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Research article

The Off-cardinal Alignment of Chiang Mai City Plan in Relation to the Orion Belt

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Abstract: Chiang Mai, the largest city in northern Thailand, was once the capital of the ancient Lanna kingdom, founded by King Mangrai on 19 April 1296 (Gregorian). The historic city plan, which may have been influenced by Vaastu Shastra (an ancient Hindu knowledge of architecture), features almost a square shape with each side length ranging from 1.52 -1.57 kilometers, bordered by four walls facing the cardinal directions. However, a careful examination reveals that the east-west orientation of the city plan is tilted southeastward with an azimuth of 92.5°, prompting further investigation as to which method was used in the city's orientation. Historically, two ways to lay out the directions were via the gnomon, such as the shortest shadow and the Indian circle methods, and via fixed stars. In this work, we carried out year-long measurements of the shortest shadow and the Indian circle methods and discovered that neither resulted in an error greater than 0.7°, allowing us to consider the orientation method as being associated with specific fixed stars. A theodolite and a GPS were used to identify the orientation axis along the northern city wall, calibrated using the positional astronomy program *Stellarium*. Using precession-corrected *Stellarium*, the ancient sky can be simulated to uncover the aligned star at the same azimuth as Mintaka (δ Ori) in the Orion's Belt at a height of 4° and possibly Alnilam (ε Ori) at a height of 1.5° (under an apparent sky condition) during the period between 1292 and 1296, which is close to when King Mangrai founded the city.

Keywords: Chiang Mai City Planning; Gnomon; Orion's Belt; Lanna Kingdom

1. Introduction

The capital of the Lanna kingdom, "Chiang Mai" (as it is now known), was established by King Mangrai in AD 1296. The Lanna inscriptions and historical data, including the Chiang Mai Chronicle (CMC) [1], all concur that King Mangrai entered the site on Thursday of the 8th Lanna lunar month, which is equivalent to the 5th Thai lunar month, 654 Culasakaraj (CS), which is equal to a Gregorian date as 3 April 1292. It was recognized as the starting date of the construction of his temporary residence, which was near the northeast corner of the Chiang Mai City Plan (now it is Wat Chiang Man; see the white circle in Figure 1: Top), where he would use to work on the city planning.

