A Review of Sources for Visualising the Royal Palace of Angkor, Cambodia, in the 13th Century

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The World Heritage site of Angkor in Cambodia which flourished between the 9th and 15th centuries is famed for its many beautiful stone temples including the renowned complex of Angkor Wat. But the stone structures we see today are only the 'religious skeleton' of what was once and thriving Southeast Asian metropolis.[1] Fluctuations of a tropical climate have largely erased the many thousands of wooden residences that made up the living city of Angkor. First among the perished wooden buildings of Angkor was the Royal Palace within the walled urban enclosure of Angkor Thom. To reconstruct a digital model of the Royal Palace that corresponds to an authentic vision of 13th-century Cambodia and takes into account uncertainty in our current state of knowledge, studies must first consult the considerable literature of history, architecture, cartography, and archaeology of the site of Angkor. Existing visualisations have had limited success in communicating a realistic Angkor, disadvantaged by partial consultation to current research. A survey of known studies of the Palace and its surrounds will pave the way for a richer and nuanced view of the Angkorian world.

Construction of the Royal Palace begun in the early 11th century and was inhabited by the Angkorian elite until the mid-15th century. The Palace was undoubtedly one of the largest wooden buildings at Angkor. Nothing of the Palace superstructure remains today, but tantalizing eyewitness accounts from a 13th-century Chinese emissary to Angkor describe a series of commanding buildings covered with lead tiled roofs linked by long corridors and complex walkways. Scholars of Angkorian history have speculated upon the appearance of the Palace in text, but none have attempted to generate visual representations of its form. To date television documentaries and magazine illustrations have reproduced the Angkorian Palace with inconsistent results. What is required is an approach that unites up-to-date scholarly knowledge and virtual modelling accommodating of alternative possibilities.

Imagining the Royal Palace in the 13th Century

Angkor Thom (in Khmer, 'Great City'), is a walled and moated square enclosure covering an area of 9 km². Likely established in the 12th century by king Jayavarman VII, it embraces an urban complex of house-mounds, ponds, canals and streets including several monuments from earlier eras. At the centre of the enclosure is late-12th-century Bayon temple, notable for its 'face-towers'. The site of the Royal Palace lies in the northwest quadrant of Angkor Thom. The Palace complex underwent numerous modifications over its life-span, the most significant during the beginning of the 13th century under the reign of Jayavarman VII.[2] Arguably, the most valuable description of the Palace is that of Chinese emissary Zhou Daguan who visited Angkor for eleven months from August 1296. Although Zhou did not enter the residences he describes his admission inside the Palace walls and audience halls:

> 'The royal palace, officials' residences, and great houses all face east. The palace… is about five or six li in circumference. The tiles of the main building are made of lead; all the other tiles are made of yellow clay. The beams and pillars are huge, and are all carved and painted with images of the Buddha. The rooms are really quite grand looking, and the long corridors and complicated walkways, the soaring structures that rise and fall, all give a considerable sense of size.
>
> In the place for doing official business there is a gold window, with rectangular pillars to the left and right of the crosspieces… I have heard that there are many wonderful places in the inner palace, but it is very strictly out of bounds and I could not get to see them.'[3]

French Archaeologist Bernard-Philippe Groslier who conducted excavations at the Palace in the 1950s and 60s provides another useful description:

> '…in former days Angkor was a sea of roofs. In the centre of the city sparkled the green and gold tiles of the royal palace, rising above its plain surrounding wall of red laterite. The general plan of the palace buildings resembles that of the flat temples: a series of main buildings intersecting at right angles and marking off various courtyards and quarters according to their respective functions – reception rooms, private apartments, gynaeceum and offices. The state rooms must have been magnificent: steep roofs carved and gilded arched roof-trees, and walls of precious woods…the audience hall…was supported by pillars resting on consoles…At the end of the hall was the elevated window where the king sat…This was the only part of the building open to the public.'[4]

Written descriptions evoke compelling images but are problematic for developing virtual models that must consider a myriad of additional material. Creating a virtual model of the palace is more challenging when many details of the Angkorian world are the foci of ongoing scholarly debates.

For example, while researchers generally agree that many aspects of the architecture of stone temples were modelled on existing wooden structures, there is question to the character of these 'temporary' buildings and ornamentations.[5] Modellers must be cautious as the interplay between stone and wood is unknown. To achieve 'authenticity' one approach is to situate the visualisation amidst its historical environs. In this example, a visualisation of the Palace can incorporate models of the monuments that adjoin it already re-imagined in illustrations,[6] 3D models[7] and real-world conservation surveys.[8]

Fig. 1 A photo of a double page spread in the 1960 National Geographic Magazine showing the New Year's festival at Angkor by Maurice Fiévet as described by Zhou Daguan.

