

Palamede — application of expert systems to the archaeology of prehistoric urban civilisations

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The PALAMEDE system is designed to evaluate the question of urbanisation supposed to reflect the Early State societies. In the East, between the 4th and the 2nd millennium, urbanisation is usually a clear concept, when cities are well developed and when a writing system keeps the administrative records. However, in many cases, like the incipient periods, or the in periphery of urbanised regions, the identification of the socio-economic system is not so easy. As we were working on such problems in Central Asia and Northern India, PALAMEDE has been conceived to help the researcher in some of such ambiguous cases. It has been written in SNARK, an inference engine developed by J. L. Laurière. It is the result of a collaboration with M. S. Lagrange and M. Renaud.

PALAMEDE, in a first part called 'doxography' (meaning 'description of opinion'), models various types of reasoning about the State process, at a high interpretative level: socio-economic, socio-cultural, political. In a second part called 'physiography' (meaning 'the description of nature'), PALAMEDE concentrates upon economic questions by measures and calculations upon material remains, approaching the socio-economic level only through a meta-terminology.

PALAMEDE is a complex of six modules (Fig. 30.1), running independently for simplicity reasons (a single 'expert' would have been quite heavy). The 'doxography' groups 2 modules; USE (Urbanisation, Société, Etat) and CIV (Civilisation). The 'physiography' groups 4 modules: TOP (Topography of activities), TEC (Technology of artefacts), ARC (Architectures) and SYN (Synthese of conclusions).

The doxography, in its first module (USE), analyses (by Gardin's logicist analysis and H. Wright's schematisations — Fig. 30.2) and models 10 sets of reasoning appertaining to existence of the State. The knowledge representation enumerates 140 concepts of the type:

Society X	Organisation-Soc	Stratified
Society X	Goods	Redistributed etc. . .

written in the ternary SNARK format.

These concepts are all extracted from the inferences used by authors in their reasonings (Whittfogel, Diakonoff, Carneiro, Adams, Wright etc.) They are used in the rule-bases of PALAMEDE.

Many of these concepts are repetitive or synonyms up to a point that only 16 concepts are sufficient for triggering all the inferences of all the reasons analysed. This core of 16 concepts has been called the facts-base PAYS-TEST (Test-country) (Table 30.1).

Besides the TEST-COUNTRY, four facts-bases have been constructed by analysing cases at the limits in order to test the good will of the reasoning analysed: Europe in the Iron Age, the Neolithic in Wessex, Large Scale Irrigation (a

single fact), and Ant-hill and Termites (as their descriptive vocabulary is nicely anthropomorphic).

Running the rules on such limit cases give interesting results (tables). The final fact-bases (initial fact-base + inferred facts) are consistent with the theories of the authors. They more or less rapidly infer the presence of State and administration from small and/or uncertain data bases. Generally speaking, the permissivity of the reasonings is great because they use concepts borrowed from more solidly founded disciplines of living societies, without proper archaeological evaluation.

In order to check if simply going further into further details in the archaeological data before manipulating the socio-cultural concepts of USE can solve the problem, the second module of the doxography PALAMEDE, CIV, was built.

The CIV module starts by analysing an article (Jacobson 1986) upon the State nature of the Indus Civilisation. The author's details are put into the archaeological data-base. Therefore, the PALAMEDE fact-base extracted (CIV\$IND) is purely archaeological and 43 rules model the reasoning of the author's conclusions about the presence of the State; this rule-based is named CIV\$JAC (Table 30.2).

This archaeological rule-base, tested with the socio-cultural facts-base PAYS-TEST of module USE, remains inactive; reciprocally, the socio-cultural rules of USE do not react to the archaeological facts of CIV\$IND. Naturally, the results of running CIV\$JAC on CIV\$IND are very consistent with the author's conclusions and the final facts-base (called USE\$IND) is consistent with the socio-cultural universe of USE. The run of the various USE rule-bases on the final facts-base USE\$IND works perfectly.

In order to test the permissivity of the CIV\$JAC reasons or its restrictiveness, a facts-base at the limits was submitted to the rules: the Chalcolithic Civilisation of Palestine, extracted from a recent article where the authors conclude the presence of a chiefdom, not a State. Simply using the socio-cultural conclusions of the authors (facts-base USE\$PALO), 4 of the USE rule-bases infer a State. Using the archaeological data-base of the authors (facts-base CIV\$PAL), the Indus reasoning CIV\$JAC infers 29 or 18 new facts (if including as untrue 'craftsmen quarters' in the original facts-base). The final facts-base is, again, submitted to the socio-cultural rule-bases of USE, producing various sorts of State formations.

