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Julian Calendar and Gregorian Calendar Algorithms

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ABSTRACT

The study aimed to develop a relationship between Gregorian calendar dates in AD and Julian calendar dates in AD which is shown as algorithms. It also solved ordinal numbers of dates and dates of ordinal numbers that are in AD with the use of algorithms. Dates of ordinal numbers were also solved using algorithms. Algorithms for converting a Julian calendar date into the Gregorian calendar date and vice versa were derived; conversions for the two calendars were derived. The study used applied Mathematics using derivation of Algorithms in answer to the objectives. There were sample problems to check the accuracy of the algorithms; the algorithms are correct. Six algorithms were established.

KEYWORDS

Algorithm, Anno Domini, calendar, formula, Gregorian calendar, Julian calendar, descriptive design, Philippines

INTRODUCTION

Calendars are used as a system of measurement for time with the day as smallest calendrical unit by convention (Doggett, 1992). More details about calendars and history were provided (Grun, 1979.). Based on the orbital motions of the solar system, time was introduced (McCarthy & Seidelmann, 2009). Astronimical algorithms are necessary to check the accuracy of calendars (Verkhovsky, 2011; Meeus, 1999). Before the use of the Gregorian calendar, the Julian calendar was used. Julian calendar has 365.25 days and leap year was introduced in 46 BCE (Verkhovsky, 2003). This is significantly different from the length of a solar year (Verkhovsky, 2011). The Gregorian perpetual calendar was proposed to the Christian world by Pope Gregory X III in 1582 which is closer to the length of a solar year (Gregory XIII. 1582).

There is a way to convert Julian calendar dates in AD into Gregorian calendar dates and vice versa by the use of a table (Nautical almanac offices of the United Kingdom and United States, 1961)

OBJECTIVES OF THE STUDY

1. To convert October 15, 1582 AD (Gregorian calendar date) into a Julian calendar date. (Problem 1)
2. To convert February 5, 400 AD (Gregorian calendar date) into a Julian calendar date. (Problem 2)
3. To convert October 5, 1582 AD (Julian calendar date) into a Gregorian calendar date. (Problem 3)
4. To convert February 5, 100 AD (Julian calendar date) into a Gregorian calendar date. (Problem 4)

METHODOLOGY

The ordinal numbers of Julian calendar dates in AD and Gregorian calendar dates in AD must be equal to having the conversion between the two calendars.

Derivation of algorithm 1 (an algorithm for knowing the ordinal number of a Julian calendar date)

A Julian calendar date that is in AD was studied. In it were three givens: the month, the day of the month and the year. The study used the day of the month, converted the month to its equivalent number of days and converted the year to its equivalent number of days. The values of the day of the month, the month and the year were added. All other dates will follow to be correct.

Given: October 3, 1582

Day of the month = 3

Month = October = 273

Notes: Add the days that passed after the month. There is a separate computation for leap years. February having 28 days was used regardless if it is a leap year. e.g. March = January (31 days) + February (28 days) = 59

Year 1582 = 1582 × 365 + 1582/4, disregard the fraction – 365

Notes: A year is equal to 365 days unless it is a leap year that has 366 days. (year times to 365 + year/4, disregard the fraction comes from here.) Year 1 AD is the start of AD. (- 365 comes from here.)

February 29 is added every leap year. (If the date be a leap year and (January or February), deduct 1)

Note: Rule for determining leap years

A year is a leap year if it is exactly divisible by 4.

Year 1582 = 577430 + 395 – 365 = 577460

Ordinal Number = Day of the month + Month + Year = 3 + 273 + 577460 = 577736th day

Simplifying, algorithm 1

If the date be a leap year and (January or February), use Formula 1 else use Formula 2.

Notes: add another day (February 29) during a leap year. The difference (the use of two formulas) is told here. February 29 is added every leap year. (If the date be a leap year and (January or February), deduct 1)

Formula 1: Ordinal Number = D + M + Y – 366

Formula 2: Ordinal Number = D + M + Y – 365

Where:

Ordinal Number is the ordinal number of the date.