Historical events and daily life at the Royal Palace have been represented in magazine illustrations and in television documentaries. With notable exceptions[9] these have not been bound to concerns of historical accuracy.

In the 1950s, the French artist Maurice Fiévet collaborated with the archaeologist Bernard-Philippe Groslier and historian George Cœdès to create a series of dramatic paintings depicting life in ancient Cambodia. These paintings appeared in the National Geographic article *Angkor, Jewel of the Jungle*.[10] Though Fiévet's images do not explicitly show the structure of the Palace several scenes are within or very close to it. The king and queen are seated on what is presumably the sandstone monument known as The Terrace of the Elephants, with the Palace behind them (fig. 1).

In another image, Palace attendants are dressed in vivid textiles and gold adornments inside a high roofed room. There is another depiction of the interior of the Palace where the king holds court in an audience hall. In this case, the partnership of artist and scholar produced visualisations with compelling authenticity.

The Channel 4 series *Lost Worlds: City of God Kings*[11] produced a CGI (computer-generated imagery) visualisation of the centre of Angkor Thom including a representation of the Royal Palace (fig. 2). This visualisation of the Palace was the first published digital modelling of the Angkorian royal enclosure. The digital model acknowledges the account of Zhou Daguan by showing lead roof tiles and partially gilded wooden structures. In one scene the king appears before an assembled crowd of costumed Angkorian officials and Chinese dignitaries. In contrast to Zhou's account the king emerges from a gold window open to an external courtyard rather than from within an audience hall.

Fig. 2 A still frame from the 2002 documentary *Lost Worlds: City of God Kings* showing the Royal Palace.

In 2011, the Korean Educational Broadcasting System (EBS) production *The Land of the Gods: Angkor*[12] generated a detailed visualisation of the Palace by lavishing considerable visual effects on decorative elements such as roof tiles, pavilions and gold statuary. Residential structures and wooden buildings were completely absent, and the impression presented was that the layout of the Palace was identical to a temple complex but without elevated levels.

Research at the Royal Palace

The Kings of Angkor habitually renovated their constructions. The Royal Palace had a complex life-span and numerous buildings were modified, altered and used for different purposes during its history. It is likely that each new sovereign placed their mark upon the Palace by remodelling structures and re-assigning the function of buildings. Conflict also likely changed the structure of the compound. During later periods (probably after the 15th century) there is evidence of the demolition of old structures and the re-employment of stone to fashion new buildings.[13] Although numerous buildings, stone walls and foundations remain, there is little robust archaeological evidence to suggest the function and operation of these structures. Nevertheless, one can envisage a series of buildings and constructions devised to service the Royal household and support the administration of the Empire.

Fig. 3 The Terrace of the Elephants and the main entry to the Royal Palace (photo, 2009).

Surrounded by a 5 metre high stone wall and a 25 metre wide moat the Royal Palace compound stretches 245 metres (north-south) and 585 metres (east-west) enclosing an area of almost 15 hectares. To the east, at the front of the Palace, there is a 300 metre long sandstone terrace, known as The Terrace of the Elephants, famed for its many representations of elephants along its walls (fig. 3). The terrace was probably once covered with a wooden pavilion which the king used as a viewing platform during events held in the adjoining 'Royal Square'.[14]

Fig. 4 The large pond – Srah Sré – on the north side of the Palace (photo, 2009).

The moat can be crossed at five points through large sandstone entry gates (*gopuras*). Inside the compound are four ponds lined with stone steps. The largest pond measures 125 x 45 metres and dates between the 12th and 15th centuries (fig. 4). At the approximate centre of the Palace compound is a temple-pyramid of three levels known as Phimeanakas and considered the 'royal shrine' of the Khmer kings (fig. 5). It is likely this temple existed before the Palace compound as it is not aligned with the eastern entry gate.[15]

Fig. 5 The temple-pyramid known as Phimeanakas (photo, 2010).

The Baphuon temple, just south of the Royal Palace, was also an important part of the ritual life of the court. Like Wat Preah Keo (The Silver Pagoda), the royal pagoda in Phnom Penh the Baphuon shrine likely serviced the specific needs of royalty.

