

From Ancient to Digital The Challenges of a Major Transition Towards the virtual Reconstruction of the Andean Past (With Special Reference to Inca Architecture.)

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Abstract. *The definition of an underlying shape grammar behind Inca architecture can assist in the virtual archaeological reconstruction of destroyed sites; that is, allowing us to step from the ancient to the digital realm. The Inca architectural style tends to be consistent throughout the Andes and was in effect, a statement of power. Geometricity, interlocking patterns, orthogonal layouts, colour and texture reversal, modular compression, derivations, rotation, mirroring, repetition, symmetry, proportion, ratios, recombination and Andean “entasis” are qualities frequently encountered in Andean art and architecture. They are “CAD-friendly” and can be integrated into predictive digital virtual reconstruction techniques representing partially damaged and substantially destroyed ancient Andean monuments (and fine arts).*

Keywords. *Inca, virtual reconstruction, shape grammars, kanchas, Ollantaytambo*

Introduction:

The Incas developed a distinctive art and architectural style, which they applied throughout their Empire (one of the largest in the world at the time) over a short timescale (200 years). Inca architecture is instantly recognizable. In view of its largely predictable standardized, modular, symmetrical nature, it is a suitable candidate for the application of parametric shape grammar theory (Mackay, 2007). Shape grammar theories have been developed for a number of topics, more specifically, for architectural styles (e.g. Palladio and Le Corbusier’s mansions, Orkadian megaliths, Wren churches, etc). Once defined, the shape grammars can be used as an additional tool in the process of archaeological reconstruction, and more specifically, the virtual reconstruction of substantially destroyed sites (e.g. Inca Tomebamba, Ecuador, now under the modern city of Cuenca; Cuzco itself is similar). Ever since the Spanish Conquest in 1532, Inca architecture has been described in a number of manuscripts and publications, and remains a major subject in its own right. From the 1970s on, a few authors, had described and catalogued the more significant Inca sites and structures. Gasparini and Margolies (1977) were to produce a benchmark study, followed by Ann Kendall’s (1976 and 1985) catalogue relating to Inca structures and form. Subsequently, John Hyslop (1984 and 1990) produced two comprehensive publications on Inca road systems and settlement patterns. His study on Inca settlement patterns discusses many of the sites on the periphery of the Inca Empire. These publications are relevant, but there is a lack of studies relating to function and use, principles of proportion, symmetry and ratios applied by the Incas. Studies have been carried out by architect Vincent Lee (1976) and also Mendizabal Lozak (2002) exploring proportioning systems. Both have attempted to go beyond mere description and understand concepts of Inca symmetry and ratios, suggesting what the preferred units of measurement were for the Incas.

Application of Shape Grammar in Inca Architecture

Shape grammar is a recent theory, which was defined by William Mitchell (1977), George Stiny (1977), Ulrich Flemming (1978) and

others. One of the seminal studies was by Mitchell and Stiny (1978) and relates to Palladio’s villa architecture. The Greek orders were well known to Renaissance, and later architects and engineers, through the works of Vitruvius, Serlio and others. In more recent times, Durand (1802-5; 1821), Wittkower (1962 and 1971) have expanded on these earlier studies. Studies by Vitruvius and others analysed the component parts, for example, of a Greek temple and broke each constituent part down and carefully established dimensions, proportions, relationships, and possible ratios and combinations using a series of formulas. Thus a pre-computer age architect/engineer/designer could make a series of design decisions based on the formulas worked out by these early architectural theoreticians. William Mitchell, in his book *Logic of Architecture* (1990) analyses their work and adds on the digital dimension; stages towards shape grammar analysis, and other related topics. For these architectural concepts to be applied to the world of computing, Mitchell, along with others working in the same area, needed to set up a series of rules, which could be understood and be translated into the digital world, and in the process they defined shape grammars.

