needle is the indicators of watch and the sundial piece is the timepiece faces, with this comes to display a point of time.

Figure 5: sundial [R17]

Since through the Spring Equinox up the 16th of the 24 solar terms period, the sun is always move at north side of the sky equatorial plane. So sundial needle reflection is fling to the sundial face upper site. Through the 16th of the 24 solar terms up the Spring Equinox period, the sun runs at south side of the that plane and causes that the sundial needle reflection flings to the sundial the below site. First of all, necessarily comprehend the two distinct particulars period sundial needle reflection place when watching the sundial.

3. “Lou Ke”

“Lou Ke” (clepsydra) is one kind of old counting time method and it is not only used in age-old China, but also it is utilized at age-old Egypt, Babylon and so on. It is through the superficial arrow of the clepsydra to calculate one day and night a point of time. The clepsydra and superficial arrows in the container two parts are formed “Lou Ke”.

Initial, Chinese forefathers discovered that water can drop out through the split of crockery. Then, they made a special earthenware one kind of clepsydra that remains the aperture. When emptying into water inner place the clepsydra, the water simply comes out through the aperture in pot opening, besides gathers water that leaks down in the way of the container again. And made the mark on the arrow was put into container similar as the display on the timepiece surface. Using a piece of small wood or bamboo makes the arrow floating on the water and an aperture is leave in the container lid heart. The arrow shaft is through the toping aperture coming out. This container is known as "arrow pot".

Following the water grows little by little in the “arrow pot“, the wood or bamboo piece hold the arrow getting up in the container. Human can observe the arrow shaft mark by the aperture of container lid and be able to realize concretely a point of time.

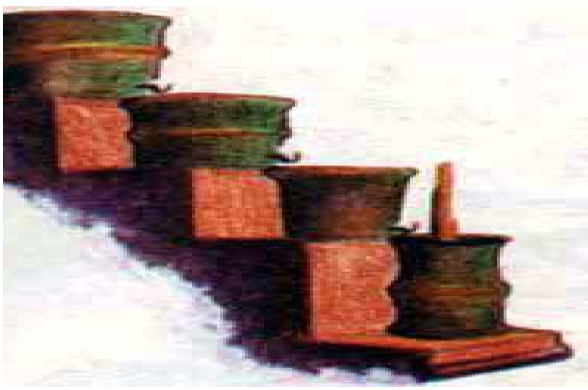

Figure 6: “Lou Ke” [R17]

“Lou Ke” (clepsydra) is a special independent counting time system, because it is only draw support from water movement. Afterward, Chinese forefathers find that when water is more in inner place the clepsydra, flowing water is faster, while flowing water is slow moment water less, apparently be able to affect the measure time the accuracy. So forefathers decided add one or two more clepsydras up the original clepsydra. Water what through the following clepsydra runs away the at the same time , upper clepsydra water in immediate continuously as the replenishment gives the next nether clepsydra, causes water evenly flows into the arrow pot inner place the next clepsydra, thereby acquires comparatively more accurately a point of time.

4. Others:

Figure 7: Hun Tian Yi [17]

The "celestial sphere instrument," the armillary sphere appeared more than 2000 years ago in China. This tool was used by Astronomers to determine coordinates for celestial bodies and to learn how the astronomical principles. It connected to a machine run automatically by the water, and move exactly as the solar system. The first one was made in 117 by Zhang heng (one of the famous astronomers in China)

Figure 8: Chinese Skaphe [R17]

A skaphe also called bowl sundial. It is made for particular latitude.
It depends on the light shadow, and can determine the time, season and so on.

Chinese traditional Festival

In China, each year has 9 main festivals, 7 defined by the lunar and solar calendars. Another 2 came from agriculture. (These 2 special holidays are the Tomb-Sweeping Festival and the Winter Solstice Festival, falling upon the respective solar terms, first at 15 degrees, another at 270 degrees)

Date	English Name	Remarks
month 1 day 1	Chinese New Year lit. Spring Festival	Family gathering and major festivities for three days; traditionally 15 days
month 1 day 15	Lantern Festival	Yuanxiao eating and lanterns
Apr 4 or 5	Qingming Festival lit. Clear and Bright Festival	Graves tending
month 5 day 5	Dragon Boat Festival	Dragon boat racing and zhongzi eating
month 7 day 7	The Night of Sevens a Valentine's Day	
month 7 day 15	Ghost Festival or Spirit Festival	
month 8 day 15	Mid-Autumn Festival or Moon Festival	Family gathering and moon cake eating
month 9 day 9	Double Ninth Festival lit. Double Yang Festival	Mountain climbing and flower shows
Dec 21 or 22	Winter Solstice Festival	Family gathering

Table 10

The first day of the first lunar month in a lunar calendar is New Year's Day. Lunar New Year is also called Spring Festival. This festival is very important in China and some East Asian country also. People in this time should back home with his family. It's a similar as the Christmas day.