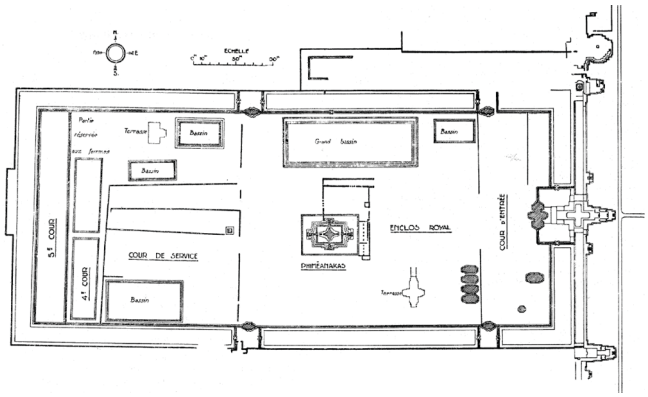

Fig. 6 Layout of the Royal Palace (Glaize 1993, p. 112 after Marchal 1926).

An early survey of the Royal Palace was conducted by French archaeologist Henri Marchal in the second decade of the 20th century.[16] Concluded from surface stone foundations Marchal's 'sketch-plan' divides the royal compound into five zones (fig. 6). Each subdivision was assigned to a specific activity of palace life including the dwellings of the king, his entourage, and various services.[17] For Marchal, the discovery of many ceramics and sandstone mortar and pestles in the third 'court' suggest the preparation of food, cosmetic make-ups and medicines in this particular area.[18]

Reconstructing the Palace

In addition to the extant structural remains a satisfactory virtual model of the Palace can draw from numerous sources including depictions of wooden architecture carved in relief on temple walls, modern and contemporary wooden architecture, and possibly the Indian prescriptive architectural treatises said to influence the architectural structures in Cambodia.

Fig. 7 3D modelling tests (2008) of wooden building components shown in the reliefs. On the left, cloth curtains hang between the pillars, and on the right, the structural framework beneath the tiles.

The bas-reliefs of the Angkor Wat, Banteay Chhmar and Bayon temples possess numerous representations of wooden architecture. A relief panel on the southern outer gallery of the Bayon, in particular, has been identified as depicting the Royal Palace (fig. 8).[19] Dumarçay[20] observes that most of the buildings depicted are open pavilions with removable hangings to demarcate space (e.g. fig. 7). When walls are shown, windows are installed with lathe-turned balusters and cloth curtains. Roofs rest on pillars, the doors are large and carved, and there are representations of large barracks, kitchens and storehouses.

Fig. 8 A bas-relief from the southern outer gallery of the Bayon depicting the Royal Palace (photo, 2009).

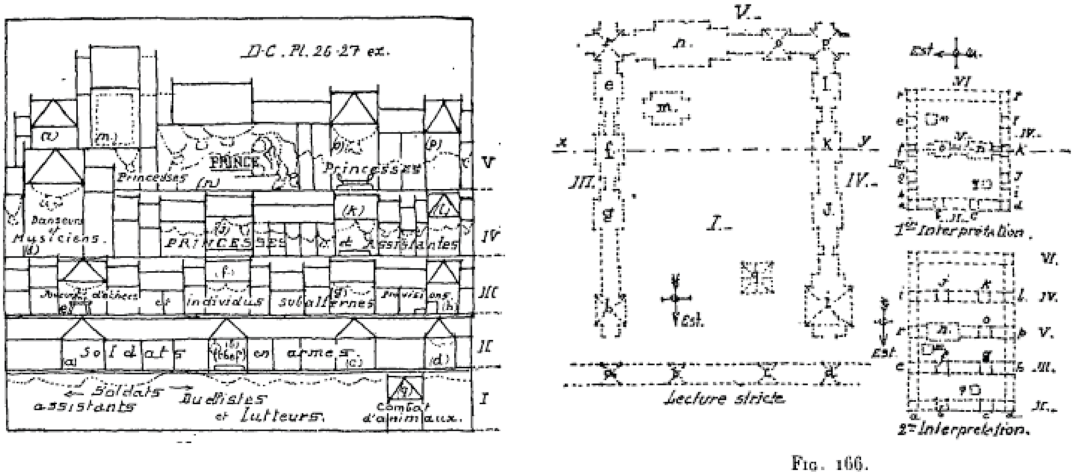

Fig. 166.

Fig. 9 On the left, a schematic drawn up by George Groslier from the bas-relief in fig. 8 above; on the right, three possible interpretations of the layout of buildings depicted in the bas-relief (both 1921).

