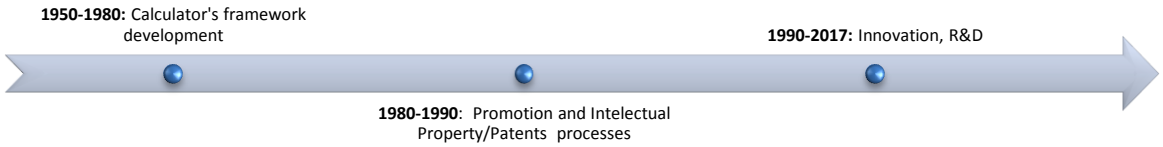
I. Context

Our gallery aims at highlighting the african contribution in the field of Gregorian calendar. Particularly, we adress the problem of finding the weekday of a given date. This framework was initiated by Malam Sidi IYE (born in 1928 in Tabotaki, Niger) in the early 1950s for adressing the issue of archiving with accuracy, historical and social events (birthdays, deaths,…) as well as for predicting future dates related to the community life (annual period of fasting, pilgrimage to mecca, first (1st) january, religious holidays, commerce, agriculture,…). This framework was important, because at that period, the majority of people in Niger were without formal education, do not have access to calendars and are living in rural areas without energy supply.
Malam Sidi IYE never went to formal school, but he learned alphabet, roman numbers and terms related to Gregorian calendar (as an autodidact) by analyzing Islamic and Gregorian calendars wich are respectively related to lunar and solar cycles; facts that allowed him to invent his calculator for Gregorian calendar's weekday finding and classification of years. The choice of the Gregorian calendar can be explained by the fact that its an international standard for civil use and each month has a determined numbers of days (30 or 31 except February which has 28 days for a normal year and 29 days for a leap year). Finding an algorithm for Islamic calendar is more complicated since all of the twelve (12) months do not have a fixed number of days (the duration of a month varies between 29 to 30 days depending on the lunar phase cycle, weather conditions,…). In the Gregorian calendar, a normal year has 365 days (28 days for February) and a leap year (which occurs each 4 years on average) has 366 days (29 days for February). The calculator of Malam Sidi IYE can be used by everyone who wants to find the weekday of a given date (from past, present or future) ; moreover, it can be used as an educational tool for individuals and schools. Currently, most of the computers only cover period from 1900 to 2200 which means that if you don't have additional access to internet you cannot find the weekday corresponding to the dates before 1900 and after 2200. The calculator of Malam Sidi IYE gives you this opportunity !!!



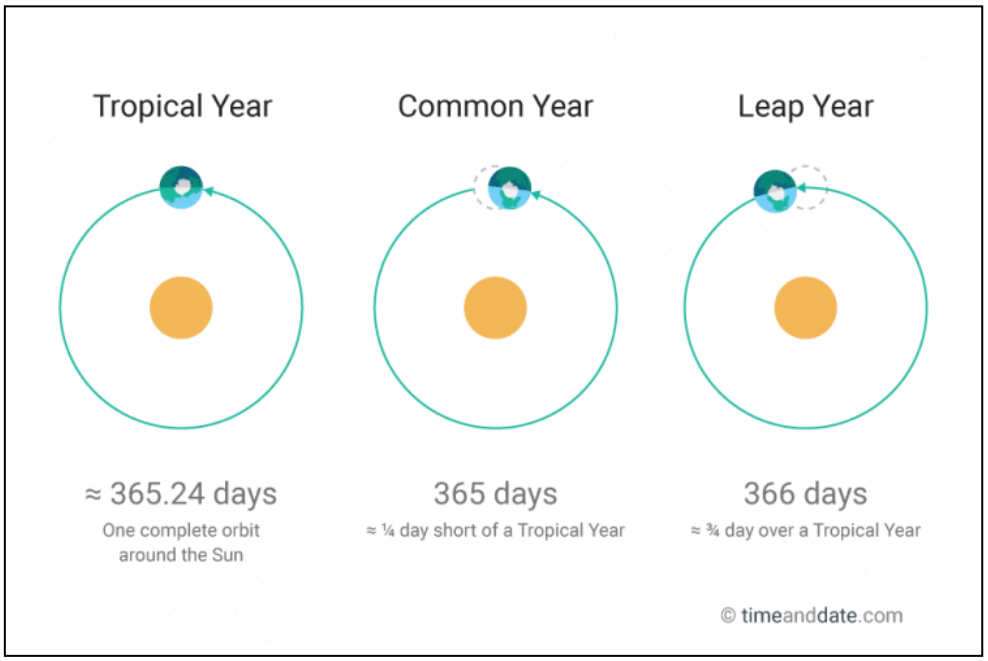
Timeline of the evolution of Malam Sidi IYE's framework.