The mathematical part of Chinese calendar

The explanation of the formula of this section

In this section, we will focus on the formula which is used to convert between the Chinese calendar and the R.D dates. (It is also named as fixed date) (The author of this book considers the first date in Gregorian calendar as the R.D day number 1, and then the author counts the day number of R.D date day by day, the R.D date does not have year and month).

First of all, the formula of converting an R.D dates into the corresponding date in Chinese calendar. In the Chinese calendar we must have cycle, year, month, day, the formula of getting these elements describe as follows:

elapsed-years= **gregorian-year-form-fixed**(*date*) **–**
gregorian-year-from-fixed(**chinese-epoch**) + N
If *month* < 11 N = 1, otherwise N = 0
Where
chinese-epoch=**fixed-from-gregorian**(-2636, 15th February) [R2e14.11]
elapsed-years is means the totally years in Chinese calendar.
In here *date* actually is RD number.

(The formula of the function **gregorian-year-from-fixed** was described in the Gregorian calendar section).

While we get the totally years in Chinese calendar, we can easily to get the totally *cycles*, the year in the Sexagesimal Cycle System, the month and the day.

$cycle = \lfloor (elapsed\_years - 1) / 60 \rfloor + 1$ [R2e14.12]

year = **elapsed-years** amod 60 (amod means Adjusted remainder function) [R2]

month = (round ((m - m_1) / **mean-synodic-month**)) – B

where:

B = 1 if **leap_year** and **prior_leap_month**(m_1, m)

B = 0 otherwise

Where

- m_1 = **chinese_new_moon_on_or_after**(s_1 + 1) if s_1 < date < s_2

  or m_1 =**chinese_new_moon_on_or_after**(s_2 + 1) otherwise

The formula **chinese_new_moon_on_or_after** is used to determine the julian day number of the first new moon on or after a julian day in local time.

- **mean-synodic-month** = 29.530588853 (days)

- **prior-leap-month**?(*m'*, *m*)= [R2e14.10]

  $m \geq m'$

  and $\{prior - leap - month?$

  (m' ,**chinese-new-moon-before**(m))

  or $no - major - solar - term?(m)\}$

The formula **chinese-new-moon-before** is used to determine the julian day number of the first new moon before a julian day in local time

- s_1 = **major-solar-term-on-or-after**

  (**fixed-from-gregorian**

  (December, 15, *g_year*-1))

The formula **major-solar-term-on-or-after()** is used to determine the date of the major solar on or after a given date.

- s_2 = **major-solar-term-on-or-after**

  (**fixed-from-gregorian**

(December, 15, *g-year*))

where

g-year = **greogorian-year-from-fixed**(*date*)

day = *date* – *m* + 1

where

m = **chinese-new-moon-before**(*date*+ 1)

m_2 = **chinese-new-moon-before**(s_2 + 1) if $s_1 <$ date $< s_2$

or

m_2 =**chinese_new_moon_before**

(**major_solar_term_on_or_after**

(**fixed_from_gregorian**

(**December**, 15, *g-year* + 1)) + 1) otherwise

Above the formulas we already determined whether there is a **chinese-leap-month -after-lunar-month** (we use *m'*) or **before-lunar-month** (we use *m*). There are two conditions, first is $m \geq m'$, second, we compare the value m' and the number we have got from the formula **chinese-new-moon-before**(*m*) by using the first condition, if it is true, or if the answer of **no-major-solar-term**(*m*) is true, then the second condition is true. If both of the conditions are true, we have a **prior-leap-month-after a leap -month** *m'* or **before a leap-month** *m*.

Where: [R2e14.9]

no-major-solar-term?(*date*) =

current-major-solar-term(*date*) (a)

= **current-major-solar-term**

(**chinese-new-moon-on-or-after** (*date* + 1)) (b)

We need the first month missing a major solar term to be a leap month. So we also use the formula **prior-leap-month?** which explained before.

