



This PDF is a simplified version of the original article published in *Internet Archaeology* under the terms of the Creative Commons Attribution 3.0 (CC BY) Unported licence. Enlarged images, models, visualisations etc which support this publication can be found in the original version online. All links also go to the online original.

Please cite this as: Hall, K. and Loy, M. 2025 *Collecting Data in the Conservation Lab for Network Visualisation*, *Internet Archaeology* 69. <https://doi.org/10.11141/ia.69.8>

Collecting Data in the Conservation Lab for Network Visualisation

Katharine Hall and Michael Loy

This article presents the results of a cooperation between conservators and archaeologists in the study of a large assemblage of broken ceramic vessels from a communal tomb, which had multiple episodes of mortuary activity as well as later disturbances. The data collected by the conservators was used with open access software to create a network visualisation of the joins between the pottery sherds found in the tomb. This contributed to the understanding of the formation of the deposits.

1. Introduction

In 2023 and 2024, conservators at the East Crete Study Center of the Institute for Aegean Prehistory ([INSTAP-SCEC](#)) worked to prepare material from Minoan multi-chambered communal tombs for publication. The material came from a series of tombs excavated by Nota Dimopoulou between 1999 and 2002 on the hill of Trypiti at Poros, which is the Neopalatial cemetery of the harbour town of the palace of Knossos. Deposits in the tombs represented multiple episodes of mortuary activity. In addition, all the tombs had been visited and partially looted in later periods, with only a small number of primary burials and the large pit deposits found undisturbed.

Some of the important small finds and complete vessels (Dimopoulou-Rethemiotaki [2004](#)) had been studied; however the large amount of broken pottery had not, and there was much information still to be collected. During conservation of the ceramics, stratigraphic data relating to the use of the tombs was recorded.

This data was investigated by the authors using software for network visualisation and analysis. The method, using data from the Laonikou tomb excavated in 2002 (Dimopoulou and Krzyszkowska [2019](#), 47-48), is presented here.

The use of network analytical techniques is now quite commonplace in archaeology, with a particular proliferation in the number of studies that have been published in recent years (Brughmans [2012](#); Brughmans and Peeples [2023](#), especially for the below sub-division of network methods with further references). Network methods handle, process, and visualise relationalities between different entities (*i.e.* a multivariate analysis), where the entities considered might variously be one or a combination of objects, people,



places, styles, production techniques, ideas or other such affordances. Networks have been used successfully to track optimal paths for crossing a landscape, to generate patterns of intervisibility, or to interrogate abstract socio-cultural phenomena; less commonly, material-culture based networks have been used, where ties are visualised either between contexts or places on the basis of similar assemblages (Bernardini [2007](#); Mills *et al.* [2013](#); Iacono [2016](#)), or between objects themselves with respect to shared styles, shapes, functional groups or otherwise (Loy [2024](#)). What such studies generally have in common is that they operate at an inter-site or regional level, mainly working on the basis of synthesising huge datasets with an interest to making further substantive conclusions about a site following the close of a project (Peeples and Haas [2013](#); Blake [2014](#)). What we illustrate in this paper is a network analysis that is used as an interpretive tool in an ongoing excavation, visualising data at the site level, to interpret specific archaeological rather than broader historical questions.

The authors chose to use network analysis for this particular case study because of the method's flexibility. The problem, as outlined below, demanded a form of multivariate calculation, and network analysis offered the benefit of organising multivariate data gathered in the lab into a spatial format. This permitted us to visualise fragmentation patterns and the dispersal of individual pottery vessels across the investigated tomb. In other words, network methods enabled the authors to analyse both object biographies and the temporality of the site within a single analytical framework: the fragments discussed below were considered both in their abstract context relational to one another and also in their primary field context.

2. Collecting the data

For the tomb discussed, well preserved vessels were catalogued and mapped during excavation. In addition, more than a hundred bags of sherds were collected, each of these containing a pottery 'lot' pertaining to a particular zone in the tomb. At INSTAP-SCEC, working in the large outdoor space, the conservators organised the pottery sherds and began carefully sorting through them, gradually piecing together vessels from the mass of fragments (Figure 1).