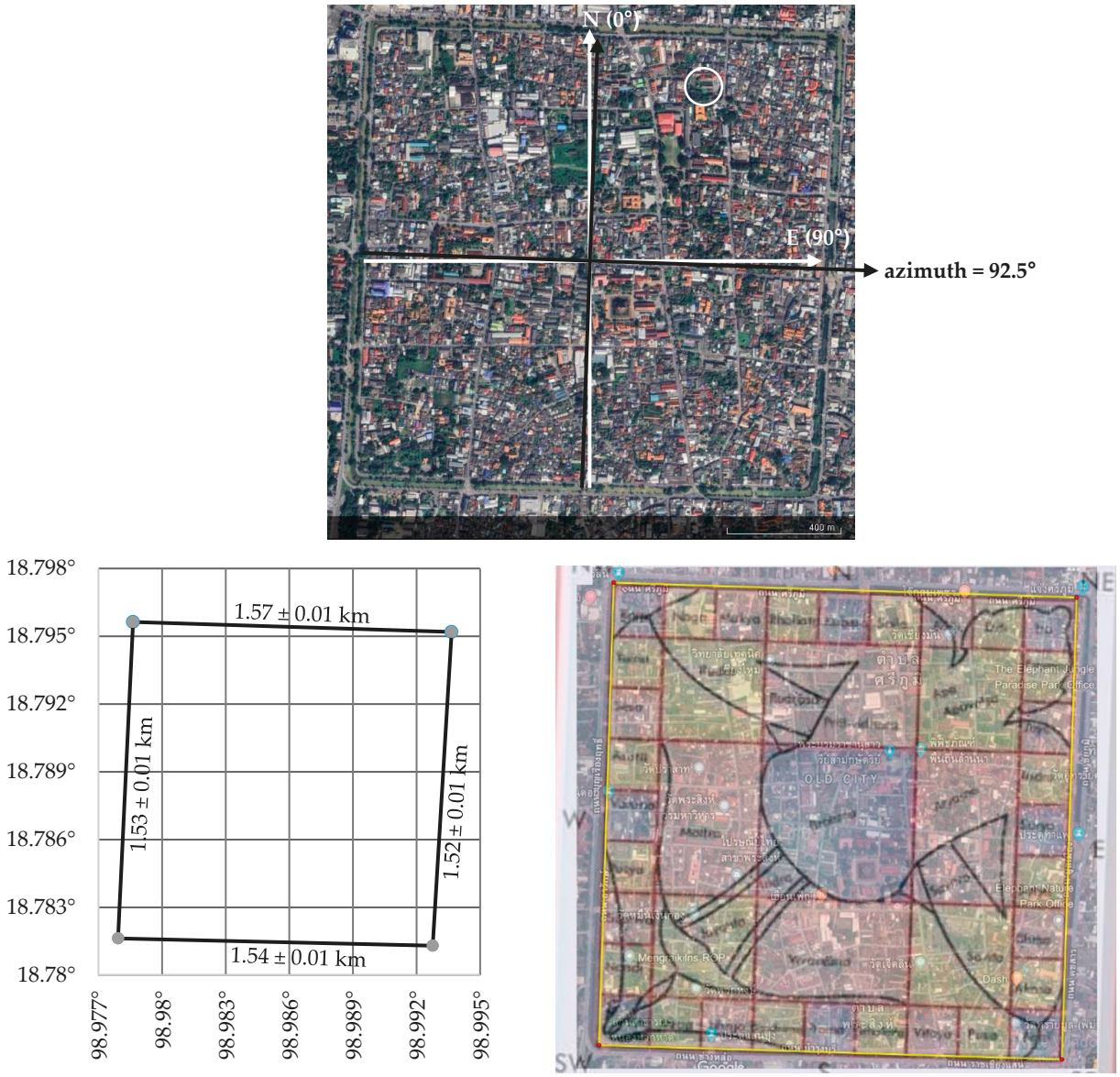

Figure 1. Top: The satellite image of the Chiang Mai old city surrounded by a moat with the east-west orientation of the city plan is tilted southeastward with an azimuth of 92.5° (image: from Google Earth). Bottom Left: Plotting of a geographic coordinate, i.e., latitude and longitude, for the GIS position collected on each of the four corners of the Chiangmai city wall and showing each side length calculated from these GPS positions. Bottom Right: Chiang Mai city site of square shape conforms well with the 9 ⊚ 9 grids of Paramasayika Mandala (image: modified after Saelee *et al*. [3])

According to the CMC, it took 4 years to plan the city before groundbreaking and installing Chiang Mai's main post on the full moon of the 8th Lanna lunar month, 658 CS. The Wat Chiang Man inscription [2] (Database of Inscriptions in Thailand | Wat Chiang Man Stale), however, was recorded otherwise on the waxing moon on the 8th day of the 8th Lanna lunar month, 658 CS, or 19 April 1296. Four months later, King Mangrai ordered to begin plowing the site from his sleeping chamber (presently Chiang Man Temple) to the northeastern corner known as the Sri Bhumi Corner, followed by the construction of four city walls and the five city gates. King Mangrai then ordered the construction of a perimeter wall and a moat, which were laid out in a rectangular shape of 900 *wa* by 1,000 *wa* (or 1.44 km by 1.6 km as 1 *wa* » 1.6 m) in the record. Once completed, the city hosted a festive celebration for three days and nights, naming it Nop Buri Sri Nakorn Ping [1].

Contrary to the record of the chronicle, the measurement of the actual size reported by Saelee *et al.* reveals a square shape with almost equal lengths in the 1.52 – 1.57 kilometers range [3], as shown in Figure 1: Bottom Left. The city plan is regarded as confidential information that could jeopardize national security if it leaks, which may be why the size differs from the CMC record. Saelee *et al*. [3] also suggest that the city planning may have been influenced by Vaastu Shastra, an ancient Hindu knowledge of architecture found in the book "Brihat Samhita" by Varaha Mihira [4]. The detailed comparison shows that the city planning followed Vaastu principles, i.e., selecting the site and selecting an auspicious day for site-plowing, which was determined by astronomical observation. The next step in Vaastu principles is to set the cardinal directions, which historically could be either using a gnomon or a fixed star, followed by the fixation of Vaastu-Purusha-Mandala, the metaphysical planning of the site. According to the analysis in the paper, the Chiang Mai city site, a square shape, bounded by moats and walls facing the cardinal directions on all four sides, conforms well with the 9 ⊚ 9 grids of *Paramasayika Mandala* [3] as illustrated in Figure 1: Bottom Right. In this work, we investigate further into the method of orientation, which has not been documented in the existing records after we have discovered that the east-west direction of the city plan is tilted southeastward with an azimuth of 92.5°.

