HOMER'S ILIAD – A SOCIAL NETWORK ANALYTIC APPROACH

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Abstract *In this paper we provide some insights in Homer's Iliad from the perspective of social network analysis. We use the original text and other public available data to create a social network (i.e. a graph) that comprises of all actors in the Iliad together with their interactions. We present some visualizations of these data and discuss concepts like connectivity, connected components and groupings. Furthermore, we calculate some well-established metrics, coming from social network analysis in this social network and discuss the numerical results. These results indicate that the Iliadic network is a small-world network, rather dissasortative and relatively easy to disconnect.*

Keywords: Homer, Iliad, social network analysis, small world, network science, centrality, epic literature

1. INTRODUCTION AND MOTIVATION

Homer's Iliad, one of the two Homeric epic works, has been extensively studied and analysed since the ancient times. Very few remarks can indeed be added in what has already been investigated from many renowned researchers and scholars, not only regarding its value as a work of art, but also in the role it played (and still plays) in education, theory of literature, drama etc.

Network theory or Social Network Analysis theory is a mature theory which can help exploring the nature of interconnected unities.[1] This theory first emerged by Moreno,[2] a field anthropologist, and then studied successively within Graph Theory, a branch of pure mathematics started from Euler and playing

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a central role in Computer Science ever since Harary's modern introduction in 1969.[3] Social Network Analysis has been one of the fields with exploding research in the past twenty to thirty years, yielding extensive literature, both in textbooks and journals. Relevant ideas and results have been used in many applications and cases, ranging from structural anthropology to marketing and banking and from viral infection to sociology.

Social Network Analysis (SNA) has not been extensively applied in literature. One of the reasons is certainly the existing barrier between scholars from completely different fields. A second reason is the fact that in order for readable and credible results, we need to deal with large works, where many "actors" interact with each other. Smaller works may show clearer examples but studying them through SNA's topological perspective could lead to trivial, not so useful results.

Homer's Iliad is a literature work with a significantly large number of such "actors" and thus is a good candidate for such an investigation. In this paper, we regard our contribution *not* in the context of philology, were we lack the appropriate knowledge, but as an invitation for discussion in the structural and topological sociological propositions emerging from our results. Little has been done in viewing Iliad from the perspective of SNA, with a bright exception of a very interesting paper, recently presented by MacCarron and Kenna,[4] who try to discriminate real from imaginary social networks and place mythological narratives on the spectrum between them. For this purpose, they study Homer's Iliad, Beowulf and Tάin Bö Cuailnge and present and compare numerous network analytic results to support their thesis.

In the following sections we organise our presentation as follows: In Section 2 we will present the formation process of the *Iliadic* network we have assembled. In Section 3, we present some terminology and basic indexes used in topological network analysis. The *Iliadic* network is used in Section 4, were we present some structural analysis and present a grouping analysis and in Section 5 were we calculate our metrics and discuss our numerical results. A final discussion and future perspectives are outlined in the last section.

2. FORMATION OF THE ILIADIC NETWORK

When we try to assemble a network, two critical questions arise:[5]

a. Who are the *'actors'* in the network? The answer to this question will yield the set of nodes of the network.
b. How do we define the '*relation*' between those actors? Obviously, the answer to this question will yield the set of links.

These two questions (and especially the second one) are not so easy to answer. In a network that represents human entities, an actor will most probably represent a human. However, sometimes an *actor* can also represent a group of humans, especially when this group acts and reacts as a whole, at some instances. After the formation of the set of nodes, we have to decide on the definition of the relation between them. This relation can take quite different meanings, especially when we try to investigate real-life situations. For example we may choose to relate actors if they like each other, if they hate or dislike each other, if they fight to each other or if they cooperate. In each one of these cases, different networks will be produced, since the links will differ, despite the fact that the set of nodes will be the same.

To our knowledge, one similar approach in forming the Iliadic network (and some other literature networks) has been defined by Knuth.[6] Knuth used such data sets to provide algorithms that solve connectivity issues and especially to provide the bi-components in graphs. As already mentioned, MacCarron and Kenna use '*The Iliad*', translated by Rieu,[7] to construct a similar network and furthermore induce *friendly* and *enemy* ties for their research. https://people.sc.fsu.edu/~jburkardt/datasets/sgb/sgb.html

In our approach we will use Knuth's data set, since it produces an error-free simple graph. In this graph the nodes are humans or Gods, engaged in some way or form in the text. Furthermore, some nodes represent monsters like Chimera and winds like Boreas, since they also play some role in the drama. Finally some nodes represent groups of people who react as one actor at some particular moment in time, like Group of Greek Soldiers, Group of Trojan soldiers, Group of Olympian Gods or Solymi (a Lycian tribe). Some of these nodes induce serious interpretation and computational problems in the overall structure. For example the first three groups do not remain stable during time, since they expand and contract after new members' entering or old members leaving the groups. Furthermore, it is quite possible that some members of these groups are also individual characters – nodes. This could insert a kind of self loops in the network, a property that we chose to dismiss. In order to avoid such situations we have decided to remove some of these groups. Hence, nodes that correspond to Greek Soldiers, Trojan Soldiers and Olympian Gods are removed, but other nodes like Solymi or Amazons are not, since they do not suffer from the above instability.