D is the day of the month.

M is the number of days of the month (January = 0, February = 31, March = 59, April = 90, May = 120, June = 151, July = 181, August = 212, September = 243, October = 273, November = 304 and December = 334.).

Y is the number of days of the year (year × 365 + year/4, disregard the fraction.).

Derivation of algorithm 2 (an algorithm for knowing the ordinal number of a Gregorian calendar date)

A Gregorian date that is in AD was studied. In it were three givens: the month, the day of the month and the year. The study used the day of the month, converted the month to its equivalent number of days and converted the year to its equivalent number of days. The values of the day of the month, the month and the year were added. All other dates will follow to be correct.

Given: October 15, 1582

Day of the month = 15

Month = October = 273

Notes: Add the days that passed after the month. There is a separate computation for leap years. February having 28 days was used regardless if it is a leap year. E.g. March = January (31 days) + February (28 days) = 59

Year 1582 = 1582 × 365 + 1582/4, disregard the fraction – 1582/100, disregard the fraction + 1582/400, disregard the fraction – 365

Notes: A year is 365 days unless it is a leap year that has 366 days. (year times to 365 + year/4, disregard the fraction – year/100, disregard the fraction + year/400, disregard the fraction comes from here.) Year 1 AD is the start of AD. (- 365 comes from here.)

February 29 is added every leap year. (If the date be a leap year and (January or February), deduct 1)

Note: Rule for determining leap years

It is called a leap year if it is exactly divisible by four but not exactly divisible by 100 unless

also exactly divisible by 400.

Year 1582 = 577430 + 395 – 15 + 3 – 365 = 577448

Ordinal Number = Day of the month + Month + Year = 15 + 273 + 577448 = 577736th day

Simplifying, algorithm 2

If the date be a leap year and (January or February), use Formula 3 else use Formula 4.

Notes: Add another day (February 29) during a leap year. The difference (the use of two formulas) is told here. February 29 is added every leap year. (If the date be a leap year and (January or February), deduct 1)

Formula 3: Ordinal Number = D + M + Y – 366

Formula 4: Ordinal Number = D + M + Y – 365

Where:

Ordinal Number is the ordinal number of the date.

D is the day of the month.

M is the number of days of the month (January = 0, February = 31, March = 59, April = 90, May = 120, June = 151, July = 181, August = 212, September = 243, October = 273, November = 304 and December = 334.).

Y is the number of days of the year (year × 365 + year/4, disregard the fraction – year/100, disregard the fraction + year/400, disregard the fraction.).

Derivation of algorithms 3 and 5

Use October 3, 1582 in Algorithm 1 and October 15, 1582 in Algorithm 2 for the date correction

577736th day (Julian calendar date) = 577736th day (Gregorian calendar date)

It is two days difference when connecting the two calendars.

Notes: Adjustment takes place in the Algorithms 3 and 5. Algorithm 3 is like Algorithm 1 and Algorithm 5 is like Algorithm 2, provided that the two days difference is included in the original algorithms.

Algorithm 3 (an algorithm for converting an ordinal number of a Gregorian calendar date that is in AD into a Julian calendar date)

If the date be a leap year and (January or February), use Formula 5 else use Formula 6.

Notes: Add another day (February 29) during a leap year. The difference (the use of two formulas) is told here. February 29 is added every leap year. (If the date be a leap year and (January or February), deduct 1)

Formula 5: Ordinal Number = D + M + Y – 368
Formula 6: Ordinal Number = D + M + Y – 367
Where:

Ordinal Number is the ordinal number of the date.

D is the day of the month.

M is the number of days of the month (January = 0, February = 31, March = 59, April = 90, May = 120, June = 151, July= 181, August = 212, September = 243, October = 273, November = 304 and December = 334.).

Y is the number of days of the year (year ×365 + year/4, disregard the fraction.).