In the literature, Yano [5] summarizes two methods for determining cardinal directions in ancient times: the gnomon method, such as the Indian circle, and the fixed-star method. The Indian circle yields four results: due east, west, north, and south. Furthermore, Kramrisch [6] concludes that Hindu temples exhibit three types of temple orientations: facing the rising sun or the cosmic orientation with reference to the sun (this implies the use of a sun shadow or a fixed star); meeting the center of man's settlement; and facing God (Vastu Purusha), where each God is related to a specific star. Since India inspired many ancient temples and monuments in Thailand's ancient kingdoms. However, several ancient temples or structures in Thailand do not face east, west, north, or south. For example, Prasat Hin Phanom Rung [7], Prasat Hin Pimai, and Wat Prathat Doi Suthep [8]. The cause of these temples' tilted orientation from the cardinal direction must have come from one of these two methods.

Given that we are uncertain of the orientation method utilized in the Chiang Mai city plan, we propose two possibilities. If the Gnomon method was applied, measurement inaccuracies could contribute to the 2.5° shift from cardinal directions. If the fixed star method was used on purpose, one star must have aligned with the city plan during construction. To test our hypotheses, we replicate the processes of the two methods to determine which produces results consistent with the city's orientation.

2. Materials and Methods

We first validated the tilting with an azimuth of 92.5° (2.5° south of east) using a theodolite and a GPS to measure the horizontal and vertical positions of the selected stars with time along the northern city wall. We then calibrated the measured positions with the positional astronomy software package *Stellarium* (version 0.21.3 with the time correction $\circledcirc T$—the difference between Terrestrial Dynamical Time and Universal Time [9]—using the default "Espenak and Meeus (2006)" model [10], accounted for atmospheric refraction and extinction, and a proper motion). The package, a free GPL software that renders realistic skies in real time with OpenGL, was used to calculate all astronomical coordinates of celestial objects in the ancient atmosphere. The Stellarium corrects the precession based on present knowledge that the equinox moves with a precessional period of approximately 26,000 years or 1° every 72 years. This work carried out two methods of orientation—using a gnomon and the fixed star—to answer why the Chiang Mai city plan is tilted.

For the gnomon method, there are two approaches called "the shortest shadow" and "the Indian circle." The shortest shadow refers to the shadow of the gnomon obtained around noon as the Sun crosses the meridian, an imaginary line along the North-South pole that divides the sky equally to the western and eastern sky. Therefore, the shortest shadow's direction points along the north-south axis, and a perpendicular line is drawn to obtain the east-west axis. This approach requires close monitoring from an observer to ensure that the shadow is the shortest. As for the Indian circle approach, the circle is drawn around the gnomon with a radius equal to the length of two shadows: one obtained in the late morning and the other in the afternoon. The east-west axis is established by connecting two points where the two shadows touch the circle. The Indian circle is preferable to the shortest shadow because it generates less human error. Therefore, the Indian circle

was the method of choice for aligning temples and cities with the cardinal directions, particularly the east direction, or with the four major astronomical dates, namely the two equinoxes and the two solstices [11].

For the fixed star method, a star of choice will be observed as it rises or falls at the horizon during sunrise or sunset. The star is chosen for its connection to the Sun or the Vaastu-Purusha-Mandala or the important person of the site. The primary axis of orientation will be the azimuth angle of the star. This method is often found in ancient areas that are not oriented along the cardinal directions, the four major astronomical dates, or towards the center of the town. Our procedures for the two methods are as follows:

1. For the gnomon method, we need to assess whether the measurement error resulting from this approach might cause the shift of 2.5° from cardinal directions. To carry out two gnomonic approaches, i.e., the shortest shadow and the Indian circle, within four days of two historical dates and 4 dates of astronomically significant dates. These dates are the vernal equinox (21 March), the autumnal equinox (23 September), the date King Mangrai entered the site (3 April), the founding date (19 April), summer solstices (22 June), and winter solstice (21 December), leading to the total of 24 measurement days in 2022.