II. Background on the Gregorian calendar

Historical background on the Gregorian calendar can be found at https://en.wikipedia.org/wiki/Gregorian_calendar and we particularly emphasis on the following parts:
« *The **Gregorian calendar** is internationally the most widely used civil calendar. It is named after Pope Gregory XIII, who introduced it in October 1582*».
«*The calendar was a refinement to the Julian calendar involving a 0.002% correction in the length of the year* ».
« *The Gregorian reform modified the Julian calendar's scheme of leap years as follows:Every year that is exactly divisible by four is a leap year, except for years that are exactly divisible*

by 100, but these centurial years are leap years if they are exactly divisible by 400. For example, the years 1700, 1800, and 1900 are not leap years, but the year 2000 is».

Leap years are essential for keeping the Gregorian calendar in alignment with the planet earth's revolutions around the sun (see the figure below).



III. Description of mathematics of the weekday calendar problem

As highlighted at https://en.wikipedia.org/wiki/Solar_cycle_(calendar) :

« *The **solar cycle** is a 28-year cycle of the Julian calendar with respect to the week. It occurs because leap years occur every 4 years and there are 7 possible days to start a leap year, making a 28-year sequence*».
« *This cycle also occurs in the Gregorian Calendar, but it is interrupted by years such as 1800, 1900, 2100, 2200, 2300 and 2500, which are divisible by four but which are common years*».
Moreover, as highlighted at https://en.wikipedia.org/wiki/Determination_of_the_day_of_the_week
In numerical calculation, the days of the week are represented as weekday numbers. If Monday is the first day of the week, the days may be coded 1 to 7, for Monday through Sunday, as is practiced in ISO 8601. The day designated with 7 may also be counted as 0, by applying the arithmetic modulo 7, which calculates the remainder of a number after division by 7. Thus, the number 7 is treated as 0, 8 as 1, 9 as 2, 18 as 4 and so on. If Sunday is counted as day 1, then 7 days later (i.e. day 8) is also a Sunday, and day 18 is the same as day 4, which is a Wednesday since this falls three days after Sunday.

The basic approach of nearly all of the methods to calculate the day of the week begins by starting from an 'anchor date': a known pair (such as January 1, 1800 as a Wednesday), determining the number of days between the known day and the day that you are trying to

determine, and using arithmetic modulo 7 to find a new numerical day of the week.

Corresponding days

Every seventh day in a month has the same name as the previous.

Corresponding months

"Corresponding months" are those months within the calendar year that start on the same day. For example, September and December correspond, because September 1 falls on the same day as December 1. Months can only correspond if the number of days between their first days is divisible by 7, or in other words, if their first days are a whole number of weeks apart. For example, February of a year which is not a leap year corresponds to March because February has 28 days, a number divisible by 7, 28 days being exactly four weeks. In a leap year, January and February correspond to different months than in a common year, since adding February 29 means each subsequent month starts a day later.

The months correspond thus:

For common years:

- *January and October.*
- *February, March and November.*
- *April and July.*
- *No month corresponds to August.*

For leap years:

- *January, April and July.*
- *February and August.*
- *March and November.*
- *No month corresponds to October.*

For all years:

- *September and December.*
- *No month corresponds to May and June.*

Corresponding years

There are seven possible days that a year can start on, and leap years will alter the day of the week after February 29. This means that there are 14 configurations that a year can have.