All nodes are represented by exactly two letters, since a full name or description would create problems in drawings. Knuth counts exactly 561 such nodes in Homer's Iliad, so after the removal of 'collective' nodes we are left with 558 nodes. It is interesting to point out that MacCarron and Kenna calculate 716 nodes. This is a rather large difference which can not be very easily explained. One explanation might be that the relative recourse (a translation) may count the same persons more than once. It is common in this epic work to address the same person with different names: for example Goddess Athina is also referred as Pallada, Zeus has at least two other names, etc.

In our approach, we added one more level of detail, with respect to nodes, by introducing a partitioning of them in four different groups, namely:

- GREEKS: Greeks or Greek-friendly actors, participating in the war.
- TROJANS: Trojans or Trojan-friendly actors, participating in the war.
- GODS: Gods, semi-Gods, nymphs, rivers, giants, monsters etc.
- OTHERS: Others, not belonging in the first three groups, including actors who were deceased before the Trojan War (ancestors of other actors).

This partitioning will serve in exploring relations within or between the groups. Again we have to point out that such a grouping can only represent a particular, static moment in time. Thus, actors that change their attitude at some time are grouped in their initial state. Dynamic networks (or longitudinal) networks that change over time need different approaches.

In the Iliadic network we investigate, a line is drawn between two nodes when the corresponding actors *interact* in some way. It must be emphasized that this is the simplest, most general form of interconnection and therefore most dangerous, in the sense that it does not incorporate a homogenous interpretation. For example, a link is defined when an actor discusses with another actor or if he kills him. This approach will provide us with a network representing interactions in the most general way. A more suitable definition of relations is a prospect of future work. All in all, there exist exactly 1566 such links, connecting the 558 nodes. In Figure 1 we present the initial Iliadic network, created following the above discussion.

3. NETWORK THEORETICAL TERMS

In pure mathematics, a graph G consists of the pair (V, A), where $V = \{v_1, v_2, \ldots, v_N\}$ is the finite set of vertices (or nodes, or actors) of cardinality $|N|$ and $A = \{l_1, l_2, \ldots, l_L\}$ is the finite set of links (or edges) of cardinality $|L|$, where $l_k = (v_i, v_j)$, $v_i, v_j \in V$ and $l_k \in A$. When the pair (v_i, v_j) is ordered, then the graph is called directed and we talk about arcs instead of links, otherwise the graph is undirected. Every directed graph can be simplified as an undirected one, however in this procedure there is a loss of probably important information. Links of the type (v_i, v_i), when allowed, are called loops. Finally, there are cases where more than one links connect the same pair of nodes, in other words there can be multiple lines in a graph. When a graph has by default no multiple lines and no loops, it is called a *simple* graph.

When one or more weights are assigned to each link, this graph is called a network. However, in recent literature, the two terms (graph and network) are not distinguishable in this manner. A graph is also a network and a network with weights on its links is met as a valued network.[8]