2. For the fixed star method, we need to simulate the ancient sky using the precession-corrected *Stellarium* software to trace back in time to uncover which star aligned with the azimuth of 92.5° and to what extent the star impacted the city. We referenced the orientation axis along the northern city wall because the planning should be along the east-west direction, according to Brihat Samhita [4]. In addition, the CMC indicates that the construction started from the Sri Bhumi northeast corner; therefore, the axis along the northern city wall is the most appropriate reference. We employed a theodolite to measure the azimuth of the north wall concerning Polaris and Alnitak in Orion's belt. We could observe Orion's belt rising near the northern wall axis.

3. Results and Discussion

We checked the city plan's east-west orientation using a theodolite and GPS along the northern city wall, measuring to Polaris and the other star, calibrating with *Stellarium* (version 0.21.3) afterward. This verified the tilting with an azimuth of 92.5° (2.5° south of east).

3.1. The Gnomic Approach

Due to poor weather conditions, insufficient sunlight to identify a clear shadow and accidental removal of the gnomon, we obtained only eight days out of the intended 24 days of measurements, giving just eight data for the shortest shadow and six data from the Indian circle method. As summarized in Table 1, the Indian circle method yields a more precise orientation angle to the actual directions than the shortest shadow method. However, neither method produces an average deviated rise more significant than 0.7°, far less than the 2.5°-tilted city wall. The error might have been even lower if performed by the skilled Brahmin who planned the city. As a result, it is more plausible that the fixed star method was the orientation method than the sun-shadow method. It is worth noting that the gnomic shadow method for determining the cardinal direction can be employed on any day of the year; however, the condition of sunlight, depending on weather or terrain, can be a limiting factor for this method.

3.2. The Fixed Star Method

We need to investigate the azimuths of stars consistent with the orientation axis during construction, from 3 April 1292 – 19 April 1296. In Figure 2, the rising azimuths after precession correction of several prominent stars obtained by the *Stellarium* software were plotted from the year 0 to 2000 A.D. for the northeast corner, 18° 47′ 42.323″ N; 98° 59′ 36.773″ E) Only the azimuths of Spica and the Orion's Belt, namely Mintaka (δ Orionis) and Alnilam (ε Orionis), are near the city alignment of 92.5°. Still, the latter was associated with the city's founding time.

Table 1. Measured azimuth angles from the orientation axis constructed *via* the sun shadow method.

Events	No.	Date in 2022	Measured Azimuth /°			
			Shortest shadow		Indian circle	
			N (0°)	E (90°)	N (0°)	E (90°)
Vernal equinox	1	19 Mar	0.0	91.0	0.0	90.0
	2	20 Mar	*na.*	*na.*	*na.*	*na.*
	3	21 Mar	-1.0	89.0	0.0	91.0
	4	22 Mar	*na.*	*na.*	*na.*	*na.*
The date that	5	2 Apr	*na.*	*na.*	*na.*	*na.*
King Mangrai entered	6	3 Apr	1.0	91.0	0.0	90.0
to the site	7	4 Apr	1.0	92.0	1.0	92.6
	8	5 Apr	-0.3	88.0	-1.4	88.0
The date that	9	17Apr	*na.*	*na.*	*na.*	*na.*
King Mangrai began	10	18Apr	*na.*	*na.*	*na.*	*na.*
to build the city	11	19Apr	*na.*	*na.*	*na.*	*na.*
	12	20Apr	*na.*	*na.*	*na.*	*na.*
Summer solstice	13	20 Jun	*na.*	*na.*	*na.*	*na.*
	14	21 Jun	*na.*	*na.*	*na.*	*na.*
	15	22 Jun	*na.*	*na.*	*na.*	*na.*
	16	23 Jun	*na.*	*na.*	*na.*	*na.*
Autumnal equinox	17	20 Sep	0.3	90.3	*na.*	*na.*
	18	21 Sep	2.0	92.0	1.0	91.0
	19	22 Sep	1.0	92.0	*na.*	*na.*
	20	23 Sep	*na.*	*na.*	*na.*	*na.*
Winter solstice	21	19 Dec	*na.*	*na.*	*na.*	*na.*
	22	20 Dec	*na.*	*na.*	*na.*	*na.*
	23	21 Dec	*na.*	*na.*	*na.*	*na.*
	24	22 Dec	*na.*	*na.*	*na.*	*na.*
		Average	0.5	90.7	0.1	90.4

na. -not available noticed for incomplete data collection.

