

CALENDARS AND PHYLLOTAXIS

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Abstract: *Everywhere we observe the periodic phenomena, for example, change of night and day, seasons. For the calendar image in most cases one use rectangular tables which can be considered as integer lattice in Cartesian coordinates. One of methods for the description of a leaves arrangement on plants (phyllotaxis) is construction of an integer lattice in polar coordinates. In this construction there are spiral rows of points which from the algebraic point of view represent residue classes. As a rule, these modules on plants are the Fibonacci numbers. For our purposes polar coordinates give some advantages in comparison with Cartesian ones. Circle and spiral can be considered as geometrical image of cyclic process (cycle means circle) and the idea of a circle lays in a basis of polar coordinates. The examples of application of phyllotaxis model for the description of some calendars are presented.*

1 PHYLLOTAXIS

The word Phyllotaxis is of Greek origin (phyllon — leaf; taxis — order). Phyllotactic patterns can be described with just a few mathematical constants and principles. In case of the most common spiral pattern it is possible to trace two families of spirals round the stem. An example of such patterns is the spiral arrangement of florets in the capituli of sunflowers and daisies. In order to make a geometrical map and integer lattice of the spiral pattern, we mark out the centre of each floret, and number them according to their age, that is according to the order in which they arise in plant (Roger V. Jean: 1994).

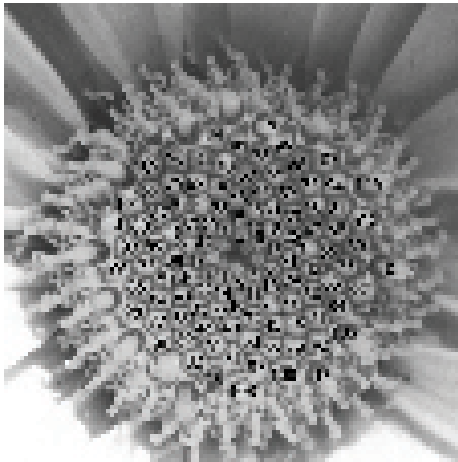


Figure 1: Numbering of florets on daisy inflorescence.

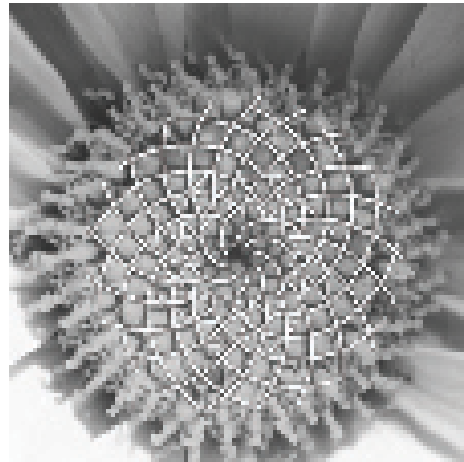


Figure 2: Rows of florets (*parastichies*) on daisy inflorescence.

Age and Year are concepts of Time. Every year in our calendars will be the homolog of some floret and its age in an inflorescence.

2 CHINESE CALENDAR

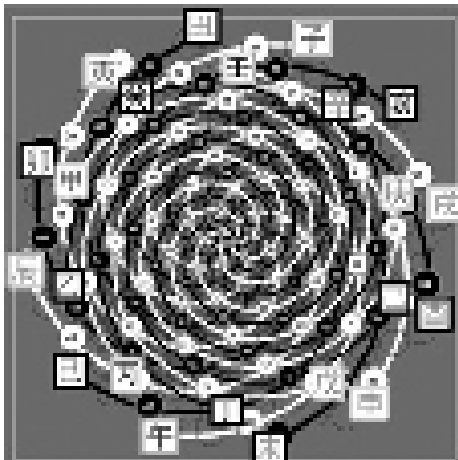


Figure 3: Phyllotactic Chinese Calendar. *Celestial Stems* are submitted by family of 10 spirals (5 white - *Yang*, and 5 black - *Yin*). *Terrestrial branches* are submitted by family of 12 spirals (6 white - *Yang*, and 6 black - *Yin*). Both families are twirled in the different directions and have mutual crossings. The *Time's Axis* is submitted by the lonely spiral which is taking place definitely through crossings of *Celestial Stems* and *Terrestrial branches*. Every year in a calendar stands in crossing of three spirals: the *Celestial Stem*, the *Terrestrial branch* and the *Time's Axis*. On color of trunks and branches (white or black) we can judge, what movement (*Yang* or *Yin*) Year of a calendar copes.

Figure 4: Combination of the 10 “*Celestial stems*” *tiān gān*, and the 12 “*Terrestrial branches*” *dì zhī*.