Figure 1: Conservator piecing together vessels from the pottery sherds. Image credit: Mike Armato

Eventually, more than a hundred vessels were created, forming a large assembly of jugs and cups, i.e. vessels for pouring and drinking. Many of these vessels were completed



from fragments scattered through different 'lots' and even through different chambers of the tomb. The conservators kept careful track of this by labelling all sherds removed from pottery groups with tiny strips of blue painters' tape labelled with fine permanent marker (Figure 2). When the new vessels were catalogued, these details were transcribed into the database for ceramic finds. Vessels were reconstructed using an adhesive of Paraloid B72 in acetone for the cups, and 3:1 Paraloid B48N:Paraloid B72 in acetone for the jugs.



Figure 2: Ceramic cup after reconstruction (left), and in fragments before reconstruction (right). Image credit: Katharine Hall

3. The problem

The question was then; how to use this data? Clearly, it is a window on human activities in the tomb. But how were we to make sense of the columns of data representing many-to-many relationships between the sherds?

4. The nature of the dataset

The information collected during conservation was stored in an [Excel spreadsheet](#) [xlsx]. The first column showed the ID number of the pottery vessel: 72 pottery vessels were catalogued with non-sequential IDs, the lowest being 30 and the highest being 376. (Vessels from a single location were not included in the dataset). The second column designated the 'lot' (or excavation unit) where a particular vessel was first identified (Figure 3). In the following 16 columns, further lots were listed where further sherds were found and added to the given vessel. Some pottery vessels (16) had sherds originating in only one other lot additional to the initial discovery lot, and only 20 had vessels with sherds spread across more than five lots.

	A	B	C	D	E	F	G	H
1	ID	Context	Join_1	Join_2	Join_3	Join_4	Join_5	Join_6
2	30	04 group 1	I4 group 3					
3	42	04 group 1	I7 group 1	05 group 2				
4	47	06 group 2	I7 group 2	K7 group 1				
5	48	06 group 2	I4 group 2	I4 group 3	04 group 2	H5 group 2	Z6 (+Z7) group 1	
6	49	06 group 2	I6 group 1	K6 group 1				
7	51	06 group 2	I7 group 1	I7 group 3	I7 group 4			
8	52	06 group 2	07 group 1	H6 group 1	H2 group 1			
9	58	H5 group 2	H5 group 1	H6 group 2	H9 group 1	Z8 group 1	Z9 group 1	
10	59	H6 group 2	07 group 1	06 group 2	K7 group 1	I8 group 2	K8 group 1	K8 group 2
11	60	H6 group 2	Z6 (+Z7) group 1					
12	64	H6 group 2	07 group 2	04 group 2	I8 group 2			
13	72	E7 group 1	Z6 (+Z7) group 1					
14	95	07 group 1	Z9 group 1					
15	96	07 group 1	K7 group 2	A8 (+A9) group 1	E2 group 1	B6 group 1	B7 group 1	F6 group 1
16	135	K7 group 1	07 group 2	I7 group 1	I7 group 2	K7 group 2		
17	140	K7 group 2	K7 group 3					
18	158	I7 group 3	I7 group 1	I8 group 1	K7 group 3	07 group 1	H9 group 1	
19	175	07 group 2	I7 group 1	I8 group 1	07 group 1			
20	181	H7 group 1	07 group 1	H7 group 1	H8 group 1			

Figure 3: The original dataset



The dataset also included (see second tab of the [spreadsheet](#)), a list of all 93 excavation lots that had yielded pottery (Figure 4). The general location of these lots was described according to five categories (translated from Greek): entrance fill, antechamber, north chamber, central chamber, south chamber.

