

Digital photogrammetry of vernacular architecture, comparison between putucos (Peru) and cocons (Spain)

Abstract: Vernacular constructions are the result of generationally inherited knowledge. These types of constructions took advantage of the resources of the environment and the knowledge of the territory to solve habitability and survival needs in rural contexts. In the research presented, two construction typologies are recorded and analyzed using digital photogrammetry (SFM): putucos (Peru) and cocons (Spain). The putucos are constructions made up of a single space that serve to shelter and are built with champa, material extracted directly from the ground. They have a quadrangular or rectangular floor, with four side walls that, through an inclination, configure the roof, through the approximation of rows of material or false dome. The cocons are constructions made up of a single interior space that serve to store rainwater and are built solely with stone. They have a circular floor, with side walls, an opening on the perimeter that allows access to the interior and covered by an approximation dome of courses with membrane behavior. The methodology applied in these two constructive typologies is based on a massive data recording technique through digital photogrammetry (SFM), to then be processed using the Agisoft Photoscan software, and finally the two-dimensional and three-dimensional data will be processed with the Rhinoceros 5 software. This methodology has made it possible to obtain three-dimensional models with millimeter precision and to make a comparison with each other; Although the uses and materials used for its construction are different, the geometry is very similar. The comparison of these has allowed us to show similarities and differences, both constructively, formally and structurally. These three-dimensional models also allow us to learn about this heritage, by definition sustainable and adapted to the environment. The dissemination of this vernacular heritage through augmented reality tools facilitates its access, prevents loss of value and increases knowledge about a more sustainable application of the material resources of the environment.

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Keywords

Putucos; Cocons; Digital photogrammetry

1. Introduction

Vernacular architecture is becoming more important nowadays as constructions that represent social, cultural and patrimonial values of a specific area, so it is necessary a big amount of documentation to record that diversity [1]. Precise studies of this rural architecture are important for the development of serious policies to protect them [2]. Several recent investigations deal with the survey and recognition of the characteristics of vernacular constructions [3, by means of technologies that allow digital reconstruction [4], that allow to take better samples and understand their unique properties.

The investigation tests the possibilities of massive data capture techniques to survey and analyze vernacular constructions and formal properties. Two typologies of vernacular constructions are selected which present a similar form. These two typologies are built with a similar construction technique, despite being located in different parts of the world and using different materials Figure 1. In addition, both typologies answer to the needs of the population that inhabits them. It was identified that both architectures seek the approach to water: the putucos due to the need for access to fertile soil for agriculture and livestock, which causes to be located in areas with constant flooding; while the cocons allow water to be stored for domestic purposes, since they are located in an area with little rainfall.

The putucos are pre-inca constructions located in the andean highlands of the department of Puno, Peru. They are located on the shores of Arapa lake and the Ramis river, a highly floodable area. The inhabitants of this area settled in this place due to the fertility of the land, however they had to face challenges such as constant flooding and the cold and dry climate of the sector. That is why the putucos are a vernacular housing response that serves as a refuge.

These constructions are characterized by presenting a dome on their roof that arises from the reduction of the champa courses from a square or rectangular plan, as can be seen in Figure 1. The champa from quechua language, is a block of earth extracted directly from the ground, which is left to dry in the sun for a few days, then they are placed in such a way that the roots are exposed under the next line of champa. With this construction system, the putuco ensures its structural stability, due to the fact that the champa blocks are joined and form a unified structure, which ensures its stability against floods. It is important to mention that the putucos work well thermally [5], which is important since they have a sleeping/cooking/storage function, or a mix of two activities.[6].

The cocó is a water tank formed by a cavity responsible for storing rainwater and an upper part responsible for protecting this water from direct solar radiation and promoting ventilation. This type of construction is isolated and linked to a slope of the land that favors the catchment and entry of water into the interior, as can be seen in Figure 1 . The cocó is covered by a dome between a system of approximation of rows and membrane behavior. There are single row roofs and others covered with little stones. The cocons arise from the need to have water for domestic consumption, for the hydration of people and animals and for hygiene. It is for this reason that the cocons are always next to a farmhouse, a shack or a shelter. The orientation of the opening of the cocó must prevent the entry of leaves and other plant elements that could damage the water, therefore, the opening is oriented against the direction of the prevailing winds [7].