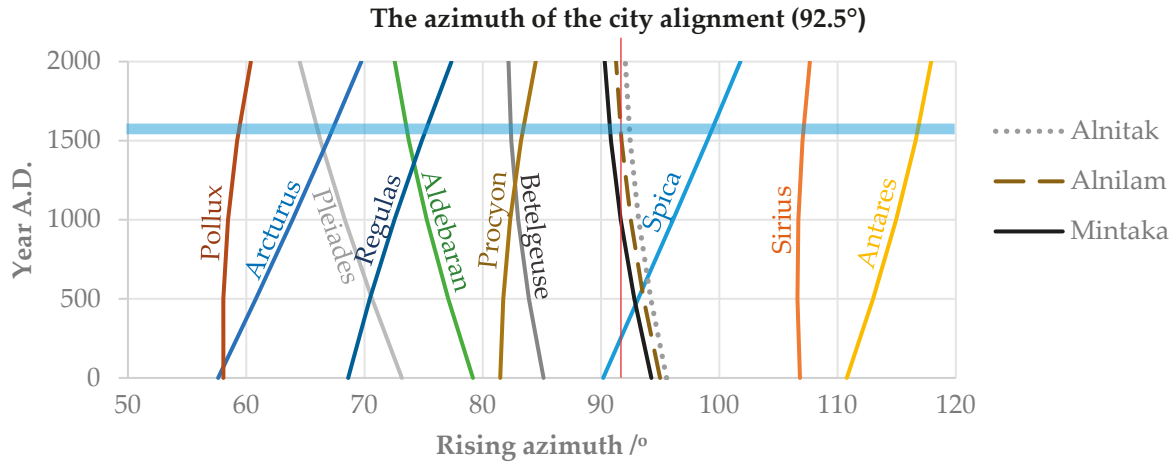

Figure 2. Observing at Sri Poom Corner (the northeast corner, 18° 47′ 42.323″ N; 98° 59′ 36.773″ E; altitude 312 m), the changing azimuths of the stars when rising on the eastern horizon over two millenniums, due to the precession of the equinoxes. The red hairline (at 92.5°) indicates the azimuth of the city alignment, and the light blue strip illustrates the city planning period during 1292 – 1296 A.D.

The stars that might be candidates for aligning the city's orientation are Mintaka (δ Ori), Alnilam (ε Ori), and Alnitak (ζ Ori), three lined-up stars that represent the belt of a famous hunter in Greek mythology. Still, the Orion constellation looks like a turtle for Thai people (see Figure 3: Top). This constellation is of great use in finding the positions of other stars. Tracing a line from Orion's belt to the southeast, we will find Sirius in the Canis Major constellation; in the opposite direction, towards the northwest, we can locate Aldebaran. A straight line that draws across both shoulders of Orion to the east will point to Procyon in Canis Minor. If one draws from Rigel to Betelgeuse, it will mean to the positions of Pollux and Castor. From all the stars mentioned, the Pollux, Castor, Procyon, and Sirius stars, which together resemble the Chinese Junk Boat images (see Figure 3: Top), are stars of the Punavasu Nakshatra. When the moon was in this nakshatra on 3 April 1292 and 19 April 1296, it set the auspicious date and time for the ceremony of entering the new site and starting the construction, respectively. During the year of planning the Chiang Mai City Wall, as can be seen as visualized in Figure 4 and Figure 5, Mintaka rose at a height of 4° and Alnilam at a height of 1.5°; these two stars had the closest rising azimuth at 92.5°.

In Figure 5, only Mintaka and Alnilam have azimuths corresponding with the azimuth of the northern city wall but at different altitudes; the apparent brightness of these two stars is a magnitude of 2.23 and 1.7, respectively. To the Rule of Thumb, the star can be observed with the naked eye at least at its critical altitude, which can be regarded as its magnitude [13]. Therefore, the Mintaka at 4.0° altitude would be seen. In contrast, the Alnilam at 1.5° altitude (close to its critical altitude of 1.7°) could also be seen under the apparent sky condition.