So, what are shape grammars? A basic summary is given here: a shape grammar consists of a series of shape rules, requiring a system (can be computing) to select, process and generate, new rules. Shape rules define how a shape or a selected part of a shape can be changed and transformed. The process usually commences with a start rule, a series of transformation rules and is completed with a termination rule. The next question is: what is the relevance of shape grammars to Inca architecture? Once we have established what the basic measurement, proportioning systems, concepts of symmetry, general ratios, etc. we can define shape grammars for Inca architecture; and their application to virtual reconstruction at partially destroyed archaeological sites. Despite the fact that many Inca structures are fairly well preserved, parametric shape grammars are probably the best suited to this study (the shapes are already in existence - we are not generating them - and may incorporate certain key features, such as trapezoidal shapes, etc.).

Identifying the key shapes in Inca Architecture

The Incas had no written documents and as a result we are largely dependent on their oral histories and the documents left us by the Spanish chroniclers for descriptions of their architecture; and more recently, plans drawn up by architects and archaeologists on the basis of extant monuments. These considerations aside, we can also establish a sequence of shape grammars based on existing structures. The Spanish chroniclers (for example Cobo and Sarmiento de Gamboa) mention Ollantaytambo/Tambo ("tambo" is generally a term for a staging post on the Inca road network) as having been planned and re-built by Pachacutec (Pachacuti) Inca Yupanqui [1438-1471] probably around the 1460s at the location which is generally accepted and identified as contemporary Ollantaytambo. Ollantaytambo includes a well-preserved, extant, highly planned urban orthogonal layout, with its series of units or compounds composed of four rectangular structures around a central patio (fig1. Paper ID985-01.jpg)+ (fig2. Paper ID985-02.jpg). These units are known as kanchas (alternatively cancha, kanka or kankha). The kanchas, are placed back to back in a structured fashion, but at other sites they can be combined, recombined, mirrored, rotated, stretched and isolated and even reduced to a single rectangular structure (fig 3 ID985-03.jpg). Much Inca architecture is situated on slopes, terraces, hills, even crags however, the urban sector of Ollantaytambo is situated on relatively land, which allowed for the development of an orthogonal layout.

Having isolated the kancha unit and its constituent parts, that is, the rectangular structures, we can develop a strategy to break down these relatively simple structures into individual elements which can be allocated specific values, and which can be adapted to the values required for computer reconstruction (e.g. algorithms, etc). Once this is done it should be a fairly simple matter to scale up or down individual structure sizes, and by applying more complicated programming developing stretch functions (for more eccentric-shaped structures in areas of restricted topography). A later stage an analysis of the trapezoidal doors, windows and niches, as well as wall "entasis" should be incorporated, as they are keys as to what makes Inca architecture so distinctive. The pervasive use of the trapezoid or trapezoidal shapes, be it for windows, doors, niches, structures, the cross sections of walls and even for the ground plans of their settlements, has to be factored in. Where sites have been substantially built over, on the basis of comparative studies at similar sites, it should be possible to generate predictive models of what the original settlement would have looked like.

Before proceeding further, we need to review some of the basic tenets of Andean art and architecture; of which the emphasis on geometric patterns is high on the list. From 2000 BC onwards the stylistic formula used would appear to be one that was based on geometric forms. I have suggested (Mackay, 1987, 1988 and 1992) that the early use of textiles and their rigid system of warps and wefts (to use architectural terminology: the orthogonal layout), naturally generated a tendency in Andean aesthetics towards the development of a geometric tradition which lasted approximately 3500 years. The mainstream artistic format for the Central Andean region remained heavily dependent on geometric traditions, and, in order to achieve variety, forms are reversed (very cleverly in the case of double-weaves), colours exchanged, shapes are rotated, repeated, proportions worked out, designs placed symmetrically in alternate bands, ratios altered, scaled up or down, compressed or expanded, modular units designed, etc. Architecture reflected state control, and demonstrates a similar development, particularly in terms of the largely orthogonal, geometrical symmetry of many structures. The Tiahuanaco (and Huari) weavers (Sawyer, 1963) were adept at reducing figures to the basic minimum of detail (modular stretch transformations and modular compression