Therefore, we can conclude that with almost any archaeological (but not only) data base, it is always possible to link data to concepts in order to produce plausible socio-cultural interpretations and that these interpretations can be easily used to infer the existence of State formations. It is just a matter of measure. The actual archaeological correlates of State formations have not been discovered because of

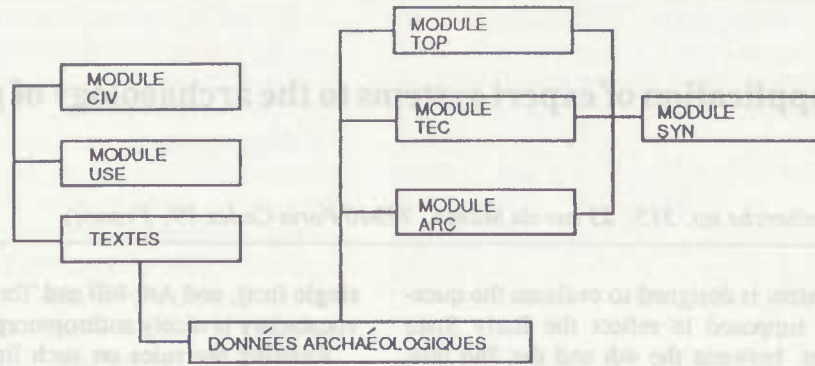


Figure 30.1: Schema for PALAMEDE

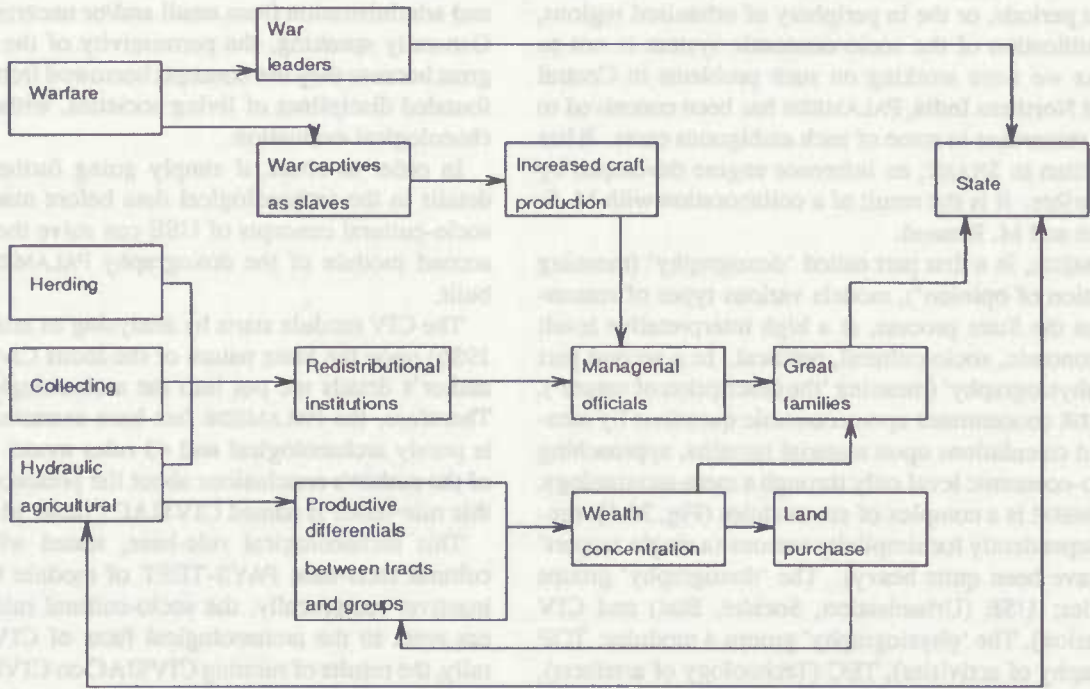


Figure 30.2: Theory of the origin of the state according to Adams after Wright 1978)

three frequently ambiguous and tautological concepts: very big urban population concentration, very large territory of an archaeological culture, and a developed and readable writing system. The macro-problem is: under what conditions can we transfer the attributes of living societies to the archaeological material data and validate it?