George Groslier[21] offers three interpretations of the Bayon bas-reliefs (figs. 8, 9). The first is a strict reading of the representation which hypothesises that the sculptors have depicted the four sides of the building by placing them one above the other and the galleries form a quadrilateral. Another interpretation considers that the artists did not depict another gallery that closed off the square. When the viewer enters from the east they encounter courtiers playing chess and chatting. This gallery is closed off on the north by a store-room, princely apartments, and another gallery sheltering a group of adorned and decorated female Palace attendants. A possible representation of the Palace garrison is illustrated by a group of armed soldiers grouped around their leader. Following Groslier's spatial logic these are situated north of the main residential area in the same relative position that barracks are sited at the contemporary Royal Palaces of Cambodian and Thai royalty in Phnom Penh and Bangkok respectively. Groslier's final interpretation suggests an adherence to social rank and hierarchy by representing the pre-eminence of the Prince or King in the relief. When laid out as a plan view, visitors must cross the gallery of guards, a courtyard, a gallery of Palace personnel, another courtyard, and the Palace harem before meeting the Prince or King. This plan apparently resembles the layout of large temple complexes, notably the late-12th-century Banteay Chhmar in Banteay Meanchey province, where to reach the sanctuary one must cross eight galleries and seven courtyards.

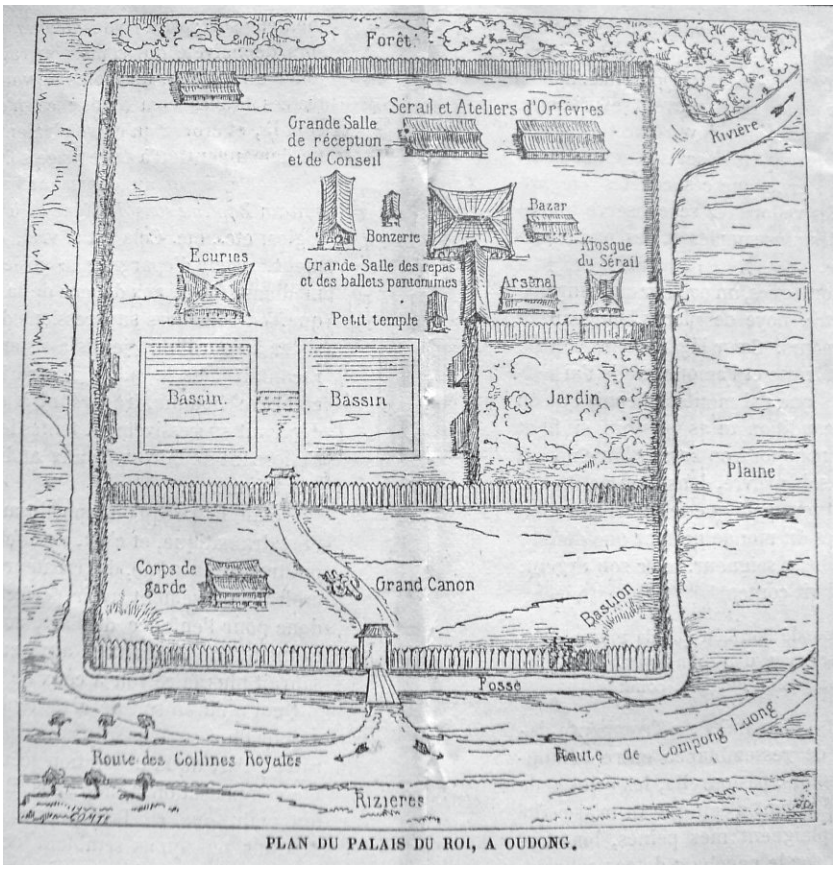

Fig. 10 A plan of the Palace at Oudong published in the magazine *L'Illustration*, 1864. Note the enclosed garden at the centre-right of the palace compound.

The bas-reliefs do not depict the entirety of the Palace compound and alternative sources of comparison must be sought. Sometime after the late 14th century the Kings of Cambodia moved their administrative and ritual centres to southern Cambodia. Although scholars must be cautious to draw comparisons between different eras, representations of palace sites at Oudong[22] (fig. 10), Longvek[23] (fig. 11) and Phnom Penh[24] provide applicable reference points for the spatial layout of the Angkorian Royal enclosure.