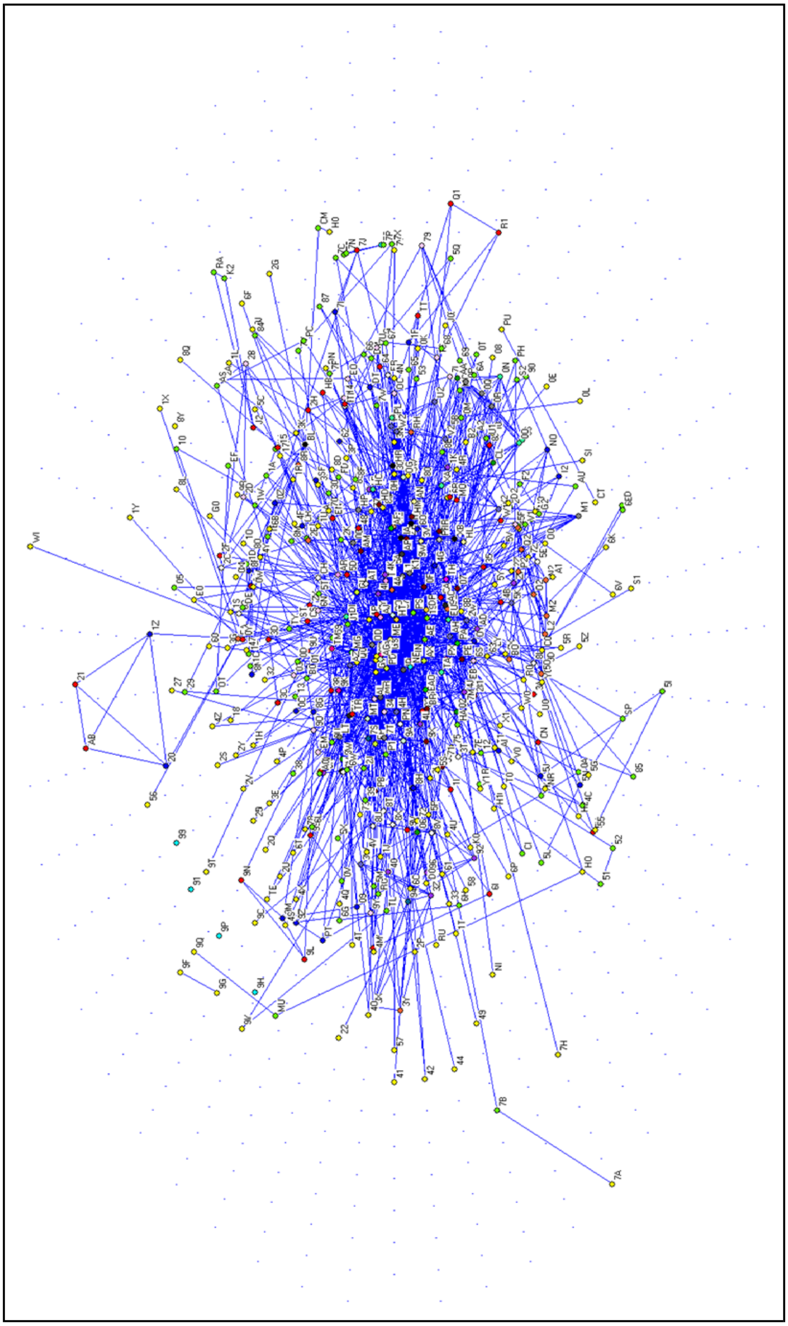

Figure 1. The Initial Iliadic Network.

A *path* is a sequence of nodes, where each node is written only once and there exists a link connecting two subsequent nodes. The length of a path is the number of “hops” needed to complete the path. The shortest path, or geodesic between two nodes is minimal, regarding its length, among all paths connecting these two nodes.

A large number of different data structures which can be used to store a network in a computer’s memory.[9] One of the most straightforward ones is the adjacency matrix A, which is a $\mathrm{N} \times \mathrm{N}$ matrix where:

$$\mathrm{A}_{i,j} = \begin{cases} 1, & if\ \mathrm{v_i} \text{ is connected to } \mathrm{v_j} \\ 0, & \text{otherwise} \end{cases}$$

Traditionally we investigate nodes in a network regarding their overall position, with respect to all other nodes. We thus try to find which (if any) nodes are more *important* than others. A common technique is to measure the centrality index of nodes and compare all nodes according to this index. We will use three different measurements of centrality, namely degree, closeness and betweenness centrality (see Sec.4.2 for precise definitions).

However, in recent literature, there is a shift in the perspective from which we examine a network, leaving individual nodes and regarding more general, topological issues that hold over the whole network. Mark Newman has assembled a set of metrics regarding the topology of a simple, undirected network.[10] We will also use this approach since it has been reported as the most important and concise. More specifically we will deal with link density, degree, distance, diameter, eccentricity, clustering coefficient, assortativity coefficient and algebraic connectivity.

Link Density, S, is the ratio of the actual number of links, L, divided by the maximum possible number of links that could exist in a network. Obviously, in a network with N nodes, the maximum possible number of links will be exactly

$$\frac{\mathrm{N(N-1)}}{2}$$

which is the case of a complete graph where each node is connected to all other N-1 nodes of the network. Thus, link density is calculated as:

$$S = \frac{2L}{N(N-1)}$$

and can take values in $[0 \ldots 1]$.

The Degree, $\mathrm{d_i}$, of node v_i is the number of links emanating from v_i. In directed networks we have to deal with in-degree and out-degree (link going to a node and links leaving a node respectively), however we will deal only with undirected networks. Since every link contributes to two nodes, the average degree of the network can be easily calculated as:

$$E(d_i) = \frac{2L}{N}$$

The Distance between two nodes v_i and v_j is the length of the shortest path that connects v_i to v_j. The average distance of a network is the average of all distances in this network.

The Diameter, D, of a network is the longest distance over all pairs of nodes.

The Eccentricity of a node is the largest distance from this node to any other node in the network. All node eccentricities can be averaged yielding the average eccentricity of the network.

The Clustering Coefficient, CC_i, of node v_i, is the ratio of the actual number of links of v_i's neighbours, divided by the maximum possible number of links in this neighbourhood. If a node has large clustering coefficient, then its neighbours tend to form highly interconnected clusters. If *vi* has exactly K neighbours which interconnect with M links between them, then CC_i is calculated as:

$$CC_i = \frac{2M}{K(K-1)}$$

The average on all *CC's* for all the nodes of a network is the average clustering coefficient of the network.

The Assortativity Coefficient, R, of a network, takes values from $[-1, 1]$ and denotes the degree-similarities between neighbouring nodes. When R is less than zero, a node is connected with other nodes of arbitrary degrees. However, when R is greater than zero and closing to one, nodes tend to connect with other nodes with similar degrees (assortative networks). Calculation of R is as follows:

$$R = \frac{L^{-1}\sum_i j_i k_i - \left(L^{-1}\sum_i \frac{1}{2}(j_i + k_i)\right)^2}{L^{-1}\sum_i \frac{1}{2}\left(j_i^2 + k_i^2\right) - \left(L^{-1}\sum_i \frac{1}{2}(j_i + k_i)\right)^2}$$

where j_i and k_i are the degrees of the nodes at the ends of the i-th link, and $i = 1 \ldots L$.

The Algebraic Connectivity of a graph, studied by Chung,[11] is the second smallest eigenvalue of its Laplacian Matrix. The Laplacian Matrix of a graph G with N nodes is the NXN matrix $Q = \Delta - A$, where A is the adjacency matrix of G and $\Delta = diag(d_i)$. The larger the algebraic connectivity, the more difficult it is to find a way to cut a graph to many different components.