Order	天干	tiān gān	Elements	Order	地支	dì zhī	Animal
1	甲	jiǎ	Wood	1	子	zǐ	Rat
2	乙	yǐ	Wood	2	丑	chǒu	Ox
3	丙	bǐng	Fire	3	寅	yín	Tiger
4	丁	dīng	Fire	4	卯	mǎo	Rabbit
5	戊	wù	Earth	5	辰	chén	Dragon
6	己	jǐ	Earth	6	巳	sì	Serpent
7	庚	gēng	Metal	7	午	wǔ	Horse
8	辛	xīn	Metal	8	未	wèi	Goat
9	壬	rén	Water	9	申	shēn	Monkey
10	癸	guì	Water	10	酉	yǒu	Rooster
				11	戌	xù	Dog
				12	亥	hài	Pig

An important aspect of the Chinese calendar is the sexagenary cycle. Within each 60-year cycle, each year is assigned name consisting of two components: *Heavenly* or *Celestial*

stem and *Earthly* or *Terrestrial branch*. Each of the two components is used sequentially. The Chinese calendar based on a combination of the 10 *Celestial stems*, and the 12 *Terrestrial branches*.

3 MAYA CALENDAR

The Maya kept time with a combination of several cycles that meshed together to mark the movement of the sun, moon and Venus. Their ritual calendar, known as the Tzolkin, was composed of 260 days. It pairs the numbers from 1 through 13 with a sequence of the 20 day-names.

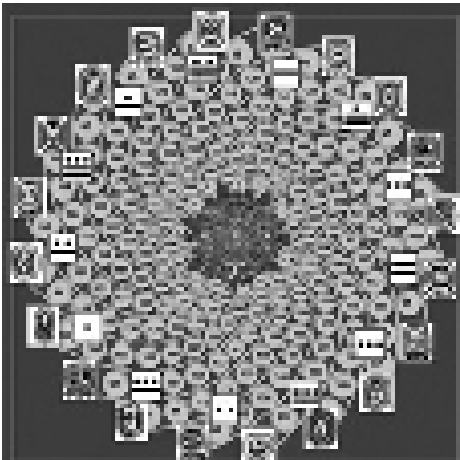


Figure 5: Phyllotactic Calendar Tzolkin.

A rectangular grid representing the 260-day Tzolkin cycle. The grid is organized into rows and columns, with each cell containing a number and a day-name. The numbers 1 through 13 are repeated in a sequence that corresponds to the 20 day-names, creating a complex, fractal-like pattern of overlapping cycles.

Figure 6: Rectangular Calendar Tzolkin.

4 METON CYCLE

Meton of Athens (ca. 440 BC) noticed that 235 lunar months made up almost exactly 19 solar years. The near commensurability of the two periods follows from the fact that $235/19$ is the 6th convergent of the ratio of the lunar month and solar year periods ($365.2425/29.53059$). This 19-year lunar cycle became known as the Metonic cycle. Since 12 lunar months equal 354.367 days, about 11 days less than a solar year, an additional $235 - 19 \times 12 = 7$ lunar months were added to synchronize the cycle. These were added in years 3, 5, 8, 11, 13, 16, and 19 of the cycle (Smith, D.).

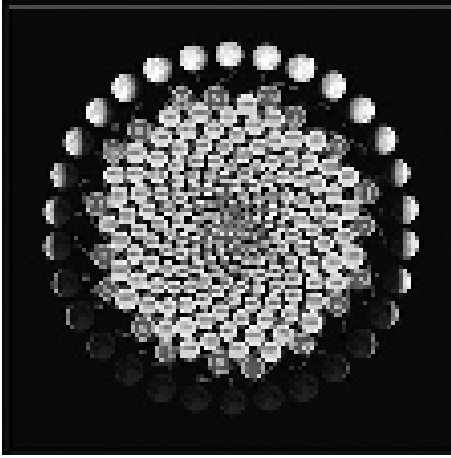


Figure 7: Phyllotactic Meton cycle. Moon return to the same shape and passing the same stars in 19 tropical years.



Figure 8: The Meton cycle published in 433 BC. (<http://olravet.fr/AideCalendes/Paques.htm>)

Phyllotactic calendars can be animated similarly to the blossoming flowers (Weise, 1998).

References

- Roger V. Jean, (1994) *Phyllotaxis: A Systematic Study in Plant Morphogenesis*. New York: Cambridge University Press.
- Smith, D. *History of Mathematics*, Vol. 2. New York: Dover.
- Weise D. (1998) *Principle of Minimax and Rise Phyllotaxis (Mechanistic Phyllotaxis Model)* <http://www.mi.sanu.ac.yu/vismath/dima/>.