Algorithm 4 (an algorithm for converting Gregorian calendar dates in AD into Julian calendar dates in AD)

After knowing the Ordinal number of the Gregorian calendar date using Algorithm 2, know the Julian calendar date using Algorithm 3.

Algorithm 5 (an algorithm for converting an ordinal number of a Julian calendar date that is in AD into a Gregorian calendar date)

If the date be a leap year and (January or February), use Formula 7 else use Formula 8.

Notes: Add another day (February 29) during a leap year. The difference (the use of two formulas) is told here. February 29 is added every leap year. (If the date be a leap year and (January or February), deduct 1)

Formula 7: Ordinal Number = D + M + Y – 364
Formula 8: Ordinal Number = D + M + Y – 363
Where:

Ordinal Number is the ordinal number of the date.

D is the day of the month.

M is the number of days of the month (January = 0, February = 31, March = 59, April = 90, May = 120, June = 151, July = 181, August = 212, September = 243, October = 273, November = 304 and December = 334.).

Y is the number of days of the year (year × 365 + year/4, disregard the fraction – year/100, disregard the fraction + year/400, disregard the fraction.).

Algorithm 6 (an algorithm for converting Julian calendar dates in AD into Gregorian calendar dates in AD)

After knowing the Ordinal number of the Julian calendar date using Algorithm 1, one comprehends Gregorian calendar date using Algorithm 5.

RESULTS

1. **To convert October 15, 1582 AD (Gregorian calendar date) into a Julian calendar date. (Problem 1)**

Solution: Use Algorithm 2 to know the Ordinal number of the Gregorian calendar date and then use Algorithm 3 to know the Julian calendar date.

Algorithm 2: Use Formula 4: Ordinal Number = D + M + Y–365

Ordinal Number = 15 + 273 + 577748 = 577736

Algorithm 3: Use Formula 6 first.

577736 = D + M + Y – 367

578103 = D + M + Y

578103 divided by 365.25 to know the year.

Year = 1582.759754, disregard the fraction

If Formula 5 is used, 578104 = D + M + Y

578104 divided by 365.25 to know the year.

Year = 1582.762491, disregard the fraction

Either formula 5 or 6 produced

Year = 1582

1582 is not a leap year. Formula 6 must be used.

578103 = D + M + (1582 **× 365 + 1582/4, disregard the fraction**)

578103 = D + M + (577430 + 395)

578103 = D + M + 577825

278 = D+M

Get the month. October is 273. M = October

278 = D+273

Get the day. D = 5

Date = October5, 1582 AD (Julian calendar date)

2. To convert February 5, 400 AD (Gregorian calendar date) into a Julian calendar date. (Problem 2)

Solution: Use Algorithm 2 to know the Ordinal number of the Gregorian calendar date and then use Algorithm 3 to know the Julian calendar date.

Algorithm 2: Use Formula 4: Ordinal Number = D + M + Y – 366

Ordinal Number = 5 + 31 + 145731 = 145767

Algorithm 3: Use Formula 6 first.

145767 = D + M + Y – 367

146134 = D + M + Y

146134 divided by 365.25 to know the year.

Year = 400.0930869, disregard the fraction

If Formula 5 is used, 146135 = D + M + Y

146135 divided by 365.25 to know the year.

Year = 400.0958248, disregard the fraction

Either formula 5 or 6 produced

Year = 400

400 is a leap year. Formula 5 or 6 must be used.

Use Formula 5 first.

146135 = D + M + (400 **× 365 + 100/4, disregard the fraction**)

146135 = D + M + (146000 + 100)

146135 = D + M + 146100

35 = D+M

Get the month. February is 31. M = February

35 = D+31

Get the day. D = 4

Date = February 4, 400 AD (Julian calendar date)

Note: Since the date is a leap year and a February, Formula 5 is used.

3. To convert October 5, 1582 AD (Julian calendar date) into a Gregorian calendar date. (Problem 3)

Solution: Use Algorithm 1 to know the Ordinal number of the Julian calendar date and then use Algorithm 5 to know the Gregorian calendar date.