4. SOME STRUCTURAL ANALYSIS

In Figure 1, every actor is drawn as a point, together with a 2-letter code. Thus, for example, Hector is found exactly in the middle with code HT. A bit to the left and upwards we see Odysseus (OD). Highly interconnected nodes are located in the middle, while other nodes having few connections are drawn in the periphery.

4.1 Connectivity issues

From Figure 1, some important features of the network emerge in a straightforward manner. It is obvious that the graph is *disconnected*, that is, there exist nodes that are not reachable from the others. Two of them are *91* and *99*, (found on the left corner of the drawing). Node 91 corresponds to Prothous, commander of Magnesian forces who is found in the rhapsody No. 2, while node 99 is Philoctetes, famous archer bitten by a snake, who was replaced by Medon. Actually not only these two nodes are isolates. In this network we can calculate exactly 5 isolated nodes (9H, 9P and 7Q corresponding to Nireus, Symian leader – Agapenor, king of Arcadians and Orestes, son of Agamemnon respectively). As Knuth points out:. ‘Great novelists are evidently under no obligation to connect everything up’.[12] We have to note, of course, that these are simple observations on the network. These nodes represent actors with quite different backgrounds within the myth. Isolation is a straightforward result of the data set creation and does not represent any other property of actors. For example, Prothous was a commander of the Magnets who contributed to the war with forty ships. However his name is just mentioned in the second rhapsody, with no other actual appearance henceforth. Instead, Philoctetes posseses a much more central role in the general myth, as told in the Little Iliad and in Sophocles’ last two tragedies: after becoming an exile because of a wound (and Odysseus’ political pressure), he returned to Troy since his weapons were irreplaceable (after Odysseus’ opposite pressure) and he even embarked in the Trojan Horse. Philoctetes thus becomes a famous ‘come-back’ actor and Odysseus fulfils his fame as a Machiavelli-like politician. Obviously our formation of the network does not present the importance of this actor, since he is just mentioned in the second Rhapsody. Finally, to conclude with these observations, there exist 208 nodes with exactly one link to connect them to the rest of the network (highly peripheral nodes) but we choose not to list them for reasons of space.

A second important feature is that, apart from isolates, there exist “chunks” of nodes connected to each other but not to the rest of the network (disconnected components). One such component can be found on the top left of Figure 1, comprising of nodes 9G (Pheidippus) and 9F (Antiphus) two brothers that lead the Dodecanese troops, who appear to interact only in Rhapsody 2. There exists a number of such small components in the network, which create “sociological noise”, since their contribution to the overall network is either very small or neglect.

Table 1. Components in the Iliadic Network.

Component	nodes	links	Actors
1	538	1557	####
2	3	2	7O (Laodice), 7N (Iphianassa), 7P (Chrysothemis)
3	2	1	9F (Antiphus), 9G (Pheidippus)
4	2	1	8Y (Daedalus), 8Z (Ariadne)
5	3	3	HO (Homer), MU (Muses), 9Q (Thamyris)
6	2	1	CT (Castor), PU (Polydeuces)
7	2	1	54 (Oedipus), 55 (Mecisteus)
Totals	**551**	**1566**	

If we remove isolates, we can compute the total number of disconnected components in the network: they are exactly seven (7) and can be seen in Table 1.

Obviously it is impossible to write down all the actors in the case of the largest connected component within Table 1. A better way is to draw this as a separate network, as in Figure 2.

4.2 Centrality issues

Important nodes in the network can emerge in terms of *centrality* measurements. In network analysis it is typical to use and compare three different measurements of centrality, namely *degree*, *closeness* and *betweenness* centrality, which will be briefly explained in terms of their natural meaning.

a. In *Degree* centrality we measure the degree of each node. It can be argued that if a node is involved in many interactions, then this is an important node, playing an important role. However, this type of centrality focuses on the local view of immediate neighbours and sometimes leads to misleading perceptions.
b. The *Closeness* centrality of vertex *v* is a summary measure of the distances from *v* to all other vertices; the number of other vertices divided by the sum of all distances between v and all others. Intuitively, shorter distances to other vertices should be reflected in a vertex's larger closeness score. In this sense, one can think of closeness as reflecting compactness. For reasons of easy interpretation we inverse this score, so actors with a higher score are more important than others.
c. The *Betweenness* centrality of a vertex v is the proportion of all geodesics between the pairs of vertices which include v. The more a vertex is needed for, say, passing of information between all the pairs, the higher is its score. In this sense, one can think of betweenness as reflecting facilitation of circulation. Nodes with high values regarding this measurement act as brokers in communication.