The cavity responsible for storing the water can be dug directly into the rock or built and covered internally with mud and lime. In this way, an impermeable barrier is created and prevents the water stored inside from being lost. In order to conserve this water, direct sunlight must be avoided and ventilation must be encouraged through the entrance of the cocons and the separations that may be left between the different stones. The construction of the cocons was based on the economy of resources [8]. The location within the farm depended on the location of the rock ledge and that it could be accessible.

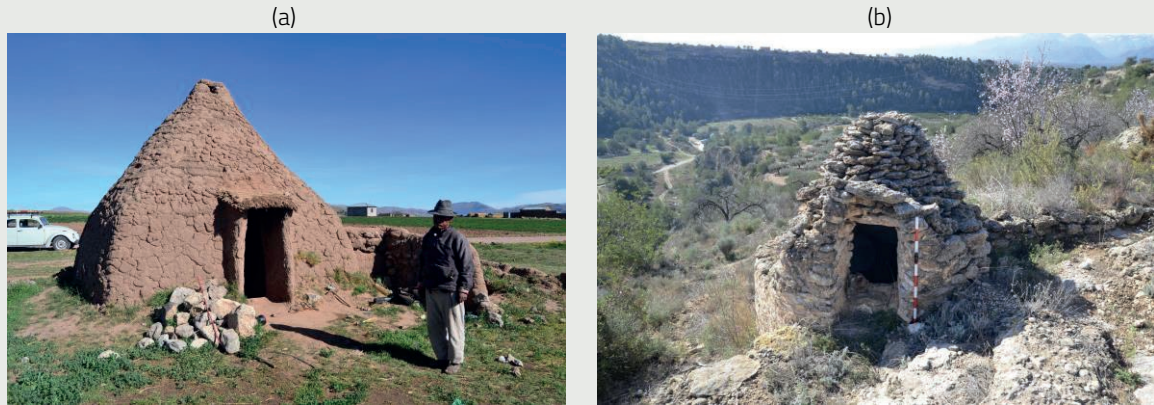


Figure 1. (a) Picture of Putuco 2 ; (b) Picture of Cocó 5

2. Materials and Methods

The methodology used is divided in three main phases: data collection, data processing, and interpretation of results. Five examples of each typology are surveyed, both the putucos and the cocons. The digital models obtained allowed to analyze dimensional and formal characteristics of both typologies.

The research is based on the surveying of vernacular constructions using digital photogrammetry based on Structure From Motion. It is a massive data capture technique which allows to obtain accurate three-dimensional models of an element, which incorporates its texture with photographic quality.

Structure From Motion (SFM) is based on three-dimensional reconstruction algorithms that generate 3D objects through a semi-automatic process. There are different software solutions that can be performed without a very specialized knowledge by the user. That is why there are many examples of its application in various disciplines. Its use is recognized especially in archeology [9,10, 11].

This digital technique makes it possible to obtain drawings that reproduce the current state of the studied elements. This technique has generally been used as a conservation measure in the so-called "monumental" heritage that, despite often having the historical floor plan, has allowed the current state to be generated in an agile and effective way [12, 13].

However, since many of the surfaces are extremely irregular, this method provides a noisy point cloud. Methods should be applied to clean the data for further area or volume studies. Along these lines, studies have been carried out to standardize the point cloud along a building [14] and eliminate noise [15].

2.1. Putucos

2.1.1. Selection and description of putucos

- Putuco 1: Currently abandoned, and does not belong to an architectural complex.
- Putuco 2: Its function is to sleep and cook, it is made of champa and earth coating, it is over 30 years old. The complex is made up of a putuco and a sheep corral.
- Putuco 3: Putuco built in exposed champa, which is currently abandoned, has no surrounding buildings.

- Putuco 4: It is the only putuco built in adobe, it has earth coating on the outside. Its function is to cook. It is over 45 years old. It forms part with four other adobe constructions that make up a central patio.
- Putuco 5: Its function is to cook, it is made of champa and earth coating. It is part of a set with four other adobe constructions forming a central patio.