Fig. 11 A reproduction of a 17th-century Dutch map of the Cambodian capital Longvek (Johannes Vingboons, ca 1665).

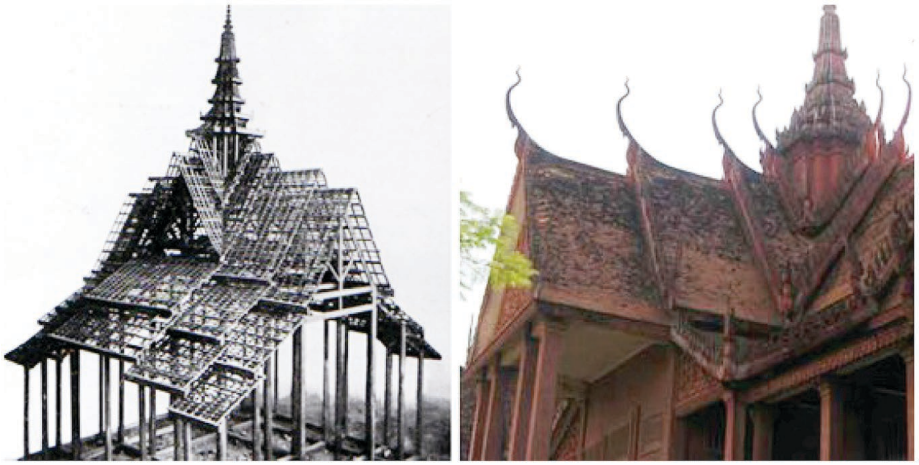

Fig. 12 Left: a photograph of a scale model detailing the internal roof structure of the School of Cambodian Art in Phnom Penh (1921).
Right: the roof over the main entrance to the National Museum of Cambodia (2008).

Another suitable reference for the wooden structures of the Royal Palace is the National Museum of Cambodia (fig. 12). Designed by the historian and curator George Groslier, and originally housing the l'École des Arts Cambodgiens de Phnom Penh, the National Museum of Cambodia was modelled on traditional Khmer architecture. The Museum inaugurated in 1920 includes a wide range of Khmer decorative elements. Local artisans from l'École des Arts Cambodgiens participated in its design and construction. George Groslier was integral in reviving traditional Cambodian arts and crafts. His considerable knowledge of Khmer architectural forms allowed him to elaborate the Angkorian palace prototypes from the bas-reliefs (see above) and reinterpret them with colonial eyes to fashion a building of requisite size.[25] This impressive building is worthy of a wooden Palace structure and of analogous size to what we might expect at the Royal Palace.

Based upon the prevalence of iconographic motifs and deities that took their origin in India and an attested knowledge of Sanskrit literature, scholars have often supposed that the metrical, proportional and compositional forms of medieval Khmer temples and urban enclosures were derived from Indian texts.[26] These texts may provide a reference point for the internal spatial layout of the Palace compound. Known generally as Śilpaśāstras (technical treatises) or Vastuśāstras (treatises on dwellings) the texts cover numerous subjects and art forms, from the layout of whole villages, to the pendants which must adorn the ears of individual images of the gods. The śāstras declare that an artwork or architectural structure (including urban plans) must adhere to specific aesthetic and spatial requirements to fulfil their proper spiritual obligations.

The temples of medieval Cambodia and the 'city' of Angkor Thom were constructed according to principles that aligned the structures to cardinal directions, emphasizing the importance of the centre, and observed rules of proportionality and symmetry. Yet reference to the application of Indian śāstras must be considered with caution. No direct correspondence between them and the Khmer monuments has been recognised. Additionally, there is no evidence within the Khmer epigraphic record that architects used such texts to create their buildings or towns. The medieval Khmer knowledge of Brahmanical literature was extensive, but there is no known mention of specific architectural treatises, or components of other works that contain passages on architecture and planning.[27]

Nevertheless, for the French archaeologist, Jacques Gaucher[28], Angkor Thom and the Royal Palace are the result of a Brahmanical conception of space on the one hand, and large scale Khmer adaptation to natural, topographical and hydraulic conditions on the other. Because the Angkor Thom design is apparently conceived without precedent, it must draw inspiration from an external urban model whose origin are the Indian śāstras. Gaucher points to the generalities of urban design discussed in treatises like the Arthaśāstra, Smarangāṅasūtradhāra, Mayamata, and Mānasāra.