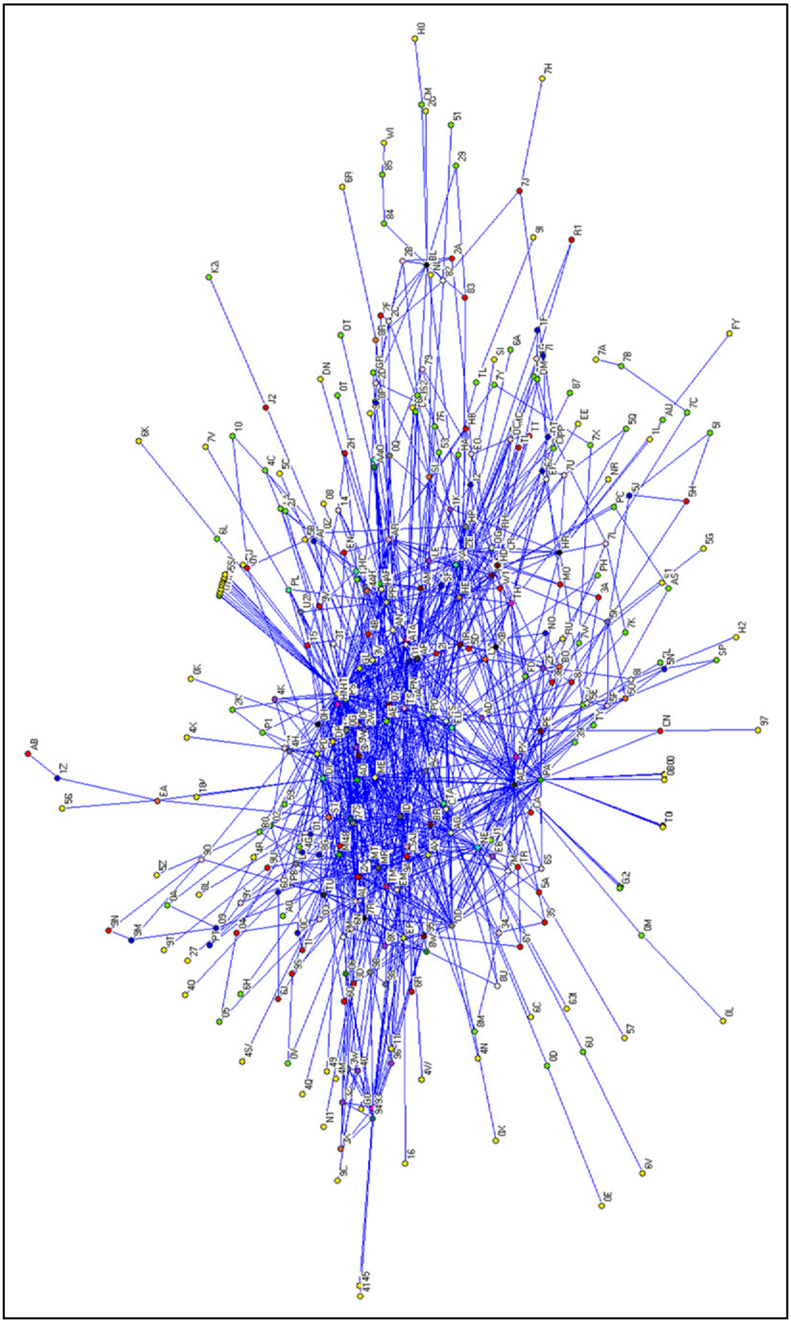

Figure 2. The largest component.

Table 2. The ten most prominent actors regarding centrality.

Rank	Node	Degree	Node	Closeness	Node	Betweenness
1	HT (Hector)	97	HT (Hector)	0.4972	HT (Hector)	0.2100
2	AC (Achilleus)	75	AC (Achilleus)	0.4661	AC (Achilleus)	0.1594
3	AJ (Ajax)	63	AJ (Ajax)	0.4629	ZE (Zeus)	0.1375
4	PA (Patroclus)	61	ME (Menelaus)	0.4486	PA (Patroclus)	0.1280
5	ME (Menelaus)	54	AG (Agamemenon)	0.4479	DI (Diomedes)	0.1036
6	AG (Agamemenon)	54	ID (Idomeneus)	0.4387	AJ (Ajax)	0.0904
7	ZE (Zeus)	52	PA (Patroclus)	0.4373	AG (Agamemnon)	0.0849
8	OD (Odysseus)	50	AE (Aeneas)	0.4341	OD (Odysseus)	0.0798
9	DI (Diomedes)	49	DI (Diomedes)	0.4331	NE (Nestor)	0.0685
10	AL (Antilochus)	45	ZE (Zeus)	0.4331	TU (Teucer)	0.0654

In Table 2, we present the ten most prominent nodes with respect to their scores in all three centrality measurements.

All three measurements present similar (but not exactly the same) rankings, at least to a person familiar to Iliad. Two main threads of elaboration come from Table 2:

- The fact that important actors, as perceived by any philological reading, are actually present in Table 2 and ranked according to their importance, that is, actual measurements in our model generally agree with common knowledge.
- The fact that some actors achieve unexpectedly high rankings. Actors like Idomeneus or Aeneas (in the case of closeness centrality) or Zeus, Diomedes, Nestor and Teucre (in the case of betweenness centrality) or even Antilochus (in degree centrality), are ranked in quite high positions. Interpreting these results is not so easy, apart from the first, simplest, degree centrality. The first and rather obvious conclusion, at least to a naive reader of the Iliad, is that one has to pay much more attention to these actors, since they seem to affect the overall drama in a much more consisted way. A more specialized scholar could present us with a different view or a different level of interpretation regarding the sociology of actors.

> A play writer could get inspired by some of these actors and continue the story in different directions (Sophocles did something of a kind, regarding *Philoctetes*).[13]

Such a line of thinking can continue in many different directions, but lies outside of the scope of this paper. In such a discussion, it must be persistently kept in mind that this network was formed in a very simplistic manner, with respect to its links. We have to remind that a link is created when there exists *any* kind of interaction between the two actors.

4.3 Grouping actors

As already mentioned, all nodes are distributed in four different groups. In Figure 3 we draw all actors in a circular manner, with respect to their group.