2.1.2. Characteristics of photogrammetric models

Table 1 shows the characteristics of the putucos after performing the photogrammetry. It should be noted that the putucos that generated the most accurate data are putucos 2 and 4, since photographs of both the interior and exterior were allowed. In the case of putucos 1 and 5, photogrammetry could be carried out only on the outside, and in the case of putuco 3 photogrammetry was carried out on the inside. The reconstruction of these putucos was carried out following observable characteristics in situ and taking into account the measure results of putucos 2 and 4.

<i>Putucos</i>	Number of photos	Link point cloud	Dense point cloud	Number of vertex (model)
<i>Putuco 1</i>	71	70.558	2.590.554	13.660
<i>Putuco 2</i>	151	162.935	12.560.897	71.309
<i>Putuco 3</i>	92	108.489	11.890.041	53.352
<i>Putuco 4</i>	184	177.086	10.402.392	57.634
<i>Putuco 5</i>	47	55.201	4.850.606	22.545

Table 1. Putucos photogrammetry data.

2.2. Cocons

2.2.1. Selection and description of cocons

- Cócó 1: This cócó is without rivet with perimeter wall and horizontal plane, visible keystone and partial integral opening.
- Cócó 2: This cócó is without rivet with wall perimeter and horizontal plane, keystone no visible and partial integral opening.
- Cócó 3: This cócó is little stones, perimeter wall, keystone not visible and integral opening complete.
- Cócó 4: This cócó is without rivet with wall perimeter and horizontal plane, keystone no visible and partial integral opening.
- Cócó 5: This cócó is without rivet with wall perimeter and horizontal plane, keystone no visible and full integral opening.

2.2.2. Characteristics of photogrammetric models

Table 2 shows the characteristics of the cocons after performing the photogrammetry. The number of processed images has varied according to the characteristics: geometry and characteristics of its context. In all cases it has been possible to perform both exterior and interior photogrammetry. These complete models have made it possible to accurately represent their formal characteristics.

<i>Cocó 1</i>	72	54.285	6.984.530	166.400
<i>Cocó 2</i>	112	81.007	18.631.023	563.339
<i>Cocó 3</i>	55	14.738	8.098.161	243.944
<i>Cocó 4</i>	57	59.205	8.539.713	270.291
<i>Cocó 5</i>	56	59.539	6.164.556	187.581

Table 2. Cocons photogrammetry data.

3. Results

To obtain the measurements of the putucos and the cocons, three sections obtained from the three-dimensional models have been used. A longitudinal section, a cross section and a horizontal section have been made Figure 2. These sections have made it possible to obtain a total of twelve characteristic data for each of the constructions Table 4, Table 5, Table 6, Table 7, Table 8, Table 9.