In the above formula we would like to calculate whether a given date has a solar term. If the value which we have got from a equals the value we have got from formula (b), then the given date has a major solar term, otherwise the given date does not has a major solar term.

current-major-solar-term(*date*)= $(2+\lfloor s/30 \rfloor)$ amod 12 [R2e14,1]

The formula **current-major-solar-term** is used to determine the index of the last solar term according to a given date.

where

s=**solar-longitude**

(**universal-from-local**

(**jd-from-moment**(*date*),

(**chinese-time-zone**(*date*))))

solar-longitude(*jd*)=**degrees**((*longitude*+**aberration**(*c*)+**nutation**(*c*))*$180/1\pi$)

degree $(\theta)=\theta$ mod 360 [R2e12.18 and 12.19]

c=**julian-centuries**(*jd*)

The formula *c* is used to convert a julian day number *jd* to Julian centuries. [R2chapter12.5]

$$longitude = 4.9353929 + 628.33196168 * c + 0.0000001 * \sum(\tilde{x} * \sin((\tilde{y} + \tilde{z} * c) * \frac{180}{\pi}))$$

where:

$\tilde{x}$ =(see table 1)

$\tilde{y}$ =(see table 1)

$\tilde{z}$ =(see table 1)

Table 11. Arguments for solar-longitude [R2 table 12.1]

$\tilde{x}$	$\tilde{y}$	$\tilde{z}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$
403406	4.721964	0.01621043	195207	5.937458	628.30348067
119433	1.115589	628.30821524	112392	5.781616	628.29634302
3891	5.5474	1256.605691	2819	1.512	1256.60984
1721	4.1897	628.324766	0	1.163	0.00813
660	5.415	1256.5931	350	4.315	575.3385
334	4.553	-0.33931	314	5.198	7771.37715
268	5.989	786.04191	242	2.911	0.05412
234	1.423	393.02098	158	0.061	-0.34861
132	2.317	1150.67698	129	3.193	157.74337
114	2.828	52.9667	99	0.52	588.4927
93	4.65	52.9611	86	4.35	-39.807
78	2.75	522.3769	72	4.5	550.7647
68	3.23	2.6108	64	1.22	157.7385
46	0.14	1884.9103	38	3.44	-77.5655
37	4.37	2.6489	32	1.14	1179.0627
29	2.84	550.7575	28	5.96	-79.6139
27	5.09	1884.8981	27	1.72	21.3219
25	2.56	1097.7103	24	1.92	548.6856
21	0.09	254.4393	21	5.98	-557.3143
20	4.03	606.9774	18	4.47	21.3279
17	0.79	1097.7163	14	4.24	-77.5282
13	2.01	1884.9191	13	2.65	2.0781
13	4.98	294.2463	12	0.93	-0.0799
10	2.21	469.4114	10	3.59	-0.6829
10	1.5	214.6325	10	2.55	1572.084

aberration(*c*)=0.0000017*cos(177.63+35999.01848*c*)–0.0000973 [R2e12.20]

The terms to compensate for aberration(the effect of the sun's motion while its light is traveling towards Earth. [R2chapter12.5]

nutation(*c*)=-0.0000834*sin $\alpha - 0.0000064 * \sin b$ [R2e12.4]

The **nutation** which is caused by the wobble of the Earth.

where:

α =124.90–1934.134*c+0.002063*c^2

b=201.11+72001.5377*c+0.00057*c^2

The function of Julian centuries is defined as follows:

julian-centures(*moment*)=(**ephemeris-from-universal**(*moment*)–**j2000**)/36525

The *moment* is the date time and the *jd* is a Julian day number [R2e12.16]

ephemeris-from-universal(jd)=*jd*+**ephemeris-correction**(**moment-from-jd**(*jd*))

The formula **ephemeris-from-universal** is used to convert a ephemeris time (The Astronomical calculations are typically done using Ephemeris time.) of a given julian day number to universal time.

ephemeris-correction(*moment*)=

$$\begin{cases} (year - 1933)/24 * 60^2 & if\, 1988 < year < 2019 \\ \sum_i coeff - 19th[i] * \theta i & if\, 1900 < year < 1987 \\ \sum_j coeff - 18th[j] * \theta j & if\, 1800 < year < 1899 \\ (196.58333 - 4.0675 * (year - 1600) + & \\ 0.0219167 * (year - 1600))^2 / 24 * 60^2 & if\, 1620 < year < 1799 \\ (x^2 / 41048480 - 15)/24 * 60^2 & otherwise \end{cases}$$

The formula **ephemeris-correction** is used for calculate ephemeris time without errors.