Figura 1



Figura 2

transformations). (fig 4 ID698-4). The Incas, despite references made to Tiahuanaco, did not follow this interest in modularity and compression in their general arts. However, when we look at the ground plans for their buildings, their architecture displays their methods for compressing or expanding key shapes (sometimes even leading to perspective and stretch transformations), probably based on a key measurement of around 1.61m. (Escalante, 1994). Interestingly enough, this measurement is not that different defined for le Corbusiers' Modulor. I would therefore suggest that what may have been the Incas' version, should be named the Andenor, in honour of Andean man. Inca structures tend to reflect a high level of internal symmetry (as opposed to external symmetry commonly observed in Western architecture), based on trapezoidal niches. Proportion, in general terms, goes hand in hand with symmetry and measurements. The proportioning systems employed by the Incas were carefully balanced with the structure's height, length and to a lesser extent the width (usually gable ends), giving consideration to the placement of doors and entrances (whether centred or offset on a facade). Many Inca structures had strictly enforced ratio rules. Such as for window spacing and particularly niche spacing. Vincent Lee's preliminary studies identified the following ratios (and a number of others) at a wide range of Inca sites: 1:3:1, 1:2:1 (being one of the more popular ratios), 1:6:1 and some considerably more complicated ratios, occasionally asymmetric ones.

Applying Shape Grammar to Inca Architecture

Until 2007, to the best of my knowledge, nothing had been written with reference to shape grammars and their application to Inca architecture and their further application to the virtual reconstruction process. Earlier this year (2009) three authors – Hwang, Mann and Cowan from Waterloo University submitted a brief paper for the 2009 New Orleans Acadia conference. Unfortunately, because of poor