We also investigate the significance of choosing this star for the city's orientation. According to the literature, Orion was used in an ancient harvest calendar in Indonesia [13]. To the Indonesians, this constellation resembles the Javanese plow (see Figure 3: Bottom) and marks the harvest season's start. For Thai people, this constellation is also known as a plowing star, which has long been considered a promising star for agriculture. King Mangrai chose the location of Chiang Mai based on the seven good omens that valued the fertility of soil, land, and plant varieties [3]. Therefore, it is possible that Orion was chosen for its auspiciousness in agriculture.

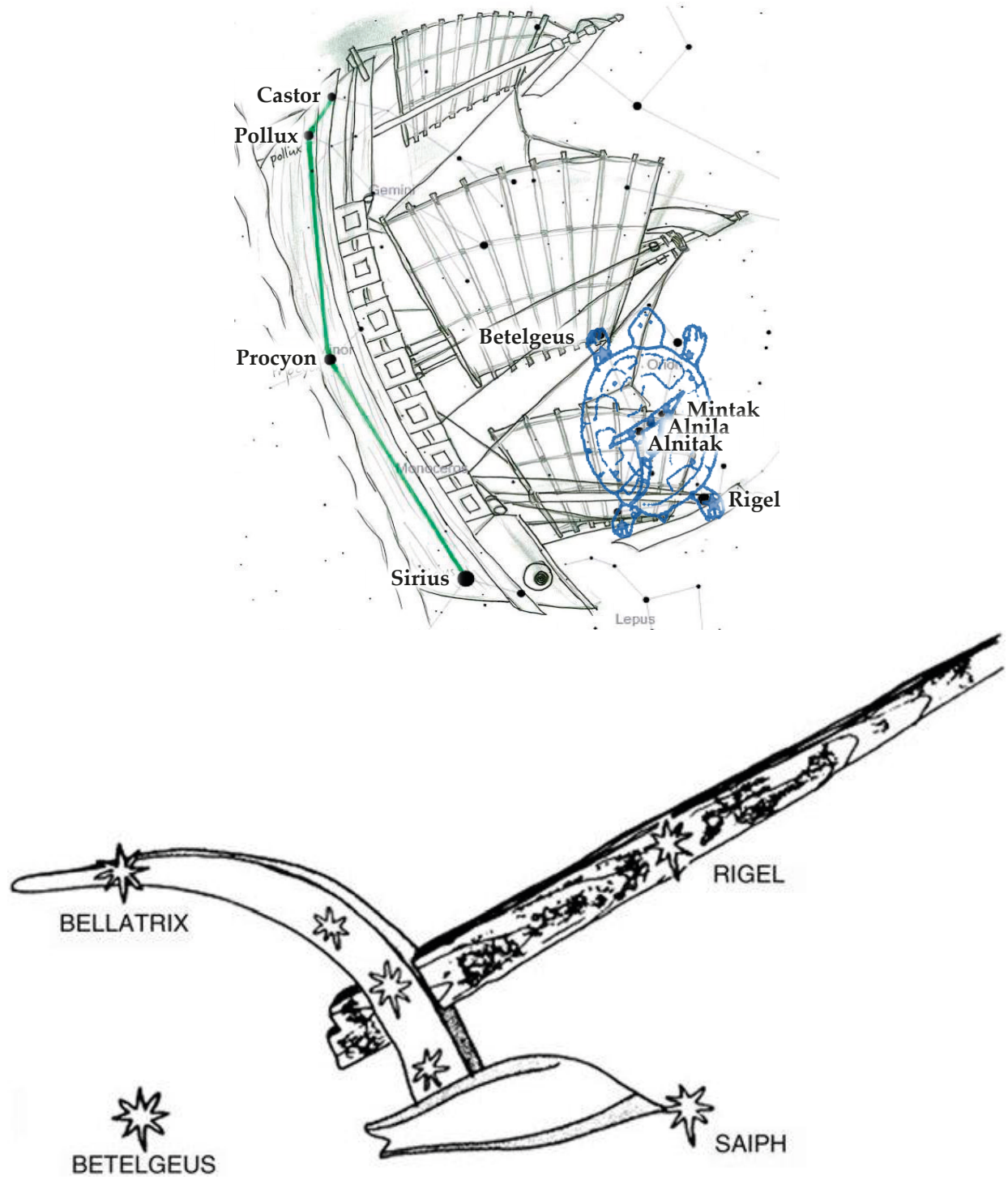

Figure 3. Top: The Orion Constellation appears to the native Thais as a turtle, and the Orion's Belt is imagined as a plow. The stars of the Punavasu Nakshatra are Pollux, Castor, Procyon, and Sirius, which resemble Chinese Junk Boat imagery (Drawing by Pisit