	A	B	C
1	ID	Context	Location
2	1	A6 group 1	Centre
3	2	A7 group 1	Centre
4	3	A8 (+A9) group 1	Centre
5	4	B5 (+A5) group 1	Centre
6	5	B6 group 1	Centre
7	6	B7 group 1	Centre
8	7	B8 (+B9) group 1	Centre
9	8	Γ5 group 1	Centre
10	9	Γ6 group 1	Centre
11	10	Γ7 group 1	Centre
12	11	Δ2 (+Δ1) group 1	South
13	12	Δ5 group 1	Centre
14	13	Δ6 group 1	Centre
15	14	Δ7 group 1	Centre
16	15	E2 group 1	South
17	16	E3 group 1	South
18	17	E5 (+E4) group 1	Centre
19	18	E6 (+E7) group 1	Centre
20	19	Z2 (+Z1) group 1	South
21	20	Z5 (+Z4) group 1	Centre
22	21	Z6 (+Z7) group 1	Centre
23	22	Z8 group 1	North
24	23	Z9 (+E9) group 1	North
25	24	H2 group 1	South

< > all joins pottery lots

Figure 4: Second tab of the original dataset, listing excavation contexts and general location in the tomb

The task set by the conservator was to visualise all the information concerning the pottery and lot joins in a graphical format. The pots and lots should be shown together on the same diagram, but easily distinguishable.

The neatest solution proposed was to use a bimodal network visualisation, as a diagram of this type allows that:

- non-equivalent entities are drawn together as nodes, but can be distinguished through node design
- the emphasis of the visualisation is on the joins or connections between all entities
- the visualisation is projected in abstract/non-geographic space (the location categories defined in the conservator's spreadsheet was relative to the tomb, and did not contain absolute geographic co-ordinates).

5. The procedure

The following procedure was undertaken to transform the dataset supplied into a format readable in the graphs and networks visualisation platform [Cytoscape](#). All steps can be performed manually in Excel by practitioners with no particular training in the Digital



Humanities, but R code is also supplied here to enable exact reproducibility of all steps described.

Cytoscape is a popular open-source software for network analysis for beginners, and several online tutorials are available. For basic analysis, two spreadsheets are needed. The first is a Node Table which lists node attributes. In our example, these attributes are the pot catalogue number and the names of the pottery lots, and their location in the tomb. The second spreadsheet required is an Edges Table, in our example a simple list in two columns of every link between a pottery vessel and an excavation lot.

The columns of the core Excel dataset were renamed to reduce confusions in processing the dataset e.g. 'ID' was re-categorised as 'Pot_ID'. It was decided that it was not important in the present visualisation to indicate the original lot from which a vessel's sherds were first located, so this column ('Context') and all subsequent columns listing lot names ('Join 1', 'Join 2' etc.) were simply renamed together in sequence 'Lot_1', 'Lot_2', 'Lot_3', etc. (Figure 5).

	A	B	C	D	E	F
1	Pot_ID	Lot_1	Lot_2	Lot_3	Lot_4	Lot_5
2	30	Θ4 group 1	I4 group 3			
3	42	Θ4 group 1	I7 group 1	Θ5 group 2		
4	47	Θ6 group 2	I7 group 2	K7 group 1		
5	48	Θ6 group 2	I4 group 2	I4 group 3	Θ4 group 2	H5 group 2
6	49	Θ6 group 2	I6 group 1	K6 group 1		
7	51	Θ6 group 2	I7 group 1	I7 group 3	I7 group 4	
8	52	Θ6 group 2	Θ7 group 1	H6 group 1	H2 group 1	
9	58	H5 group 2	H5 group 1	H6 group 2	H9 group 1	Z8 group 1
10	59	H6 group 2	Δ7 group 1	Θ6 group 2	K7 group 1	I8 group 2

Figure 5: Renaming columns in the original dataset for ease of processing

```
new_column_names <- c("Pot_ID", paste0("Lot_", 1:17))
```

```
colnames(data) <-new_column_names
```

The second tab of the Excel [spreadsheet](#), the list of all the excavation lots, was used to create the Node Table. Cytoscape requires that nodes are imported from spreadsheets with sequential integer key ID numbers. A column was therefore created that combined 'Pot_ID' and 'Lot_ID' as 'Node_ID'. In order that each entity had a unique number, 'Lot_IDs' had to be renumbered starting from 74 (i.e. the next number available after the 73 pottery vessels) (Figure 6).