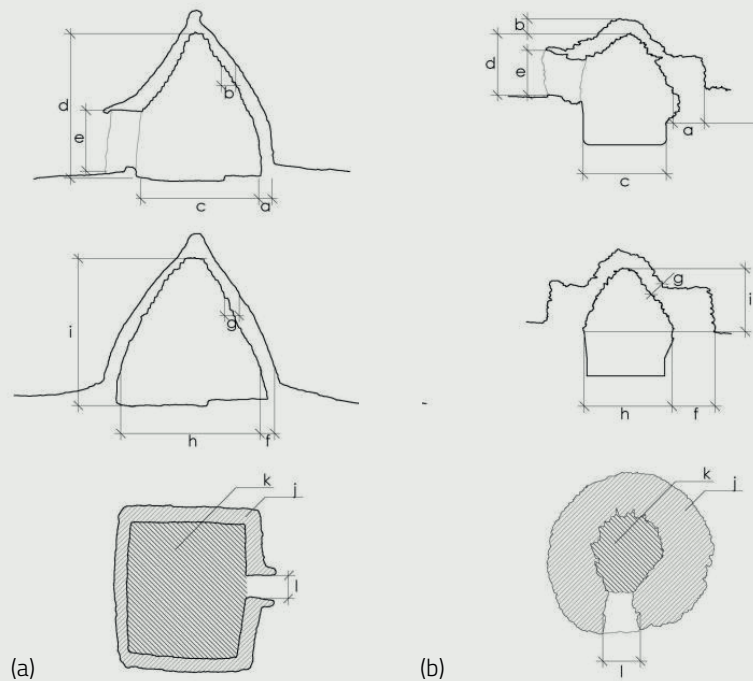


Figure 2. (a) Section data of putucos; (b) Section data of cocons

3.1. Measurement results

Longitudinal section (<i>putucos</i>)	(a) Average wall thickness (m)	(b) Average dome thickness (m)	(c) Indoor width (m)	(d) Indoor height (m)	(e) Door height (m)
<i>Putuco 1</i>	0,33	0,34	2,26	3,75	1,40
<i>Putuco 2</i>	0,34	0,34	2,89	3,53	1,46
<i>Putuco 3</i>	0,33	0,32	2,87	4,28	1,45
<i>Putuco 4</i>	0,25	0,35	2,52	3,44	1,08
<i>Putuco 5</i>	0,30	0,31	2,82	3,90	1,72

Table 4. Measures of the putucos.

Cross section (<i>putucos</i>)	(f) Average wall thickness (m)	(g) Average dome thickness (m)	(h) Indoor width (m)	(i) Indoor height (m)
<i>Putuco 1</i>	0,30	0,31	3,29	3,74
<i>Putuco 2</i>	0,36	0,31	3,27	3,52
<i>Putuco 3</i>	0,33	0,32	3,19	4,31
<i>Putuco 4</i>	0,35	0,25	3,31	3,46
<i>Putuco 5</i>	0,30	0,33	3,43	3,87

Table 5. Measures of the putucos.

Horizontal section (<i>putucos</i>)	(j) Wall surface (m ²)	(k) Indoor surface (m ²)	(l) Door width (m)
<i>Putuco 1</i>	3,59	7,88	0,46
<i>Putuco 2</i>	4,30	8,81	0,52
<i>Putuco 3</i>	3,66	8,82	0,45
<i>Putuco 4</i>	3,97	8,34	0,48
<i>Putuco 5</i>	3,70	9,04	0,60

Table 6. Measures of the putucos.

Longitudinal section (<i>cocons</i>)	(a) Average wall thickness (m)	(b) Average dome thickness (m)	(c) Indoor width (m)	(d) Indoor height (m)	(e) Door height (m)
<i>Cocó 1</i>	0,373	0,552	2,882	2,305	1,346
<i>Cocó 2</i>	0,826	0,418	2,673	3,025	1,725
<i>Cocó 3</i>	0,751	0,289	2,279	1,732	0,771
<i>Cocó 4</i>	1,103	0,375	3,608	3,317	1,802
<i>Cocó 5</i>	0,621	0,231	1,560	1,432	0,627

Table 7. Measures of the putucos.

Cross section (cocons)	(f)Average wall thickness (m)	(g)Average dome thickness (m)	(h)Indoor width (m)	(i)Indoor height (m)
<i>Cocó 1</i>	0,686	0,268	2,669	1,896
<i>Cocó 2</i>	0,845	0,391	3,301	2,324
<i>Cocó 3</i>	0,647	0,327	2,683	1,364
<i>Cocó 4</i>	1,080	0,294	3,045	3,114
<i>Cocó 5</i>	0,685	0,218	1,568	1,369

Table 8. Measures of the cocons.

Horizontal section (cocons)	(j)Wall surface (m2)	(k)Indoor surface (m2)	(l)Door width (m)
<i>Cocó 1</i>	8,601	6,053	0,960
<i>Cocó 2</i>	10,372	7,626	1,038
<i>Cocó 3</i>	6,775	5,076	0,697
<i>Cocó 4</i>	11,910	6,592	1,084
<i>Cocó 5</i>	1,794	1,527	0,636

Table 9. Measures of the cocons.

3.2. Data collection results

Table 10 shows the relationship between the number of model points of each putucos and cocons processed. It is observed that the number of points obtained in relation to the images is lower in the putucos than cocons.