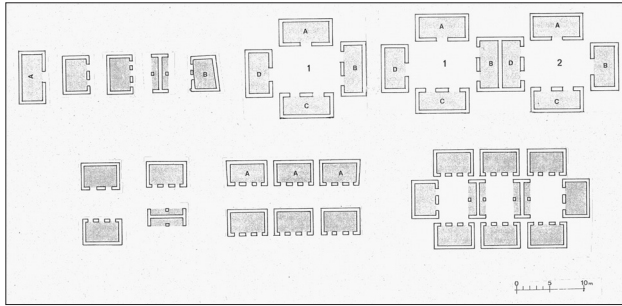


Figura 3

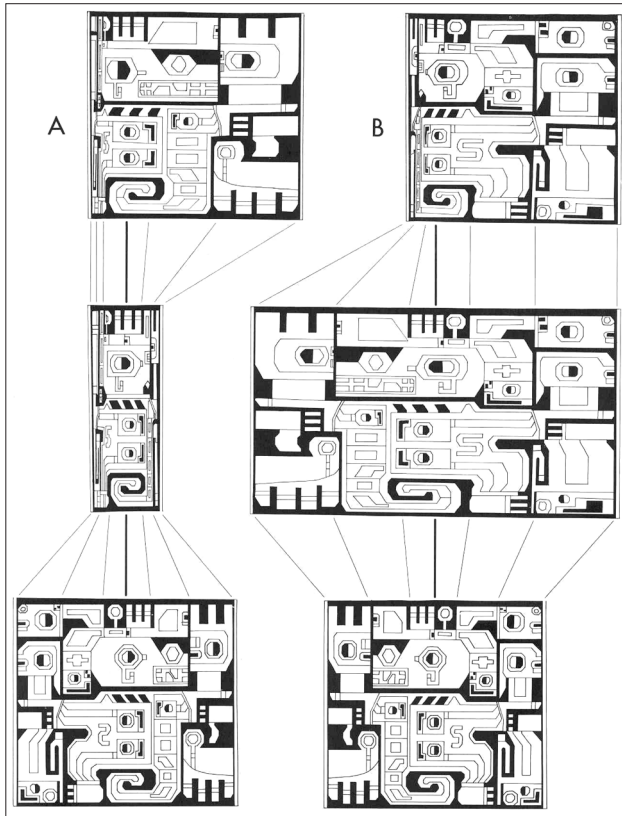


Figura 4

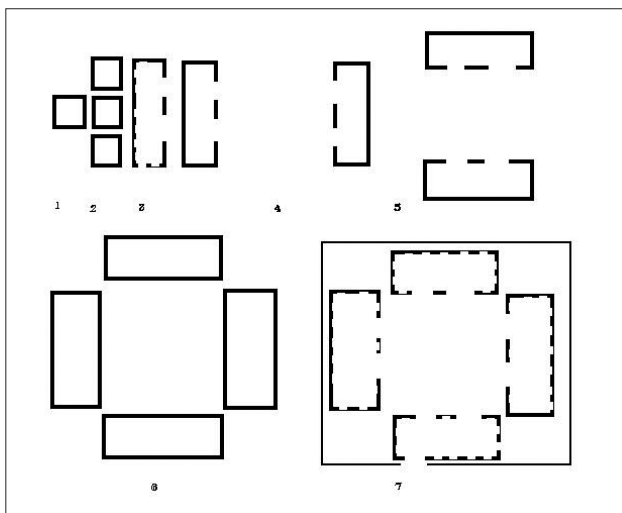


Figura 5

interpretation of the ground plans used, and misunderstanding of Inca architectural principles the resultant product is not accurate and would be misleading in a reconstruction. Nonetheless, it is a step in the right direction. This is probably the second publication to explore the potential of shape grammars and their use in the virtual reconstruction of Inca structures (Mackay, 2007).

Below we will give a basic outline of a Shape Grammar for Inca architecture (including dimensions, angles, proportions and etc) in a relatively procedural way, by means of a step by step descriptorial format, and a computational method, employing if/then statements. In other words, we have worked from an initial state, in this case, an “empty space” to a termination, in the final drawings of a kancha.

In this way the procedure has carried on, step by step, awaiting the completion of the entire kancha.

Rule number one (in its simplest format) can be envisaged as follows: If you start off with a blank space. Then replace it with a rectangle which is 8.5 m long and 4.5 m wide.

Rule number two: If you have a rectangle which is 8.5 m long and 4.5 m wide. Then replace it with an extrusion formed by this rectangle with a height of 2.5 m. and a base width of 1.2 mts.

Rule number three: If you have a rectangular extrusion with a height of 2.5 and a base width of 1.2 m. Then add to the ends (ie 4.5m wide ends) a triangular top 1.2 m. wide, which at its apex is 1.5 m. higher than the rectangular extrusion (rule two).

Rule number four: If you have a rectangular extrusion with a height of 2.5m and; 4 m high at the gable ends only. Then replace it with a volume with the same base shape, and sides inclined in -1,5 degrees on the external (outer) face of the extrusion

Rule number five: If you have a rectangular extrusion with a height of 2.5m and; 4 m high at the gable ends only. Then replace it with a volume with the same base shape, and sides inclined in -1,0 degrees on the internal (inner) face of the extrusion.

Rule number six: If you have a developed a structure which includes rules one to five. Then add to it a roof with a longitudinal value of 9 m (ie allowing some overlap), which has a watershed in the middle (equivalent of an inverted V)

Rule number seven If you have a rectangular structure that encompasses rules one to six.

Then you can place the extruded roofed rectangular structure parallel to a square (internal patio) measuring 9m x 9 m. Windows and niches can be added with sub-rules.

Rule Number eight If you have one extruded roofed rectangular structure facing onto an internal face or patio.

Then you can add three identical roofed rectangular structures symmetrically around the central patio.

Rule number 9 If you have four identical roofed rectangular structures around the central patio.

Then, all four structures should have an all-encompassing wall, placed round their external facades, to a height of 2.5, and a width of 1.2, and an inclination of approximately 1.2 m

Rule number 10 If rule 9 is applied in its entirety, the sequence is now terminated and we have produced a Kancha, one of the standard units amongst the Incas. The concept can be applied to archaeology, as well as virtual reconstruction, as part of a vision for the future and means to understanding the past.

Acknowledgments

I would like to thank Dr Neander Silva Furtado and Eclimar Lima for their support. I am also grateful to the eminent Peruvian archaeologist Dr Federico Kauffmann Doig for pointing me in the direction of relevant articles, to Dr Ann Kendall for generously lending me her key compendium of Inca architectural types and to the architects of the Instituto Nacional de Cultura, Cuzco, for generously sharing plans of the key urban sector of Ollantaytambo.

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