Nitiyanant). Bottom: Illustration of the rising of Orion, which is also known as the Waluku (a traditional Javanese plough; an asterism in the constellation Orion) to indicate the start of the harvest season in Java (Drawing after Ammarell and Tsing [12]; Fig. 212.1, p. 2210)

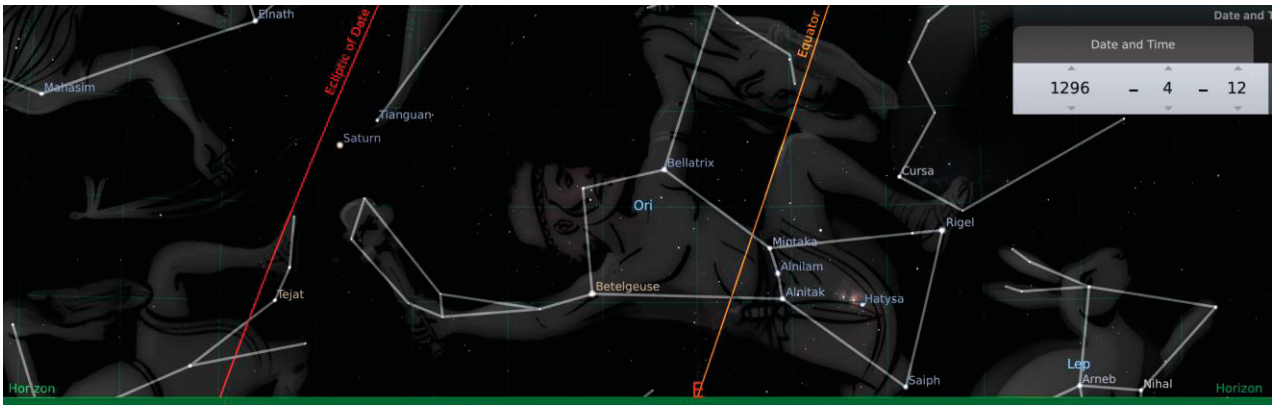

Figure 4. The visualized ancient eastern sky on the auspicial founding date, 19 April 1296 (note: the date labeled in the figure is used as Julian in the software), showing how the Orion Constellation appears to be rising on the horizon (Image generated by the *Stellarium* software, version 0.21.3)

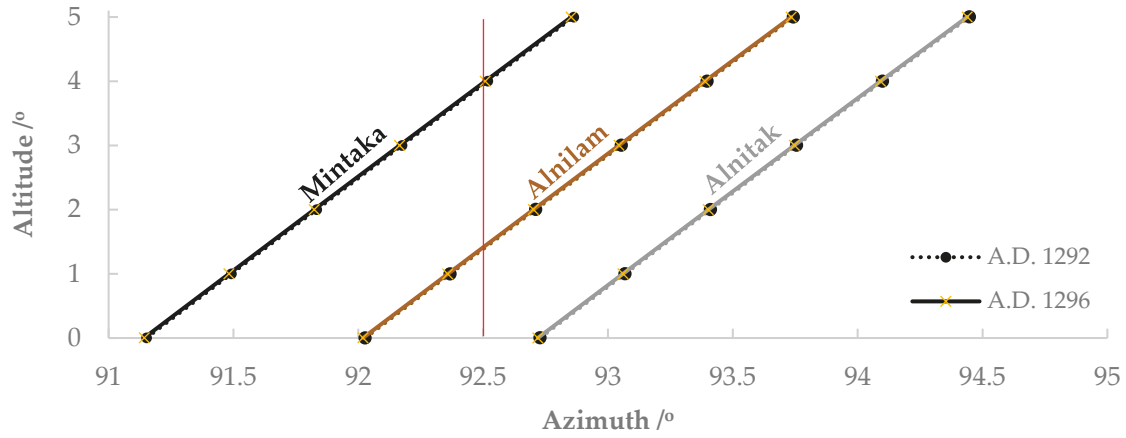

Figure 5. The azimuths and altitudes of Orion's belt stars in the year 1292 when the new site was to be chosen (dotted lines with a circle marker), and in the year 1296 when the ancient Chiang Mai city was being constructed (solid lines with a cross marker). The red hairline indicates the azimuth of the city alignment.