Putuco	Relationship between images and points	Cocó	Relationship between images and points
<i>Putuco 1</i>	36.486,68	<i>Cocó 1</i>	97.007,36
<i>Putuco 2</i>	83.184,75	<i>Cocó 2</i>	166.348,42
<i>Putuco 3</i>	129.239,58	<i>Cocó 3</i>	147.239,29
<i>Putuco 4</i>	56.534,74	<i>Cocó 4</i>	149.819,53
<i>Putuco 5</i>	103.204,38	<i>Cocó 5</i>	110.081,36

Table 10. Putucos and cocons relation photogrammetry data.

Table 11 shows the averages of the measurements obtained between the putucos and cocons, in order to make a comparison between both typologies. It can be seen that the (c) indoor width is very similar between both constructions, as well as the (b, g) average dome thickness. However, the putucos have a (d, j) indoor height higher by more than one meter, also the (a, f) average wall thickness and therefore the (j) wall surface, vary a lot due to the different material.

Measures	Putucos	Cocons
(a) Average wall thickness (m)	0,310	0,735
(b) Average dome thickness (m)	0,332	0,373
(c) Indoor width (m)	2,672	2,600
(d) Indoor height (m)	3,780	2,362
(e) Door height (m)	1,422	1,254
(f) Average wall thickness (m)	0,328	0,789
(g) Average dome thickness (m)	0,304	0,300
(h) Indoor width (m)	3,298	2,653
(i) Indoor height (m)	3,780	2,013
(j) Wall surface (m ²)	3,844	7,890
(k) Indoor surface (m ²)	6,816	5,375
(l) Door width (m)	0,502	0,883

Table 11. Measures of the putucos and cocons.

Table 12 shows the proportional relationship between the access openings to the interior habitable space, both of the putucos and of the cocons. Proportional relationships allow geometric comparison and see if there are repeating patterns.

<i>Putuco</i>	Relation of proportionality (door)	Relation of proportionality (indoor)	<i>Cocó</i>	Relation of proportionality (door)	Relation of proportionality (indoor)
<i>Putuco 1</i>	0,329	0,603	<i>Cocó 1</i>	0,713	1,250
<i>Putuco 2</i>	0,356	0,819	<i>Cocó 2</i>	0,602	0,884
<i>Putuco 3</i>	0,310	0,671	<i>Cocó 3</i>	0,904	1,316
<i>Putuco 4</i>	0,444	0,733	<i>Cocó 4</i>	0,602	1,088
<i>Putuco 5</i>	0,349	0,723	<i>Cocó 5</i>	1,014	1,089

Table 12. Putucos and cocons relationship data

4. Discussion and conclusions

Photogrammetry has allowed us to obtain an exhaustive record of these two construction typologies that are sustainable, understanding that they respond correctly to the environment, where they are located, and that they solve the needs related to agriculture and livestock. In addition, it was identified that both constructions are made in measures related to the human body.

4.1 Putuco - Cocó relationship

Although they are constructions located thousands of kilometers apart, both have a similar formality due to the construction process carried out by people intuitively, without any rules or previous technical knowledge.

The activity or use of the architecture has a great influence on the size of the spaces, although similarities have been found in the constructive principles between both constructions, the cocons are slightly smaller because the human being does not inhabit them constantly, unlike the putucos where they serve to shelter people (sleeping, eating, storing).

Both constructions have the purpose of relating daily life with the need for water. In the case of the cocons, it allows the storage of water in an area with a lack of running water, while in the case of the putucos, it allows settling in a flood zone, which is fundamental for the harvest and domestic economy.

4.2 Photogrammetry

The interior light conditions in both cocons and putucos influence the meshing process. The putucos have a much darker interior, which impedes the complete generation of the photogrammetric process, on the other hand the cocons, being more illuminated in their interior, favor the generation of the complete model.

Cocons generate many more points during the meshing process due to the irregularity of the surface, while the surface of the putucos is more regular and requires fewer points to correctly complete the three-dimensional model.

The present investigation gives evidence to understand different sustainable architectures. By means of a previous knowledge of the place that allows building taking advantage of the materials and resources of the environment, these acquired constructive knowledge serve to be able to realize a sustainable contemporary architecture.

In addition, future comparisons between vernacular architectures are sought in order to encourage new constructions that re-signify this knowledge and constructive principles.

Supplementary Materials: Annex: sections

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Annex: sections