	A	B	C	D	E
1	ID	Pot	Lot	Label	Node_ID
66	65	1	0	Pot 358	65
67	66	1	0	Pot 359	66
68	67	1	0	Pot 361	67
69	68	1	0	Pot 362	68
70	69	1	0	Pot 363	69
71	70	1	0	Pot 366	70
72	71	1	0	Pot 367	71
73	72	1	0	Pot 370	72
74	73	1	0	Pot 376	73
75	74	0	1	A6:1	74
76	75	0	1	A7:1	75
77	76	0	1	A8(+A9):1	76
78	77	0	1	B5(+A5):1	77
79	78	0	1	B6:1	78
80	79	0	1	B7:1	79
81	80	0	1	B8(+B9):1	80
82	81	0	1	F5:1	81
83	82	0	1	F6:1	82

Figure 6: Creating a Node Table from the datasheet shown in Figure 4, adding a Node ID for each excavation context

This code uses the package 'readxl'

```
joins_data <- read_excel(file_path, sheet = "all joins")
pottery_lots_data <- read_excel(file_path, sheet = "pottery lots")

nodes_data <- add_row(
  nodes_data,
  ID = 0,
  Pot = 0,
  Lot = 0,
  Label = "Null",
  NodeID = 0,
  Location = "0"
)

joins_labels <- paste("Pot", joins_data[[1]], sep = " ")
nodes_data <- rbind(nodes_data, data.frame(
```



```
ID = NA,  
Pot = 1,  
Lot = 0,  
Label = joins_labels,  
NodeID = NA,  
Location = 0,  
stringsAsFactors = FALSE  
))  
  
lot_labels <- pottery_lots_data[[2]]  
lot_locations <- pottery_lots_data[[3]]  
nodes_data <- rbind(nodes_data, data.frame(  
  ID = NA,  
  Pot = 0,  
  Lot = 1,  
  Label = lot_labels,  
  NodeID = NA,  
  Location = lot_locations,  
  stringsAsFactors = FALSE  
))  
  
nodes_data$ID <- c(0, seq(1, nrow(nodes_data) - 1))  
nodes_data$NodeID <- nodes_data$ID
```




Figure 8: Creating the Edges Table

This search needed to be repeated 17 times for all 73 pottery vessels, to catch all possible joins in the field (i.e. for all 73 rows in column B, C, D, all the way through to column R). Where the IF formula did not find a match (i.e. where there was no join between a vessel and a lot), a value of '0' was pasted for both the source and target columns. These 'double 0' returns can then be stripped out of the dataset to leave a clean Edges Table, in this case 297 joins.

```
edge_creation_data <- joins_data

edge_creation_data[[1]] <- ifelse(!is.na(edge_creation_data[[1]]),
                                paste("Pot", edge_creation_data[[1]]),
                                edge_creation_data[[1]])

block <- edge_creation_data[1:73, 1:18]

lookup <- setNames(nodes_data$NodeID, as.character(nodes_data$Label))

block_id <- apply(block, 2, function(col) unname(lookup[as.character(col)]))
# block_id is a matrix with NodeIDs where labels matched, NA otherwise

edges <- do.call(rbind, lapply(seq_len(nrow(block_id)), function(i) {
  ids <- unique(na.omit(as.integer(block_id[i, ])))
  if (length(ids) < 2) return(NULL)
  prs <- t(combn(ids, 2))
  # normalise so Source < Target to de-duplicate undirected edges
  cbind(pmin(prs[,1], prs[,2]), pmax(prs[,1], prs[,2]))
}))
```



```
edges_data <- as.data.frame(unique(edges))
```

```
names(edges_data) <- c("Source", "Target")
```

```
row.names(edges_data) <- NULL
```