Of possible correspondence were the proportional subdivision of the space into rectilinear and square components, and the location and proportionality of the 'Royal Palace' relative to the

greater complex.[29] The Mayamata and the Mānasāra, contain numerous descriptions of villages, towns, temples, houses and palaces with declarations of proper orientation, dimensions, and materials. The Mayamata, in general, specifies plans for palaces that comprise three separate square enclosures with the innermost enclosure centred around a shrine dedicated to Brahma, situated next to the dwellings of the king and queen respectively; the whole group of buildings open to the east.[30] A possible correspondence is provided by Zhou Daguan who situates the Phimeanakas as being within the king's sleeping quarters when he says: 'About one li further north again there is the residence of the king. There is another gold tower in his sleeping quarters.'[31]

Recent archaeological investigations provide considerable information for reconstruction of the Palace. The application of innovative remote sensing technologies like LiDAR[32] allows archaeologists to see below the dense forest and ascertain the layout of urban settlements, hydraulic features and temple structures. Preliminary examination of the data clearly reveals the first enclosure originally proposed by Marchal[33], and shows elevated ground on all sides of the Phimeanakas shrine. Additional analysis of the Palace LiDAR has potential to reveal the composition of the original wooden structures of the compound.

As the centre of the capital, the Royal Palace was no-doubt a bustling administrative hub overseeing many aspects of Empire management. Among the duties of the administration was to commission and manufacture images of the gods to furnish the temples. The Khmer Kings invested great resources in sculpture making consistent with an image's ability to fulfil spiritual necessity and confer political legitimacy. One centre for manufacture of sandstone and bronze images was just outside the northern of the Royal Palace. The close proximity to the Palace suggests that these ateliers were of great importance to the kings of Angkor. Ongoing archaeological excavations[34] at this site reveal the activities that surrounded the Palace during the 13th century and can provide a perspective point from which to situate an eye-level view of the compound as it might have been viewed from outside the walls.

The Palace in Context: Vegetation, Houses and Inhabitants

Visualisations of Angkor produced by the author have thus far focused on subsidiary architecture, urban agriculture and most importantly moving figures.[35] In contrast to the architectural focus of many previous 3D visualisation studies at Angkor, these reconstructions consider the space between the monumental structures and the archaeological layout of the site. The monuments are indistinct because they are viewed from afar. By contrast, the vertical forms of shade and fruit trees clustered around urban settlement dominate the visual field of the image.

Based upon the information in his accounts, it is likely that Zhou Daguan spent much of his time at Angkor inside the walls of Angkor Thom. Zhou's descriptions of social differentiation among the residences and seems to describe a layout of buildings near the Palace and he talks of the 'great houses' facing east.[36] Dumarçay and Royère hypothesise that the dwellings in Angkor

Thom were not contiguous but consisted of houses detached from one another and surrounded by a small plot of land serving as a garden.[37] Both Gaucher's surveys of Angkor Thom[38] and the LiDAR data appear to substantiate this proposal. Using the Angkorian bas-reliefs and contemporary architecture Dumarçay and Royère[39] reconstitute the appearance of a house and residential quarter to populate the city. It is likely that Angkor Thom was indeed occupied by such wooden dwellings and was also complete with utilitarian vegetation (e.g. fig. 13).

Fig. 13 A virtual model depicting a section of Angkor Thom based on archaeological mapping, circa 1300 CE (2009).

An understandable preoccupation with the stone temples belies the probability that Angkor was fundamentally a 'green city' abundant with vegetation. Graham[40] notes the lingering prejudice among historians and archaeologists to regard social complexity and civilization and the absence of agriculture and vegetation. In this view tropical low density pre-industrial cities are problematic because they do not conform to recognizable patterns or urban development or demonstrate a dichotomy between green space and urbanization.[41]

In contemporary mainland Southeast Asia specific trees maintain religious and utilitarian associations with Buddhist pagodas.[42] For example, sugar palm leaves are used for temple manuscripts and the Bodhi tree *(Ficus religiosa)* is symbolically associated with the enlightenment of the Buddha. Palaeobotanical analysis conducted at Angkor supports the supposition that temple grounds probably contained large and deliberately planted stands and groves of trees.[43] Dumarçay[44] notes a 'very impressive tree' in the Palace grounds at Oudong in the 17th century and a walled garden is clearly evident in a 19th-century plan of the site (fig. 10). The Oudong walled garden accords with late-17th-century accounts of gardens at Ayutthaya[45] identified by