The top left group comprises of actors from the Gods, Giants, Numphs category (GODS). There exist exactly 68 such actors. 'Other actors', like already deceased ancestors, bards like Thamyris or Homer himself, or actors that do not take actual part in the Trojan war, form the bottom right group (OTHERS). All in all these are 104 actors. Those two groups are similar with respect to the number of actors, but differ in the number of in-group interactions. While actors from GODS interact thoroughly to each other, actors in OTHERS have little or no interaction (a rather obvious result, since they do not coexist in the same area or time period).

The GREEKS group with 124 actors (Greeks or Greek-friendly soldiers), lies in the top right area, while TROJANS group (Trojans and friends), with 262 actors, lies in the bottom left area. Trojans are many more than Greeks, a rather expected result since they inhibit the area. It is also obvious that the largest bulk of links lie between those two groups. It can be easily deduced that these links represent 'fighting' or 'killing'.

GREEKS' density is 0.043, while TROJANS' density is 0.01, a rather large difference. If we accept density as a measurement of group's cohesion, it is obvious that the Greeks were far more cohesive (i.e. they formed a strongly interconnected group) than the Trojans. This should be (in the Poet's mind) one reason for the final Greek victory.

Yet another very interesting feature is the actual involvement of GODS. We calculated 70 links (interactions) between GREEKS and GODS in contrast to 63 interactions between TROJANS and GODS. It seems that the divine element has either played very little role in the outcome of the war, or this role was carefully balanced between the two camps. This may be perceived as yet another proof that TROJANS were perceived (at least to the poets mind) as having a Greek national consciousness, since they believed (and were supported) by the same Greek Pantheon. Hence, Homer may have actually written about an archetypical civil war.

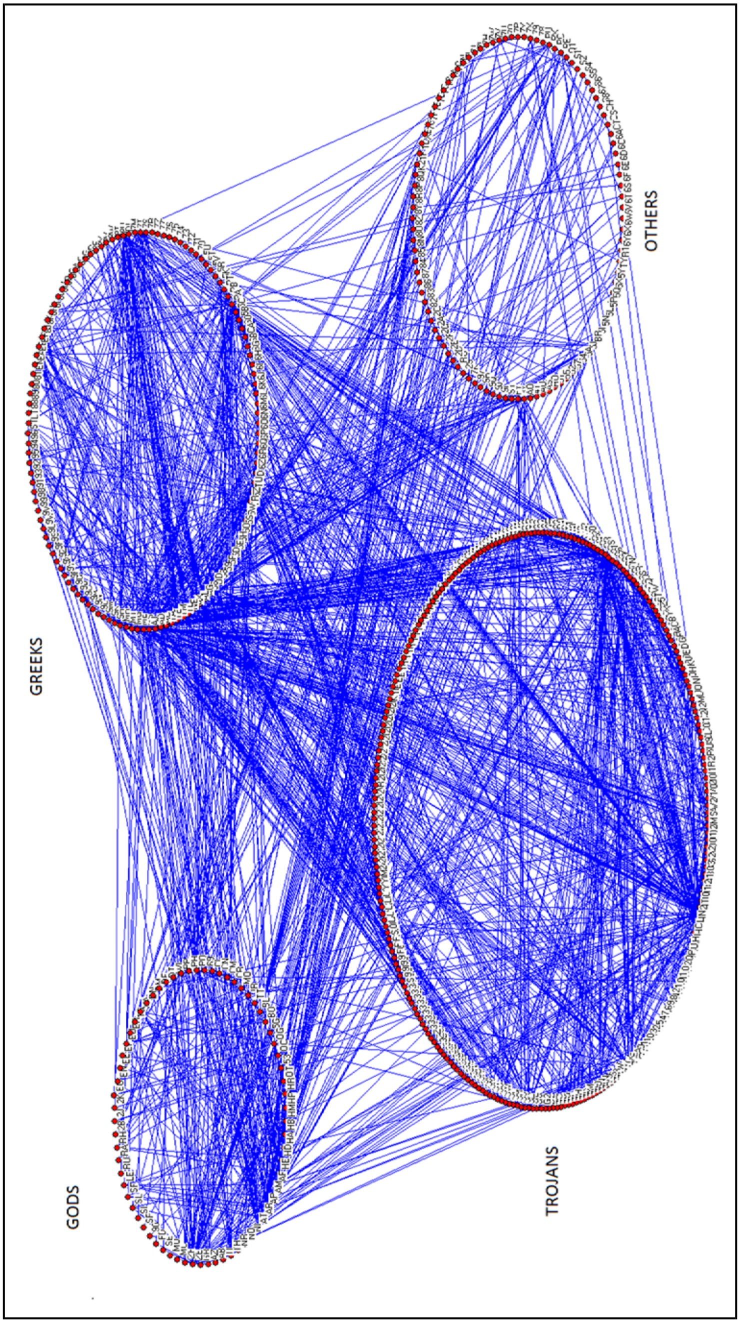

Figure 3. Drawing using actor's partitioning.

Table 3. Some network metrics in Iliad.

Metric	Value
Link Density	0.01
Average Degree	5.78
Average Distance (average shortest path)	3.33
Diameter of graph (the longest distance)	9
Average Eccentricity	6.56
Clustering Coefficient	0.41
Assortativity Coefficient	−0.0005
Algebraic Connectivity	0.162

As with centrality, further discussion of those groups can continue in many directions. Actually, one can apply all structural and topological measurements in these groups regarding them as separate networks in a similar manner we discuss these properties for the whole Iliadic network. These directions can be followed in future research.