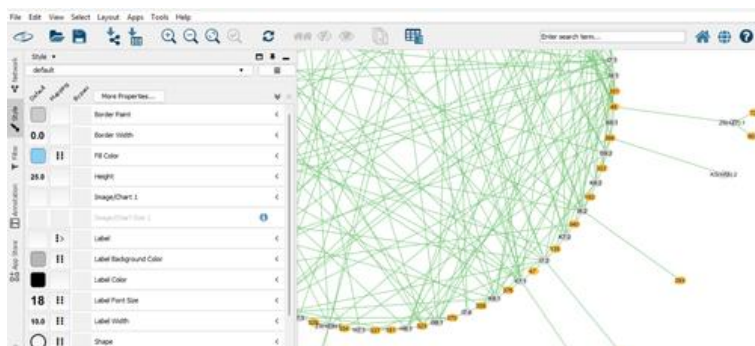


Figure 9: Labelling nodes in Cytoscape

Both the Node and Edges Table are importable as CSVs into Cytoscape. In our visualisation, using 'Fill Colour' in the Style menu defined the colour of the nodes (lots were coloured grey, and pots, yellow). In the same menu, using 'Label' displayed the name of a node drawn directly from the attribute list (Figure 9). An image annotation was then added to the Cytoscape session (using the tomb plan drawn by Pepi Stefanaki) and the nodes were then arranged manually in their correct positions. The image was then exported as a JPEG. A small key was added using Photoshop (Figure 10).

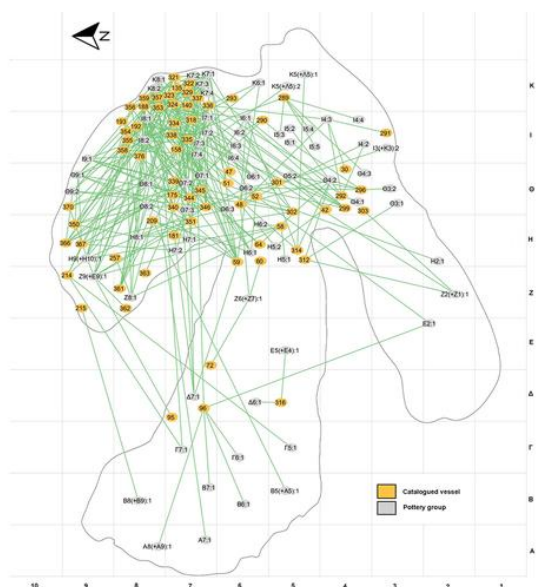


Figure 10: Network visualisation from Cytoscape of the joins between pottery sherds in the tomb



6. Discussion

The visualisation shows that most vessels were found in the north chamber of the tomb. More than 50% of these vessels were comprised of sherds only from the north chamber; perhaps these vessels are in their original place of deposition. Post-depositional disturbances in the tomb are also mapped, with sherds from separate chambers of the tomb joining together. For the Laonikou tomb, the network diagram prompted further interrogation of the data and the excavation notebooks.

Obviously, the diagram presented in Figure 10 is only one way of imaging this dataset. Once cataloguing is complete and each vessel has been dated and classified, other network diagrams can be created and analysed, or other forms of visualisation used to answer different questions. In this way, we hope to contribute to the understanding of the formation processes of the deposits. We also present this as an example of the process of investigative conservation, in which the collaboration of conservators and archaeologists can provide new insights into material processes.

We have since used this methodology in the ongoing study of two other chamber tombs from the series. Each had a pit into the floor of a chamber, filled with broken pottery and other small finds. We used vertical sections of the stratigraphy in the pits together with network visualisation to illustrate depositional events in these pits.

The innovation in this study has been to combine field and lab data for enriching an understanding of the archaeological context. In addition, by using a reproducible framework, it has been possible to quickly enhance the field analysis whenever new information became available from the conservation lab.