Branigan and Merrony[46] using a range of archaeological methodologies. In Java, Satari documents temple gardens as recorded in inscriptions and depicted on temple reliefs. These references distinguish specific plants cultivated near a hermitage and palace grounds.[47]

While domestic architecture, vegetation and trodden thoroughfares convey visions of an inhabited space, the inclusion of animated inhabitants brings the visualised city to life. Zhou Daguan's account includes numerous descriptions of the city's residents and provides considerable material to visualise the people of Angkor. For example, Zhou specifically observes the servant women of the Palace known as *chenjialan*:

> 'At the lower level there are also the so-called *chenjialan*, servant women who come and go providing services inside the palace and number at least a thousand or two. In their case they have husbands and live mixed in among the ordinary people. They shave back the hair on the top of their head….They paint the area with vermillion, which they also paint on to either side of their temples…They are the only women who can go into the Palace; no one else below them gets to go in. There is a continuous stream of them in on the roads in front of and behind the inner palace.'[48]

Though Figure 14 depicts an unspecified location at Angkor, its application of cultural and environmental specific aspects of 13th-century Angkor, such as ox-carts and sugar palms, produces a framework for which animated figures of the *chenjialan* might traverse outside the Palace compound.

Fig. 14 The virtual populace of Angkor: 3D animated models traverse a road beside a high laterite wall at an unspecified location at Angkor, circa 1300 CE (2009).

Alternative Approaches to Uncertainty

The material record recovered from archaeological sites represents only a fraction of the information needed to interpret and reconstruct the visual appearance of historical landscapes. Missing data therefore generates uncertainty about visions of the past.[49] The primary uncertainty of visualising the Royal Palace of Angkor is the precise character and layout of wooden structures of which it was composed. Notwithstanding considered historical and archaeological interpretations reconstructing a detailed view is a largely speculative undertaking. A complimentary approach is to visualise the Palace from the outside. Several key 'eye level' viewpoints from outside the compound could serve to communicate the size and scale of the Palace ensemble while avoiding specific decorative and structural details. During the 13th century the Palace was undoubtedly inaccessible to the common resident of Angkor Thom and adopting the perspective of these individuals provides an alternative authentic visualisation of the living city. Inhabitants of Angkor Thom walking along the roads near the Palace might glimpse commanding edifices with lead tiled roofs glinting in the tropical haze.

Privileged residents of Angkor Thom also likely viewed the Palace from elevated positions. Possibly obscured by trees, the Palace could have been seen from the summit of both the Bakheng and Baphuon temples. However, the most commanding view can be reconstituted from Zhou's account of the temporary New Year's festival structures:

> 'A large stage is set up in front of the royal Palace…it is hung everywhere with globe lanterns and flowers. Facing it on a bank more than two or three hundred feet away are some tall structures that are made of wood joined and bound together, like the scaffolding used to make a pagoda. They must be well over two hundred feet high. Every night they put up three or four of these…and set out fireworks and firecrackers on top of them… When night comes the king is invited to come and watch… the fireworks can all be seen a hundred li away…and make enough noise to shake the whole city…'[50]

Portrayed in Maurice Fiévet's painting (fig. 1) a complimentary virtual model could shift the viewpoint from behind the King's viewing platform to the heights of the scaffolding where the rockets are ignited. Moreover, a virtual reconstruction set in the evening with diminished lighting would obscure the details of the Palace compound which become indistinct and silhouetted thereby eluding the obligation for an uncertain detailed restitution.

Future Directions for the Palace

Given the limited definitive historical and archaeological evidence for the composition and function of the 13th-century Angkorian Royal Palace a single peremptory vision is not feasible. What is required is a plural approach that communicates alternative possibilities. Working from the

bas-reliefs of the Bayon, a parallel approach was pioneered by George Groslier[51] who offered multiple interpretations to imagine the layout of the Palace compound. Within the scope of contemporary computer and multi-media interfaces it is unproblematic to offer plural visions of the Palace open to manipulation. In a visualisation that uses graphic scripting parts of buildings or entire edifices can be repositioned, realigned and rescaled according to art historical, archaeological or architectural evidence. Corresponding transformations can be applied to the positioning of trees and vegetation sets both inside and around the compound. An interactive visualisation (perhaps framed within a game engine) allows scholars and students to model the archaeological landscape directly.