IV. Mathematical background of the calculator of Malam Sidi IYE

The Calculator of Malam Sidi IYE is based on arithmetic modulo 28 for finding the weekday corresponding to 1st January and additional use of a second table for finding any other date. We use the following convention for the weekdays :
1=Sunday, 2=Monday, 3=Tuesday, 4=Wednesday, 5=Thursday, 6=Friday, 7=Saturday.

Examples on how to use the calculator

	1st January						1st January	Remainder of the division of a year by 28
Leap year	7	1	2	3	4	5	6	0
3 Common years	1						1	1
	2						2	2
	3						3	3
Leap year	5	6	7	1	2	3	4	4
3 Common years	6						6	5
	7						7	6
	1						1	7
Leap year	3	4	5	6	7	1	2	8
3 Common years	4						4	9
	5						5	10
	6						6	11
Leap year	1	2	3	4	5	6	7	12
3 Common years	2						2	13
	3						3	14
	4						4	15
Leap year	6	7	1	2	3	4	5	16
3 Common years	7						7	17
	1						1	18
	2						2	19
Leap year	4	5	6	7	1	2	3	20
3 Common years	5						5	21
	6						6	22
	7						7	23
Leap year	2	3	4	5	6	7	1	24
3 Common years	3						3	25
	4						4	26
	5						5	27

Table 1: The calculator of Malam Sidi IYE (step 1) for finding the weekday corresponding to 1st January

Remainder of YYYY/28						
1	2	3	4	10	0	6
7	8	14	9	16	5	12
18	13	20	15	21	11	17
24	19	25	26	27	22	23
1st January						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

Table 2 : Remainder of the division of a year YYYY by 28 and corresponding weekday for 1st January.

1. Finding the weekday corresponding to the 1st of January (step 1)

The Table 2 is a simplification of Table 1 by focusing on the remainders (see Table 1) corresponding to the same weekday (same color).

- **Example 1: Year 1905**

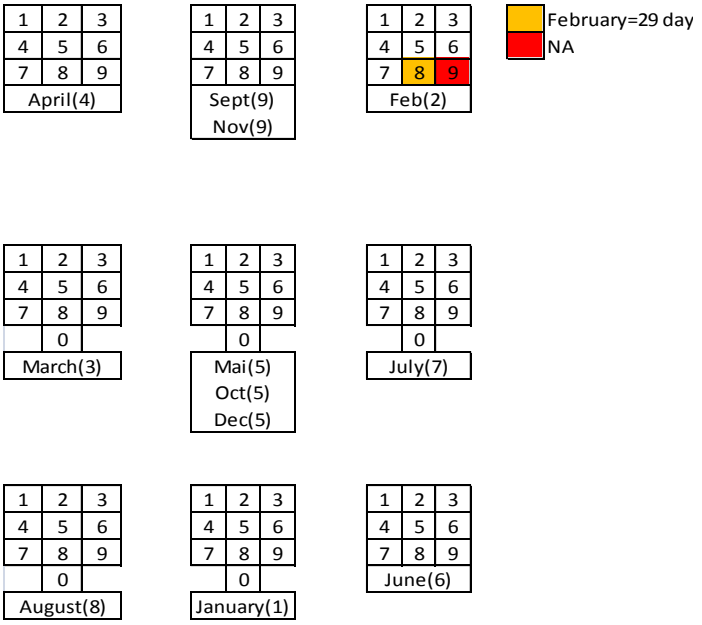
The remainder of the division of 1905 by 28 equals 1 (1905=68*28+1) which corresponds to Sunday (see Table 1 or Table 2).