Algorithm 1: Use Formula 2: Ordinal Number = D + M + Y – 365

Ordinal Number = 5 + 273 + 577460 = 577738

Algorithm 5: Use Formula 8 first.

577738 = D + M + Y – 363

578101 = D + M + Y
578101 divided by 365.2425 to know the year.
Year = 1582.786779, disregard the fraction
If Formula 7 is used, 578102 = D + M + Y
578102 divided by 365.2425 to know the year.
Year = 1582.789517, disregard the fraction
Either formula 7 or 8 produced
Year = 1582
1582 is not a leap year. Formula 8 must be used.
578101 = D + M + (1582 × **365 + 1582/4, disregard the fraction** – 1582/100, disregard the fraction + 1582/400, disregard the fraction)
578101 = D + M + (577430 + 395 – 15 + 3)
578101 = D + M + 577813
288 = D + M
Get the month. October is 273. M = October
288 = D + 273
Get the day. D = 15
Date = October 15, 1582 AD (Gregorian calendar date)

4. **To convert February 5, 100 AD (Julian calendar date) into a Gregorian calendar date. (Problem 4)**

Solution: Use Algorithm 1 to know the Ordinal number of the Julian calendar date and then use Algorithm 5 to know the Gregorian calendar date.
Algorithm 1: Use Formula 1: Ordinal Number = D + M + Y – 366
Ordinal Number = 5 + 31 + 36159 = 36170
Algorithm 5: Use Formula 8 first.
36195 = D + M + Y – 363
36558 = D + M + Y
36558 divided by 365.2425 to know the year.
Year = 100.0924044, disregard the fraction
If Formula 7 is used, 36559 = D + M + Y
36559 divided by 365.2425 to know the year.
Year = 100.0951423, disregard the fraction
Either formula 7 or 8 produced
Year = 100
100 AD is not a leap year. Formula 8 must be used.
36558 = D + M + (100 × **365 + 100/4, disregard the fraction** – 100/100,

disregard the fraction + 100/400, disregard the fraction)

36558 = D + M + (36500 + 25 – 1 + 0)

36558 = D + M + 36524

34 = D + M

Get the month. February is 31. M = February

34 = D + 31

Get the day. D = 3

Date = February 3, 100 AD (Gregorian calendar date)

In summary, the following were recorded:

1. Algorithm 1 produced the desired results for knowing ordinal numbers of Julian calendar dates.
2. Algorithm 2 produced the desired results for knowing ordinal numbers of Gregorian calendar dates.
3. Algorithm 3 produced the desired results for converting ordinal numbers of Gregorian calendar dates that are in AD into Julian calendar dates.
4. Algorithm 5 produced the desired results for converting ordinal numbers of Julian calendar dates that are in AD into Gregorian calendar dates.
5. Algorithm 4 produced the desired results for converting Gregorian calendar dates into Julian calendar dates.
6. Algorithm 6 produced the desired results for converting Julian calendar dates into Gregorian calendar dates.

DISCUSSION

1. Days until A.D. 8. Julian calendar dates before 8 A.D. are proleptic, and do not necessarily match the dates observed in the Roman Empire. (Nautical almanac offices of the United Kingdom and United States. 1961)
2. The author used a Julian calendar that has a constant table having leap years occurring every four years. This is one limitation of the paper.
3. Julian calendar dates January 1, 1 AD and January 2, 1 AD when converted to Gregorian calendar dates will be in Before Christ (BC) which is not covered here. This is the second limitation of the paper.
4. BC is not included in the algorithms. This is the third limitation of the paper.

CONCLUSIONS

Algorithms 1 and 2 are correct to determine the ordinal numbers of dates with reference to January 1, 1 AD. Algorithms 3 and 5 are correct in converting ordinal numbers with reference to January 1, 1 AD to their respective dates. Algorithms 4 and 6 are correct in converting Gregorian calendar dates into Julian calendar dates and vice versa.

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