4. Conclusions

We find that the orientation method for the Chiang Mai city plan may have been the fixed star rather than the gnomon, like the Indian circle method or the shortest shadow method. The results of this investigation suggest that the orientation of Chiang Mai's old city wall might be aligned to the rising of the Mintaka star in Orion's belt at a height of 4° and possibly the Alnilam start at a height of 1.5° (under a very clear sky condition) between 1292 and 1296. The star may have been selected because of its optimistic role in agriculture, which was highly valued in the founding of Chiang Mai city for King Mangrai.

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Conflicts of Interest: The authors declare that they have no competing interests.

References

[1] Wichienkaeo, A.; Wyatt, D. K. *The Chiang Mai Chronicle*. Chiangmai: Silkworm Books; 1995. (in *Thai*)

[2] Princess Maha Chakri Sirindhorn Anthropology Centre. *Wat Chiang Man Inscription Face I* 2021. https://db.sac.or.th/inscriptions/inscribe/image_detail/26515 (accessed June 4, 2023).

[3] Saelee, C.; Riyaprao, O.; Komonjinda, S.; Sriboonrueang, K. An archaeoastronomical investigation of vaastu shastra principles (vedic architecture) implemented in the city planning of ancient Chiang Mai. In: Orchiston, W.; Vahia, M. N., editors. *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities*, Cham: Springer, 2021; 461–485. https://doi.org/10.1007/978-3-030-62777-5_13.

[4] Sastri, V. S.; Bhat, W. M. R. *Varahamihira's Brihat Samhita: with an english translation and notes*. Bangalore: V.B. Soobbiah & Son; 1946.

[5] Yano, M. Knowledge of Astronomy in Sanskrit Texts of Architecture (Orientation Methods in the īśāna śiv a gurudev apaddhati). *Indo-Iranian Journal*, 1986; 29. https://doi.org/10.1163/000000086790082163.

[6] Kramrisch, S. *The hindu temple: volume one*. Delhi: Motilal Banarsidass Publ.; 1976.

[7] Komonjinda, S.; Riyaprao, O.; Sriboonrueang, K.; Saelee, C. Relative orientation of Prasat Hin Phanom Rung Temple to Spica on New Year's Day: the chief indicator for the intercalary year of the luni-solar calendar. *Proceedings of the International Astronomical Union*, 2019; 15, 260–264. https://doi.org/10.1017/S1743921321001034.

[8] Riyaprao, O.; Sriboonrueang, K.; Komonjinda, S.; Saelee, C. Astronomical Orientation of Phra That Doi Suthep Temple in Relation to Acronychal Rising of Corona Borealis and Visakha Bucha Day. *Journal of Astronomical History and Heritage* 2023; (in press).

[9] Espenak, F. *Delta T (ΔT) and Universal Time*, 2011. https://eclipse.gsfc.nasa.gov/SEhelp/deltaT.html (accessed September 10, 2023).

[10] Espenak, F.; Meeus, J. *Five Millennium Canon of Solar Eclipses: -1999 to +3000*, 2006. https://eclipse.gsfc.nasa.gov/SEpubs/5MCSE.html (accessed September 9, 2023).

[11] Burgess, E. *Translation of the Surya Siddhanta*. Delhi: Indological Book House; 1977.

[12] Ammarell, G.; Tsing, A. L. Cultural Production of Skylore in Indonesia. *Handbook of Archaeoastronomy and Ethnoastronomy*, New York, NY: Springer New York; 2015; 2207–2214. https://doi.org/10.1007/978-1-4614-6141-8_236.

[13] Thom, A. *Megalithic Sites in Britain*. Oxford: Clarendon Press; 1967.

[14] Gislén, L.; Eade, J. C. The Calendars of Southeast Asia. 4: Malaysia and Indonesia. *Journal of Astronomical History and Heritage*, 2019; 22, 447–57.