At a practical level, where the spatial visualisation indicates a high concentration of pottery fragments for which there are many joins between pieces, a high area of disturbance with much fragmentation can be interpreted. In the case of the Laonikou tomb, such an area is to be found in the north-east sector of the tomb, in excavation plots Θ8, Θ9, Ι8, Ι9, Κ8 and Κ9. This area functioned as a niche (Dimopoulou and Krzyszkowska [2019](#), 78) where piles of bones and small finds were concentrated. Furthermore, something can be said of the vessels that are widely distributed over multiple excavation units, such as finely decorated (and precisely dateable) cups 72, 95, 96, 209 and 214; the visualisation perhaps allows us to begin to reconstruct primary placement of key artifacts despite the damage done by later looting.

By contrast, at a conceptual level, network analysis offers a new dimension on investigating the object biography. While the location of a pottery fragment within this tomb might simply show its final position, looking at the relationships between a sherd and its neighbouring pieces can give some indication of *where* it came from and *how* it was deposited. Considering how the pieces fragmented offers deeper insight into the tomb's use-history.

Methodologically, this paper has presented a use of network analysis that adds to the growing arsenal of material-culture based approaches. Our motivation for using multivariate methods was to enhance our understanding of the excavation process, and our analysis was focused between only a few contexts within a single site. We present our use-case as a very practical example of problem-solving, demonstrating the flexibility of multi-scalar network methods, more usually applied to broader interpretive and substantive historical problems.



Acknowledgments

The authors would like to thank Dr. Nota Dimopoulou for permission to experiment with the dataset.

Disclosure statement

No conflict of interest was reported by the authors

Bibliography

- Bernardini, W. 2007 'Jeddito Yellow Ware and Hopi Social Networks', *Kiva* **72**(3), 295–328. <https://doi.org/10.1179/kiv.2007.72.3.001>
- Blake, E. 2014 *Social networks and regional identity in Bronze Age Italy*, Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9781139879262>
- Brughmans, T. 2012 'Thinking through networks: a review of formal network methods in archaeology', *Journal of Archaeological Method and Theory* **20**, 623–62. <https://doi.org/10.1007/s10816-012-9133-8>
- Brughmans, T. and Peeples, M.A. 2023 *Network Science in Archaeology*, Cambridge: Cambridge University Press. <https://doi.org/10.1017/9781009170659>
- Dimopoulou-Rethemiotaki, N. 2004 “Το επίνειο της Κνωσού στον Πόρο-Κατσαμπά,” in G. Cadogan, E. Hatzaki, and A. Vasilakis (eds) *Knossos: Palace, City, State. Proceedings of the Conference in Herakleion Organised by the British School at Athens and the 23rd Ephoreia of Prehistoric and Classical Antiquities of Herakleion, in November 2000, for the Centenary of Sir Arthur Evans's Excavations at Knossos*, BSA Studies 12, The British School at Athens. 363–380.
- Dimopoulou, N., and O. Krzyszkowska 2019 'Seals from the Minoan Chamber Tombs at Poros', *Athenische Mitteilungen* **134**, 41–96. <https://doi.org/10.34780/8ja7-cybp>
- Iacono, F. 2016 'From networks to society: pottery style and hegemony in Bronze Age southern Italy', *Cambridge Archaeological Journal* **26**(1), 121–40. <https://doi.org/10.1017/S0959774315000190>
- Loy, M. 2024 'Coinage networks in fifth-century BCE Ionia', *Anatolian Studies* **74**, 97–127. <https://doi.org/10.1017/s006615462400005x>
- Mills, B.J., Clark, J.J., Peeples, M.A., and Haas, W.R. 2013 'Transformation of social networks in the late pre-Hispanic US Southwest', *Proceedings of the National Academy of Sciences of the United States* **110**(15), 5785. <https://doi.org/10.1073/pnas.1219966110>
- Peeples, M.A. and Haas, W.R. 2013 'Brokerage and Social Capital in the Prehispanic U.S. Southwest', *American Anthropologist* **115**(2), 232–247. <https://doi.org/10.1111/aman.12006>