Appraising the pending Palace of Angkor requires further research. Complimentary study of the layout and function of contemporary mainland Southeast Asian palaces, specifically those in Bangkok and Phnom Penh, may suggest possible correspondences. For example, there is a known correlation between the locations of the military garrison and artisanal studios relative to the ceremonial and administrative centre of the Kingdom. Additional research can also be made of historical palaces that have been too little studied. Identifying palaces at the urban predecessors to Angkor; the 7th-8th-century site of Sambor Prei Kuk,[52] and the 9th-century site of Mahendraparvata[53] (on the Kulen hills, bordering Angkor) could similarly assist in understanding the 13th-century Palace.

Arguably the most important historical source concerning Angkor and its Royal Palace are the first-hand observations of Chinese Emissary Zhou Daguan. Rather than a collection of sterile imposing structures, his vision of the city is one of a lived place; bustling with the activities of its population, its King and his court; replete with an ever changing landscape of rice fields and forest. Correspondingly, any endeavour to comprehend and visualise the glorious Angkorian past and its grand Palace must necessarily consider the context of its prosperity.

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Illustrations

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[1] Cf. Groslier, B.-P. 1958, p. 108.

[2] Dumarçay and Smithies 1991, p. 41.

[3] Zhou (trans. Harris) 2007, p. 49.

[4] Groslier 1966, p. 163.

[5] Coral-Rémusat 1934, p. 246; Cunin 2004, 2007; Dumarçay, 1973; Dupont 1952, p. 40; Groslier, B.-P. 1960, p. 2; Marchal 1951, p. 10; Parmentier 1914, p. 246; Polkinghorne 2008.

[6] Delaporte 1880.

[7] Cunin 2007.

[8] Royere 2011.

[9] Fiévet in Moore 1960.

[10] Moore 1960.

[11] Day 2002.

[12] Kim Yu Yeol 2011.

[13] Marchal 1926, p. 305.

[14] Freeman and Jacques 1999, p. 155.

[15] Freeman and Jacques 1999, pp. 112-113.

[16] Marchal 1926; See also Aymonier 1904, pp. 121-122, 127-136, fig 17; Fournereau 1890.

[17] Marchal 1926, p. 316.

[18] Marchal 1926, p. 326.

[19] Dumarcay and Smithies 1991, pp. 42-44; Groslier, G. 1921, p. 303.

[20] Dumarcay and Smithies 1991, p. 44.

[21] Groslier, G. 1921, p. 303.

[22] Dumarcay and Smithies 1991, p. 45; Groslier, G. 1921, p. 334.

[23] Vingboons, c. 1665.

[24] Dumarçay and Smithies 1991; Jeldres 2003.

[25] Collins 2005; Peters 1994.

[26] Dagens, 1985a, 1985b, 1994; Gaucher, 2002, 2004a.

[27] Dagens and Barazer-Billaret, 2000, p. 269.

[28] Gaucher 2003, p. 242.

[29] Gaucher 2004b, p. 78.

[30] Dumarcay and Smithies 1991, p.5.

[31] Zhou (trans. Harris) 2007, pp. 47-48.

[32] LIDAR (Light Detection And Ranging) is an optical remote sensing technology that penetrates forest canopy with an approximate resolution 20 cm horizontally and vertically. The survey was coordinated by the Khmer Angkor LiDAR Consortium (KALC) in April 2012.

[33] Marchal 1926.

[34] The Ateliers of Angkor Project, an Australian Research Council Discovery Grant (DP110101968) coordinated by The University of Sydney. See Polkinghorne 2012.

[35] Chandler 2011; Chandler and Polkinghorne 2012.

[36] Zhou (trans. Harris) 2007, p. 49.

[37] Dumarçay and Royère 2001, p. 106.

[38] Gaucher, 2003, 2004b, KALC 2012.

[39] Dumarçay and Royère 2001, fig. 98, 104.

[40] Graham 1999, p. 191.

[41] Graham 2005; Evans et al 2007; Hawken 2011.

[42] Chandler and Polkinghorne 2012.

[43] Penny et al 2006; Penny et al 2007.

[44] Dumarçay and Smithies 1991, p. 45.

[45] de Chaumont and de Choisy 1998 (1685); de Choisy 1994 (1685-1686); Gervaise 1996 (1688); la Loubere 1693; Tachard 1688.

[46] Branigan and Merrony 1999, p. 19.

[47] Satari 2008.

[48] Zhou (trans. Harris) 2007, pp. 54-55.

[49] Zuk et al, p. 99.

[50] Zhou (trans. Harris) 2007, pp. 62-63.

[51] Groslier, G. 1921.

[52] Shimoda 2011.

[53] Chevance 2011.