Where:

year=**gregorian-year-from-fixed**(*moment*)

$\theta = (\left| January \middle| 1 \middle| 1900 \right|, \left| July \middle| 1 \middle| year \right|)/36525$

coeff-19th=<-0.00002, -0.000297, 0.025184, -0.181133, 0.553040,

-0.861938, 0.677066, -0.212591>

coeff-18th=<-0.000009, 0.003844, 0.083563, 0.865736, 4.867575, 15.845535,

31.332267, 38.291999, 28.316289, 11.636204, 2.043794>

x=0.5+**gregorian-date-difference**($\left| January \middle| 1 \middle| 1810 \right|, \left| January \middle| 1 \middle| year \right|$)

Where

gregorian-date-difference(*g_date2, g_date1*)=

(**fixed-from-gregorian**(*g_date2*)–**fixed-from-gregorian**(*g_date1*))

j2000=**jd-from-moment** [R2e12.5]

(0.5+**fixed-from-gregorian**(January, 1, 2000))

(The formulas of **fixed-from-gregorian** and **gregorian-date-difference** are already defined in Gregorian calendar section)

jd-from-moment(*moment*) = *moment–jd-start*

jd-start=-1721424.5

universal-from-local(*1-time, zone*) = *1-time–zone*/(24*60)

chinese-time-zone(*date*)=

$$\begin{cases} 465+40/60 & if\_year<1929 \\ 480 & otherwise \end{cases}$$

where:

year=**gregorian-year-from-fixed**(*date*)

In the above formula **universal-from-local()** is used to convert between the universal time (*u-time*) and the local time (*1-time*). Because before 1929, the time difference between local time of Beijing and UT was 7 hours, 45 minutes, 40 seconds which was 465 + 40/60. After year 1929, the Chinese adopt the standard time zone, the difference changed to 8 hours which is 480 minutes. If the year number less than 1929, the value of function is 465+40/60, otherwise, the value of the function is 480.

chinese-new-moon-before(*date*)=
fixed-from-jd
(**local-from-universal**
(**new-moon-before**
(**universal-from-local**
(**jd-from-moment**(*date*),
chinese_time_zone(*date*))),
chinese_time_zone(*date*))) [R2e14.8]

where:

fixed-from-jd(*jd*)=[**moment_from_jd**(*jd*)]

local-from-universal(*u-time, zone*)=*u-time*+*zone*/24*60 [R2e12.8]

new-moon-before(*jd*)=**new-moon-at-or-after**(**new-moon-at-or-after**(*jd*)-45)

chinese-new-moon-on-or-after(*date*)=
fixed-from-jd
(**local-from-universal**
(**new-moon-at-or-after**
(**universal-from-local**
(**jd-from-moment**(*date*)
chinese-time-zone(*date*))
chinese-time-zone(*date*))) [R2e14.7]

where:

new-moon-at-or-after(*jd*)=**new-moon-time**(*approx*+*error*)

where:

$date$=**gregorian-from-fixed**$(\lfloor moment-from-jd(jd)\rfloor)$ [R2e12.31]

$approx=\lfloor y*12.3685\rfloor-1$

$$error = \sum_{k\geq approx}^{P(k)} 1$$

where

p(k) =**new-moon-time**(*k*)<*jd*

y=date year+(**day-number**(*date*))/365.25–2000 [R2e12.32]

where

new-moon-time(*k*)=**universal-from-ephemeris**(*jde*+*correction*+*additional*)

jde=(2451550.09765+**mean-synodic-month***1236.85**c*+0.0001337*c^2 –

0.000000150*c^3+0.00000000073*c^4)

mean-synodic-month=29.530588853 [R12e12.30]

c=*k*/1236.85

e=1–0.002516**c*–0.0000074*c^2

correction=

-0.00017*sin*w*+

$$(\tilde{v}*e^{\tilde{w}}*\sin(\tilde{x}*solar-anomaly+\tilde{y}*lunar-anomaly+\tilde{z}*moon-\arg ument))$$