5. CALCULATIONS AND NUMERICAL RESULTS

In this section we present our numerical results. It must be noted that relevant software like *Pajek* and other similar packages are mostly dealing with the traditional, structural indices on networks from Social Network Analysis.[14] In order to obtain the most recent topological metrics, i.e. assortativity coefficient and algebraic connectivity, we used *NetworkX*,[15] a Python-based package for the creation and manipulation of networks and *igraph* for R,[16] a similar package, and we developed some code, written in Python and R, to calculate these metrics.

From Table 1 we have already seen that the largest connected component of the Iliadic network is comprised of $N = 538$ nodes and $L = 1557$ links. In Table 3 we present the actual numbers for all the metrics defined in Section 2, calculated on the largest connected component.

The average Link Density, L, equals 0.01. The meaning of this metric is that in these networks there exist 1% actual links over the maximum possible number of links. The network is definitely not dense; however it is not extremely sparse. The Average Degree, $E(d_i)$, is 5.78, meaning that in average, every actor in Iliad interacts with (close to) 6 other actors. Of course, as already shown in Section 4, the actual degrees vary from 1 to 97 (Hector). Actually, there are exactly 198 pendant nodes (degree = 1) and 105 more nodes with degree = 2.

A more interesting result is the average Distance, the average shortest path over all actors. An average value of 3.33, means that we can generally find a path of this length between any two pairs of actors. Reversely, a Diameter of value 9 means that the longest geodesic (the longest shortest path) is rather large. The path that achieves this value starts from node 21 (Bucolion) and reaches node 7A (Molus) (or vice versa). The complete path is: 21 (Bucolion), 20 (Pedasus), EA (Euryalus), ST (Sthenelus), AG (Agamemnon), PX (Phoenix), 7L (Amyntor), 7C (Autolycus), 7B (Amphidamas), 7A (Molus).

This value, together with an average *Eccentricity* of *6.56* leads us to the conclusion that even these, rather sparse, networks can be traversed in very few steps. It is not a surprise to see that these steps are very close to the value of 6, which in turn is exactly the number proposed known widely as the *six degrees of separation* principal, which holds for a vast number of different real-life networks.[17] Our results indicate with no doubt that the iliadic network follows this principal with relative stability.

The relatively small average shortest path, together with the very high values of Clustering Coefficient (0.41) yields the very interesting property of a small – world. Indeed, as noted in Watts (1999), the relationship found between these two metrics also proves that such a network is generally a small-world. One other property of this type of networks is the existence of a small number of hubs (nodes with very high degree), while all other nodes have relatively small degrees. All actors (and some more not listed) from Table 3 are actually hubs.

The close-to-zero value for the Assortativity Coefficient, ($R = -0.0005$), reveals that within the Iliadic network actors do not tend to interact with other actors possessing a similar or reversely, none similar degree. If R was equal to 1, then all actors would connect to others with exactly the same degree. On the other hand, if R was -1, then all actors would connect to others with different degrees in an extreme manner (i.e. hubs with pendants). In our case, however we cannot draw a stable conclusion from such a value. This result is in contradiction to the generally accepted principle of *homophily* in real-life networks, i.e. the general belief that nodes tend to connect to similar nodes, regarding one property. Of course, the particular relation examined on one network does influence this metric: friendship ties do indeed behave differently than other ties. However, recent results, indicate that homophily is generally met in human interaction networks, where human psychological factors play a very important role or networks freely formed in nature, whereas the opposite holds for networks formed in economy and business.[18] For example, large banks tend to lent money in small banks – not in other large banks. The Iliadic network does not belong to any one of the two categories, probably because the process of its formation over time does not obey any psychological or sociological rules (but only to the Muses – through the author). It is interesting to see that Homer does not try to "balance" interconnections. Instead, he follows his intuition and builds relations on a more natural way, with respect to the story he tells: indeed, Iliad is an archetypical war story, so it seems reasonable to expect that while a fierce war is in place, killings and interactions come in a chaotic manner. In this sense, this metric can be expected to be larger than 0 and probably closer to 1 in literature works where the overall story is not so brutal.

Our final result, Algebraic Connectivity (0.162), is a measurement of the general robustness of the networks. Small values would indicate that the networks are easily cut in disconnected components. A value of zero (0) means that the network is already disconnected. It is reported in the literature that this metric is bounded below by 1/(N*D) and in fact by 4/(N*D).[19] Thus, in the iliadic network, a lower bound for the algebraic connectivity is 4/(542*9) = 8.2E-4. Algebraic Connectivity is upper-bounded by the traditional connectivity of a network, that is, by the size of its smallest cut-set.

6. CONCLUSIONS – FURTHER RESEARCH

In this paper we investigated one of the most famous works of literature, Homer's Iliad, through the perspective of Social Network Analysis. We used an already prepared data set of interactions between actors in the text and formed a network with the assistance of some Python code and software like Pajek. In turn, we investigated some structural features of this network, explored a grouping of all actors and calculated some important topological metrics on the largest connected component of this. Our main motivation and goal was not to yield results in a philological manner, but to provide with some insights or different views on the famous text of Homer.