- **Example 2: Year 1990**
  The remainder of the division of 1990 by 28 equals 2 (1990=71*28+2) which corresponds to Monday (see Table 1 or Table 2).
- **Example 3: Year 2000**
  The remainder of the division of 2000 by 28 equals 12 (1831=71*28+12) which corresponds to Saturday and 2000 is a leap year.
- **Example 4: Year 2016**
  The remainder of the division of 2016 by 28 equals 0 (2016=72*28+0) which corresponds to Friday and 2016 is a leap year.
- **Example 5:Year 2027**
  The remainder of the division of 2027 by 28 equals 11 (1831=28*72+11) which corresponds to Friday.
- **Example 6: Year 2100**
  The remainder of the division of 2100 by 28 equals 0 (2100=75*28+0) which corresponds to Friday and 2100 is a common year.

2. Finding the weekday corresponding to a given date (step 2)

Malam Sidi IYE classified the 12 months as follows:

April 4	September November 9	February 2
March 3	May October December 5	July 7
August 8	January 1	June 6
	0	



-**For a given month**: each cell is considered as a day. Moreover, we can easily verify that if **x** (cell 1) is the first day of the month, the day **x**+9 corresponds to the day **x**+2; which means that a line (cells 1,2,3) can be considered as 10 days; so that 2 lines (cells 1,2,...6) represent 20 days and 3 lines (cells 1,2,...9) represent 30 days. The cell 0 is only used for 31 days months.

For February, we don't consider the cell in red (9); and the cell (8) is only used for leap years (February=29 days).

Table 3 : The calculator of Malam Sidi IYE (step 2) for finding the weekday corresponding to a given date.

Example 1: 27th of January 1990

- We have already seen that 1st of January 1990 was Monday.
- The cell 1 of the square (January) corresponds to Monday (**x**=Monday)
- The first line (cells 1,2, 3) corresponds to 10 days (10th of January 1990 was Wednesday, since **x**+9=**x**+2)
- The second line (cells 4,5, 6) corresponds to 10 days (20th of January 1990 was Saturday)
- By adding seven (7) days we obtain that 27th January 1990 is Saturday.

Example 2: 9th of February 1990

- We have already seen that 1st of January 1990 was Monday and 20th of January was Saturday (**x**=Saturday).
- x+9=x+2 (29th of January 1990 was Monday) and 31th of January was Wednesday
- If x=Wednesday, the rule x+9=x+2 leads to 9th of February 1990 was Friday.

Example 3: 23rd of December 1990
We use the same principle for months from January to November (by taking into account the fact that February had 28 days and also similarities for corresponding months) ; we then count 23 days on the December's square and we can verify that 23rd of December 1990 was Sunday.

Example 4: 1st of January 1991
Taking into account the previous example, since the 23rd of December 1990 was Sunday, the 1/1/1991 was Tuesday.

NB: For comparison, the reader can verify our results by using online tools like : https://www.timeanddate.com/calendar/

3. Algorithm (Step1 and Step 2)

For a date DAY-MONTH-YEAR, do the following:

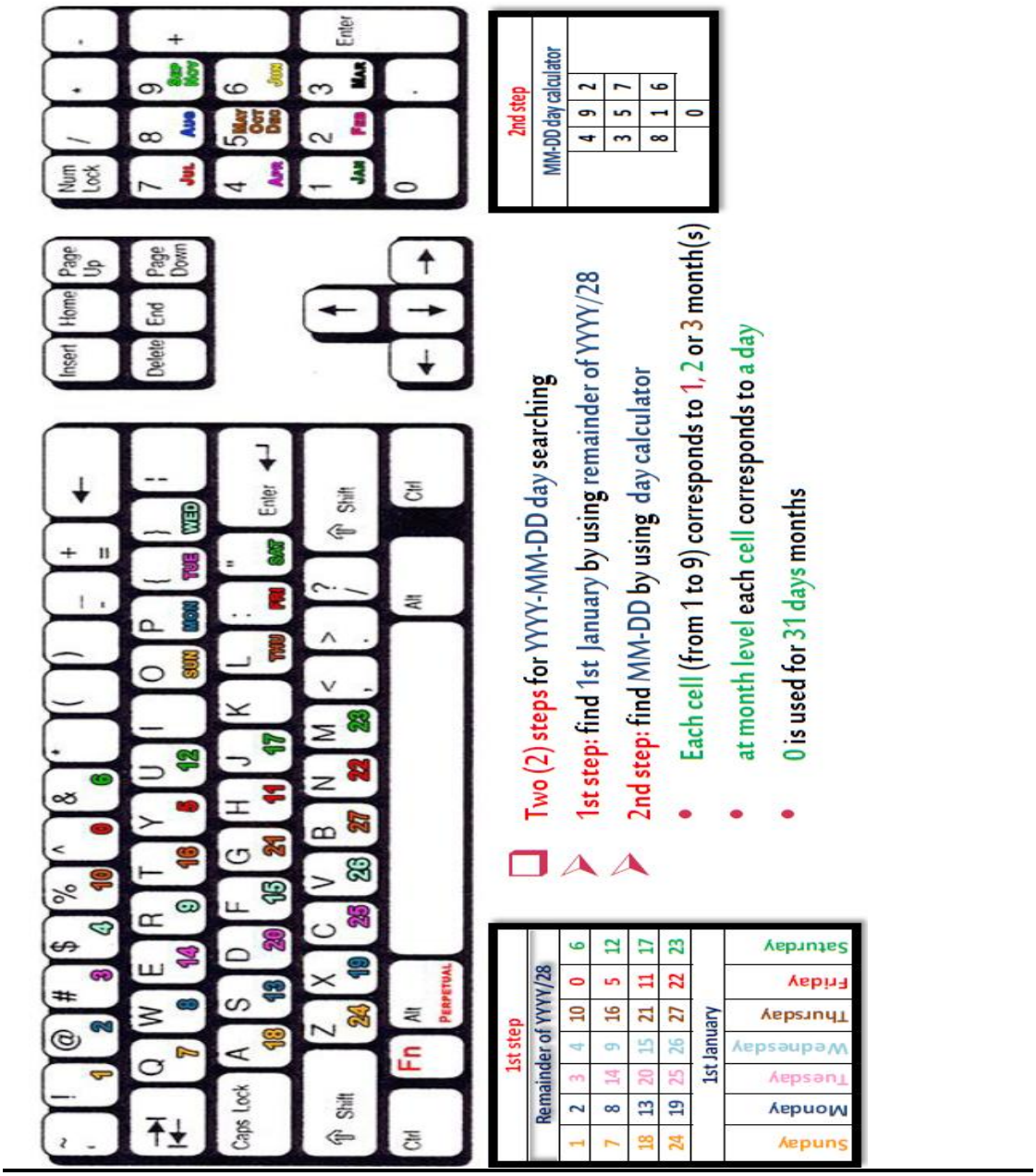
1.- Do the integer division of YEAR by 28, and look up the remainder in Table 2. This will give you the weekday of 1st January of YEAR, call it STARTDAY

2.- Identify the MONTH in Table 3 and find the weekday corresponding to the 1st of MONTH (call it X) by applying the rule STARTDAY+9= STARTDAY+2 (or STARTDAY+7= STARTDAY) until you reach MONTH

3.- Find the weekday corresponding to DAY by using the rule X+9=X+2 (or X+7=X) until you reach DAY.

V. Innovation, R&D

- The calculator contributed for publishing a 600 years perpetual calendar with classification of years for the period from 1701 to 2300. This calendar is extensible.
- We are currently working on developping an innovative Computer keyboard named «Tabtakey» which integrates the calculator's of Malam SIDI IYE. Find below the prototype and also the implementation plan.



Tool	Options	Initial cost	Funding source	Customers	Pricing $
Virtual TABTAKEY	Linux, Windows, Mac OS, Android, iOS	$10 000	Investors Sponsors Partnerships Calendars selling National Research and Innovation funds	App store, Google play,...	3---5
Physical TABTAKEY	AZERTY, QWERTY,...			Individuals, e-commerce platforms, stores, universities, schools, museums, institutions	10---100
Calendars database	Printed, 5-stars Open Data				0---10
Communication	Advertising, scientific events, Wikipedia, website, blog, social network pages, scientific publishing, CD or DVD				