solar_anomaly=2.5534+29.10535669*1236.85**c*–0.0000218*c^2–0.00000011*c^3

lunar_anomaly=201.5643+385.8693528*1236.85**c*+0.0107438

*c^2+0.00001239*c^3+0.000000058*c^4

moon_argument=160.7108+390.67050274*1236.85**c*–0.0016341* c^2 –0.00000227*

c^3+0.000000011*c^4

w=124.7746+(-1.56375580)*1236.85**c*+0.0020691*c^2+0.00000215*c^3

$additional = (\tilde{l} * \sin(\tilde{i} + \tilde{j} * k + \tilde{n} * c))$ [R2e12.32]

$\tilde{v}$ = (see table 12)

$\tilde{w}$ = (see table 12)

$\tilde{x}$ = (see table 12)

$\tilde{y}$ = (see table 12)

$\tilde{z}$ = (see table 12)

$\tilde{i}$ = (see table 13)

$\tilde{j}$ = (see table 13)

$\tilde{l}$ = (see table 13)

$\tilde{n}$ = (see table 13)

Table 12 Arguments for new-moon-time [R2 table 12.3 and 12.4]

$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$	$\tilde{v}$	$\tilde{w}$	$\tilde{x}$	$\tilde{y}$	$\tilde{z}$
-0.40720	0	0	1	0	0.17241	1	1	0	0
0.01608	0	0	2	0	0.01039	0	0	0	2
0.00739	1	-1	1	0	-0.00514	1	1	1	0
0.00208	2	2	0	0	-0.00111	0	0	1	-2
-0.00057	0	0	1	2	0.00056	1	1	2	0
-0.00042	0	0	3	0	0.00042	1	1	0	2
0.00038	1	1	0	-2	-0.00024	1	-1	2	0
-0.00007	0	2	1	0	0.00004	0	0	2	-2
0.00004	0	3	0	0	0.00003	0	1	1	-2
0.00003	0	0	2	2	-0.00003	0	1	1	2
0.00003	0	-1	1	2	-0.00002	0	-1	1	-2

-0.00002	0	1	3	0	0.00002	0	0	4	0

Table 13 Arguments for new-moon-time

$\tilde{i}$	$\tilde{j}$	$\tilde{n}$	$\tilde{l}$	$\tilde{i}$	$\tilde{j}$	$\tilde{n}$	$\tilde{l}$
299.77	0.107408	-0.009173	0.000325	251.88	0.016321	0	0.000165
251.83	26.641886	0	0.000164	349.42	36.412478	0	0.000126
84.66	18.206239	0	0.000110	141.74	53.303771	0	0.000062
207.14	2.453732	0	0.000060	154.84	7.306860	0	0.000056
34.52	27.261239	0	0.000047	207.19	0.121824	0	0.000042
291.34	1.844379	0	0.000040	161.72	24.198154	0	0.000037
239.56	25.513099	0	0.000035	331.55	3.592518	0	0.000023

Second, we will introduce the formula which is used to convert from a R.D dates to the Chinese calendar.

fixed-from-chinese(*cycle, year, month, leap, day*)=**prior-new-moon**+*day*+1

where:

g-year=(*cycle* – 1)*60 +*year*-1+**gregorian-year-from-fixed**(**chinese-epoch**)

chinese-epoch=**fixed-from-gregorian**(-2636, 15th February)

new-year=**chinese-new-year**(*g-year*)

d= **chinese-from-fixed**(*p*)

p=**chinese-new-moon-on-after**(*new_year*+(*month*–1)*29)

prior-new-moon=

$$\begin{cases} p & if\_month = dmonth\_and\_leap = dmonth \\ chinese-new-moon-on-or-after(p+1) & otherwise \end{cases}$$

chinese-new-year(*g-year*)=

chinese-new-moon-on-or-after(m_2 + 1) [R2e14.13]

if round(($m_{11} - m_1$)/mean-synodic_month)=12

and { **no-major-solar-term**?(m_1))

or **no-major-solar-term**?(m_2)}

m_2 otherwise

where:

s_1 =**major-solar-term-on-or-after**

(**fixed-from-gregorian**(December, 15, *g-year* -1))

s_2 =**major-solar-term-on-or-after**

(**fixed-from-gregorian**(december, 15, *g-year*))

m_1 =**chinese-new-moon-on-or-after**(s_1 + 1)

m_2 =**chinese-new-moon-on-or-after**(m_1 + 1)

m_{11} =**chinese-new-moon-before**(s_2 + 1)