Standard, philological approach and interpretation of the Iliad, is mainly based on the role, ethos and personal actions of the heroes. However, as in any classic great literary piece of art, Iliad can be read in different ways and interpreted in different levels. Our network-analytic approach introduces actual measurements of the importance of actors and their topological positions regarding the Homeric "universe". To our surprise, some of the actors in a drama seem to play more important roles then a casual reader of Iliad expects. For example, from Table 2 we can see that Idomeneus, Aineias, Antilochus or Teucre, although generally perceived as second-class actors in the drama, are positioned in quite central places, thus being able to play important mediating roles. However, in-depth interpretation of such results is not (and could not be) our target in this paper which mostly serves as an introduction to this type of research.

Another interesting result comes from our grouping of actors as in Section 4.3. The already known neutrality of Olympian Gods has been exactly measured. We also highlighted the difference regarding within-group interactivity between the Greeks and the Trojans and suggest that a much more cohesive group in the end will win the war, or at least this is what Homer had in mind. Different definitions of links in a more precise manner could lead in somehow different result, but this again is a prospect of future work.

Our mathematical approach also introduces a set of well-established metrics through which one can compare Iliad to other literary works. It would be interesting to explore, for example, if Tolstoy in *Anna Karenina*, also produced disconnected networks, or if all interactions in the Holy Gospels produce similar metrics. It is therefore a good candidate for a framework that could categorize literature works or even be explored as a branch of general literary theory. It should be noted that such an analysis requires a rather large work of literature, or similarly, a work with many actors and interactions. Results coming from small networks cannot be regarded as adequate, in the topological context. On the other hand, smaller works and especially theatrical plays, could serve as first-class candidates in teaching or applying SNA metrics and ideas but also easily exploring relationships between actors in the classical sense of graph-theoretic structures (like cliques, cores, clans etc.).

END NOTES

1 S. Wasserman and K. Faust, *Social Network Analysis: Methods and Applications*, (Cambridge University Press, 1994), 1–35.

2 As noted by J. Scott, *Social Network Analysis. A Handbook*, (Sage Publications, 2000), 7–16.

3 Almost all modern graph theory has been introduced in this famous textbook by F. Harary, *Graph Theory*, (Addison-Wesley, Reading, MA, 1969).

4 P. Mac Carron and R. Kenna R., 'Universal Properties of Mythological Networks', *EPL*, 99, 2 (2012), 28002.

5 Wasserman and Faust, *Social Network Analysis: Methods and Applications*, 17–21.

6 Donald Knuth has assembled a set of networks, some of them representing great literature works, incorporated them in *The Stanford Graphbase* as data sets and applied some well known graph theoretic algorithms on them. Apart from *Homer's Iliad*, the Stanford Graphbase contains data representing *Anna Karenina*, *David Copperfield*, *Huckleberry Finn*, and *Les Miserables* as simple graphs. In D. Knuth, *The Stanford GraphBase, A Platform for Combinatorial Optimization*, (ACM Press, Addison–Wesley, 1993), 12–14, 45–46.

7 The authors in P. Mac Carron and R. Kenna R., 'Universal Properties of Mythological Networks', 28002, note that they used a translation of the ancient text from E. V. Rieu, *The Iliad*, (Penguin Classics, London, 2003).

8 R. Hanneman and M. Riddle, *Introduction to social network methods*, (University of Ca lifornia, Riverside, 2005), 58

9 Wasserman and Faust, *Social Network Analysis: Methods and Applications*, 92–166.

10 M. E. J. Newman, 'The structure and function of complex networks', *SIAM Review, 45* (2002), 167–256.

11 F. R. K. Chung, *Spectral graph theory*, Conference Board of the Mathematical Sciences, 92 (1997), 113–120.

12 Knuth, *The Stanford GraphBase, A Platform for Combinatorial Optimization*, 14.

13 It is very well understood that ancient dramatists drew many of their ideas from myths or other literature works. Actually these works 'continue' the original myths. In the case of Iliad, some of these myths are collectively known as 'Ilias parva'. A clear example comes from Sophocles, *Philoctetes in Troy*, (409BC)

14 Pajek is a quite powerful software package for network analysis and can be freely accessed from http://pajek.imfm.si/doku.php. A very intuitive accompanying textbook on this software was written by W. De Nooy, A. Mrvar and V. Batagelj, *Exploratory social analysis using Pajek*, 2nd ed., (Cambridge University Press, 2011).

15 A. Hagberg, D. Schult and P. Swart, 'Exploring network structure, dynamics, and function using NetworkX', *Proceedings of the 7th Python in Science Conference (SciPy2008)*, Pasadena, CA USA (2008), 11–15.

16 G. Csardi, T. Nepusz T., 'The igraph software package for complex network research', *International Journal of Complex Systems*, 1695 (2006), http://igraph.sf.net.

17 For a full and comprehensive analysis of these principle one can see D. J. Watts, *Small-Worlds: The Dynamics of Networks between Order and Randomness*, (Princeton University Press, 1999) and also D.J. Watts, *Six Degrees: The Science of a Connected Age*, (W.W. Norton & Company, 2003), 30–45 and also D. J. Watts and S. H. Strogatz, 'Collective dynamics of small-world networks', Nature, 393 (1998), 440–442.

18 M. E. J. Newman, 'Assortative mixing in networks', *Phys. Rev. Lett.*, 89: 208701 (2002),

19 F. R. K. Chung, *Spectral graph theory*, 118.