The second part of PALAMEDE — ‘physiography’ — is more constructive. It applies mostly to the data from a proto-historic site we excavated: Shortughai in N.E. Afghanistan. The ‘physiography’ goes back to the archaeological data, considering mainly the economy of production. This part of PALAMEDE is devoted to the relative comparative measure of successive stages of production economy under intra-site conditions. PALAMEDE builds conclusions by using for criteria a number of ‘meta-notions’ in a specific field (local). All the meta-notions are build upon evaluations of archaeological data, at the most basic level. A meta-notation for example is the ‘sophistication of craft production’ which is precisely calculated in a limited sense and differs therefore from the common use concept.

The ‘physiography’ groups the four modules: TOP, TEC, ARC, SYN. The module TOPpography of activities analyses the intra-site spatial distribution of artefacts measured by 3 (meta) functions; ‘domestic, craft, prestige’. Successive periods are compared 2 by 2. The archaeologist writes the fact-base TOPESHOR listing all the finds in their architectural context with indications about the origin of raw material; the Shortughai base has 600 lines. The rule-base TOPESHOR is founded on the simple principle of cumulative meters. The 100 rules of TOP attribute, according to the evaluation by the archaeologist, a value to the finds in terms of their explicitly supposed ‘domestic, craft or prestige’ function. The values are accumulated by places (95) and periods (9) and synthetised by phases (2). The number and percentage of places of each function at each phase are given. The results are written in words by PALAMEDE, such as:

BR FINALE	N REGLES	N DECLEN	BF
NUAG	73	72	62
ADAM	15	13	30
CARN	11	10	26
TOCH	27	16	26
WIDI	15	13	28
WRJO	23	18	33

Table 30.1:

REGLE: JACOBS1

SI	NATURE	(X)	=	CIVILISATION
	NATURE	(Y)	=	SITE
	DIMENSION	(Y)	=	GRAND
	OBJ	(Y)	=	SOPHI
	QUALIF	(Y)	=	URBAN
ALORS	POPULATION	(X)	<==	URBAN
FR				

REGLE: JACOBS2

SI	NATURE	(X)	=	CIVILISATION
	NATURE	(Y)	=	SITE
	DIMENSION	(Y)	=	GRAND
	QUALIF	(Y)	=	URBAN
	INCLUT	(X)	=	(Z)
	QUALIF	(Z)	=	CENTRE-URBAN
	NOMBRE	(Z)	=	4
	CULTURE	(Z)	=	HOMOGENE
ALORS	POP-URB	(X)	<==	150000
FR	ETAT-POLIT	(X)	<==	ORGANISE

Table 30.2: Urbanisation rules

'from phase A to phase B, the domestic meter increases, the crafts meter remains stable, the prestige meter decreases, conclusion: in the site of Shortughai, from phase A to phase B, the spatial specialisation decreases sensibly (-2), the long-distance trade diminishes enormously (-4)'. This conclusions are consistent with those of a written intuitive version of the interpretation of the same body of material.'

The module TEChnology of artefacts evaluates the 'intensity' and the 'sophistication' of artefacts production using the measures of the weight of objects, their typological diversity and the 'chains of technological operations'. The weight is a purely physical measure; the typological diversity is a regular output of any excavation. The 'chains of technological operations' are not extensively used except by the French prehistorians of Leroi-Gourhan's school: it is simply the succession of acts performed in order to transform the raw matter into artefacts. The facts-base TECESHOR has 250 lines listing the weights, number of types and values of chains by place and time and the 44 rules of the rule-base calculate the value and direction of change from a phase to another (Table 30.3). The conclusions are written by PALAMEDE, such as:

'from phase A to phase B the volume of production decreases considerably (-4), the sophistication of production is stable (0)'.

Again these conclusions are consistent with the intuitive perception.

The module ARChitecture evaluates the architectural and urban features using similar scales and meters for measuring the meta-notions of 'architectural techniques', the 'city planning', the 'capacity of calculations', the 'amount of work', the 'organisation of work' and the 'collective control'. The facts-base lists the architectural structures of any sort from the most monumental to modest bricks, by place and time; the facts-base ARC\$STG has 680 lines. The rule base ARC\$HIT uses 84 rules and also applies a principle of meters for evaluating 9 meta-notions; the values are always given by the archaeologist (for example, in a given wall, baked bricks give 10, mud bricks give 5 and pise give 1, and so on on, to the meter of architectural-sophistication'). The conclusions are written by PALAMEDE, such as:

REGLE: CHAINEI

SI	NATURE	(X)	=	BUTTE
	APPARC	(Y)	=	(X)
	MASSE	(Y)	<>	(0)
	TYPE	(Y)	=	(Z)
	COT	(Z)	=	1

ALORS

COMPT-TYPE	(X)	<--	+ 1	COMPT-TYPE (X)
COMPT-MAS	(X)	<--	+ MASSE (Y)	COMPT-MAS (X)
COMPT-COT	(X)	<--	+ COT (Z)	COMPT-COT (X)
COMPT-MI	(X)	<--	+ *MASSE (Y)	COT (Z) COMPT-MI (X)
COMPT-CHI	(X)	<--	+ 1	COMPT-CHI (X)

Table 30.3:

	Shortugai	Mitathal	Kalibangan	Banawali	Shahr-i-Sokhta
TOP	oui	non	non	non	oui
TECH (PROD)	oui (mass)	oui (n.obj)	oui (n.typ)	non	non
TECH (COT)	oui	oui	oui	non	oui
ARCHI	oui	oui	oui	oui	non

Table 30.4:

'In the burrough [from superficiality] of Shortughai from phase A to phase B:

- 'architectural techniques' decrease considerable (-3)
- 'city' planning is stable (0)
- 'capacity of calculation' is stable (0)
- 'amount of work' decrease a little (-1)
- 'organisation of work' decreases enormously (-4)
- 'collective control' decreases a little (-1)
- 'defense of territory' is stable (0) [no relevant data]
- ideology is stable (0) [no relevant data].

These conclusions are consistent with the intuitive approach.

The last module, SYNthesis, uses the results of the previous three modules and verbalises a conclusion about a 'tendency towards a socio-economic system' of more 'urban' or 'rural' type, more or less 'technical', 'producer' and 'organised'.

At Shortughai, using all the 12 indices (2 from TOP, 2 from TEC, 8 from ARC), PALAMEDE prints: 'From phase A to phase B, the site of Shortughai reveals a simple tendency towards a socio-economic system of rural type less technical, less producer and less organised'.

Again, this is consistent with the intuitive observations. It must be noted however that PALAMEDE has more nuances than the human expert. In each of the three modules of 'physiography', it appears that the decline of the site of Shortughai is not as generalised as thought and written. The module of SYNthesis which offers the possibility of 729 possible cases of evolution (giving warnings to the user if the data are not sufficient) is more sensitive than any natural language evaluation of a relative evolution. Nevertheless, PALAMEDE is more modest than the reasonings analysed in the doxography USE, and if we look into the representation of knowledge of USE for finding equivalents

to the 12 indices of SYN, we see that only 10 are represented. PALAMEDE is poorer in extension but stronger and locally richer. PALAMEDE cannot compare sites or take a whole 'culture' or 'civilisation (relative comparison of succession phrases)', but its field of application is clearly defined at a less ambitious interpretative level. PALAMEDE has been tested on data from other sites with various success depending principally to the availability of precise published archaeological data: Mitathal, Kalibangan, Banawali, Shahr-i-Sokhta (Table 30.4).

In conclusion, PALAMEDE is open to users for other evaluations of archeological material, though not yet by an interactive interface (to be written). Focussing upon a limited technological approach, using the concepts of Matter-Energy-Information-Time in a strictly archaeological way, which is clearly defined, PALAMEDE complements other mathematical treatments and leaves room for all other possible interpretations. PALAMEDE (physiography) is open to simulations (discussions) by modifications of the values in the facts and/or in the rules.

The use of rule-base systems is not necessarily the best or longest-lasting achievement in this field, but we must note that it is always possible to analyse reasoning into chains of syllogisms in our field, the most difficult question being to measure, evaluate and handle the uncertainty. But this is an archaeological and not a computer-science question. With PALAMEDE, we are invited to evaluate and measure the material data at the lowest possible interpretative level.

Such a system of material (if not physical) measures, thanks to the capacity for building meta-notions, helps to avoid the drawbacks of linking rigidly, through natural language, the concepts of socio-cultural living systems to the old objects which have been excavated.

The future of such systems, in our opinion, is in the construction of several bases of knowledge for the various themes or domains of archaeology. Such knowledge bases will be the core of our interpretative powers at a given stage of the art; this is because our bodies of inferences are always (*volens nolens*) to some extent standardised and can easily and painstakingly be modeled and simulated.