Methodology

In the following part, we would like to introduce the method of converting a given date into the corresponding date in Gregorian calendar. After we have read some literatures, it is no the formula which can convert a given Chinese date into the corresponding Gregorian calendar directly. So, we decide to use our own method to execute the converting process by using some of the formulas in the history of

Chinese calendar section and the history of Gregorian calendar section. There are two steps. The first step is to convert the given date from Chinese calendar into the R.D date (it is also named as fixed date) (The author of this book considers the first date in Gregorian calendar as the R.D day number 1, and then the author counts the day number of R.D date day by day, the R.D date does not have year and month). The second step is to convert the R.D date we have got from the first step into the Gregorian date. On the other hand, if people want to convert from the Gregorian calendar into the Chinese calendar, first, they need to convert the given Gregorian calendar into the R.D. date, and then convert the R.D. date into the corresponding date in the Chinese calendar.

The formulas are described as follows:

(1) The formula of converting from the Chinese into the Gregorian calendar.

First of all, we use the formula in the fifth parts in the mathematical part in Chinese calendar which used to convert from the Chinese calendar into the R.D date.

Second, we use the formula in the second part in the formula explain in history of Gregorian calendar section which is used to convert from the R.D date to Gregorian calendar. The graph of the process is described as follows:

Chinese calendar → R.D. date → Gregorian calendar

The formula of converting is from the Gregorian calendar into the Chinese calendar. First of all, we use the formula in the first part in the formula explain in Gregorian calendar which is used to convert from the Gregorian calendar into the R.D date.

Second, we use the formula in the fourth part in mathematical part in the history of Chinese calendar section which is used to convert from the R.D date to Chinese calendar.

The structure of the process describe as follows:

Gregorian calendar → R.D. date → Chinese calendar

Conclusion and discussion

In this project, we have research the history of the Gregorian calendar, the Chinese calendar and the formulas which are used to convert between the Chinese calendar and Gregorian calendar.

1. The reflection and relation to the semester theme

- For the history part, it can easily to find the astronomical origin. And astronomical of the development restricted the calendar's development in ancient time. In each step of astronomical development, the calendar was also developed after that time.

- For the mathematics part, it can know the development of mathematics, and the assisted with the calendars development. The basic of science is mathematics, every kinds of science can transform by mathematics way to solve and explain.

2. Answer the problem formulation

1. The Chinese Calendar and Gregorian Calendar are the product of the social

development. They processed long time to consummated. In the history also can reflect the development history of science.

2. There are three steps of these processes to convert Gregorian Calendar to Chinese Calendar and Chinese Calendar to Gregorian Calendar.

- The first step is to find the way to convert the given date in Chinese Calendar to the corresponding date in R.D. date, and also convert the R.D. date to Chinese Calendar.

- The second step is to find the way to convert the R.D date to corresponding date in Gregorian Calendar, and also convert the Gregorian Calendar to R.D. date.

- The third step is use the medium of R.D. date to convert each other.

Perspective

The Calendar we used now is not perfect.

- The lengths of each month are not the same. They have four kinds of numbers 28, 29, 30, 31. And it is different to find the rule.
- The lengths of each season are not same. They have three kinds of numbers 90, 91, 92, and it affects the different length of half year.
- The day's number and the week's number are not corresponded in each year.

A new calendar

The main content is:

1. 12 months in one year, divided by four quarters. Each first month of the quarter has 31 days, the other two months have 30 days
2. Each quarter will have 91 days, can divide by 7 exactly, so every quarter has 13 weeks and fixed each first day of quarter is Sunday, the last day is Saturday
3. Each half-year is 182 days. So add two half-years together is 364 days. The other one-day will add at the end of year, not consider the date or week. if it is leap year, the one day more will add the date between June 30th and July 1st and not consider anything or as a international festival.

The new plan of the calendar is better than what we used now. You can find the fixed rules for months and weeks. And 12 months can divide by 3, 4 or 6 parts, easy to scheme, Statistic and comparison. [R5]

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Appendix:

Reference to chapter 2 and 14