

COSMOS: An Innovative, Graph-based Application for the Relational Presentation and Visualization of Greek Mythology and the Associated Art

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Abstract: The project “COSMOS. Cultural Osmosis - Mythology & Art” covers the development of an application for the presentation of Greek Mythology and its related Art, in an innovative and interactive way, using AI technology. The COSMOS application takes one step beyond the usual practice of the linear narration of myths and the depiction of related artwork images, as found in existing applications. COSMOS is developed in two interconnected levels, Myths, and Art, each organized in three data visualization, dynamic windows. In level Myths, these windows present a) the Stories in a Character-oriented organization (e.g., Zeus Thematic), b) the participating Characters, and c) the Places where the Stories unfold. In level Art, respectively, they present a) the depictions of the myths in ancient Artworks, b) the depicted Characters, and c) the Artworks place of origin if known, as well as their present location. The user can discover relations that are not obvious, such as (i) the connections and influences between different Stories, (ii) the various stories that take place in a specific location or (iii) the various stories that a specific Character participates, (iv) the Artworks exhibited in the same location, etc. To reveal the aforementioned relations, the User Interface design adopts a node-based approach, where the nodes' connections, based on shared elements, are displayed. Regarding the implementation, two systems were developed: The Knowledge Organization System and the Knowledge Presentation System. Employing cutting-edge technologies in the fields of Machine Learning, Natural Language Processing, and 3D Graphics, COSMOS visualizes Myths, Artworks, and the connections between them, engagingly and coherently. The COSMOS application was tested and evaluated in two events. The evaluation results from both events reflect the overall positive response of the audience, and validate the fulfillment of the objectives set at the beginning of the project. The final product intends to address a vast audience and it can be used a) as a study aid for anyone interested, b) for educational purposes, by teachers and students, c) as a reference tool for the production of research projects, and d) as a scientific documentation tool and artworks database, for exhibition curating purposes.

Keywords: Greek Mythology, Cultural Heritage, Knowledge Organization, Information Extraction, Information Retrieval, Conceptual Graphs

1. Introduction

What is COSMOS? COSMOS [1] is an application that offers a new non-linear approach to encoding Greek Mythology in its written and visual forms, through the myths and their related artifacts. At the same time, it presents the different relations between myths as well as artifacts. The application is available in two languages, Greek and English.

The project “COSMOS. Cultural Osmosis - Mythology & Art” run from July 2018 to December 2021. The project partners are Ekdotike Athinon S. A. [2] (Project Coordinator), responsible for the content of the application, and the Integrated Systems Laboratory (ISL) of the Institute of Informatics & Telecommunications (IIT) at the National Center for Scientific Research (NCSR) “Demokritos” [3] (Scientific Coordinator), responsible for the development of the application.

Ekdotike Athenon, based in Athens, Greece, and founded in 1962, is a well-established publishing house that has collaborated with leading scientists from Greek and foreign universities to provide the reading public with publications on history and culture. For the needs of the COSMOS project, Ekdotike Athenon has created a revised content (texts and images), based on one of its well-known publications “The Greek Mythology” by I. T. Kakridis [4], perhaps, the unique, scientifically sound, and complete work regarding Greek Mythology, as well as other of its publications regarding ancient Greek art [5-8].

NCSR “Demokritos” is the largest multidisciplinary research center in Greece, with 50 years of contribution to science. The Integrated Systems Laboratory (ISL) aims at the convergence of Informatics and Telecommunications, carrying out research and development for various projects around cutting-edge technologies. The laboratory has successfully led the scientific project management of European and Greek national projects. ISL has special interest and significant experience in the development of innovative applications in the field of Cultural Heritage and applications with dynamic data visualization components, as well as on the organization of educational workshops on Digital Arts and Informatics.

2. The Questions That Led to the Creation of COSMOS

2.1. Highlighting the Relations Between Mythology and Art

Greek Mythology has been a source of inspiration in art throughout time. How should the relations between myths and artifacts be visualized to highlight both? The answer should consider that the artworks belong to different art forms and periods, and their presentation should not be limited to that of accompanying images.

2.2. Showcasing the Information

Myths

1. We are familiar with the Stories and their protagonists,

but who are the other Characters participating in these Stories?

2. Which are the Places, that these Stories occur, and where are they located on the map?

Art

1. Which are the related Artworks of these Stories?
2. Who are the depicted Characters?
3. Where do these Artworks originate from, and where are they exhibited today?

2.3. Showcasing the Relations

Myths

1. How can we display the relations between myths due to story-based shared elements?
2. When reading a myth, we might wonder if the Characters or the Places of that Story appear in other myths. How can we reveal the relations between Stories due to shared Characters or Places?

Art

1. How can we display the relations between Artworks due to shared depicted Characters, Places of origin or exhibition and Artists?

2.4. An Attempt to Reveal Temporal Relations Between Myths

In Mythology there is a sense of a time sequence among the different myths. Without being absolute, since there is no chronological order, could we set the Stories on a mythological timeline?

3. The Answers Given by COSMOS

3.1. A Repository of the Depictions of Myths

Greek Mythology has been a source of inspiration for various forms of art, from ancient times until now. Ideally, the goal of COSMOS is to collect and connect these artworks with the Stories they emerged from, thus, creating a repository of Greek Mythology’s depictions in Art. It is a pioneering venture since there is no similar feature in any other application regarding Mythology. This collection of Artworks can span from Archaic to Contemporary Art, including tangible and intangible forms. Currently, the application contains artifacts from Ancient times.

In order to showcase both the narrations and the depictions of Greek Mythology, COSMOS is developed in two levels; level Myths and level Art, respectively. These levels are interconnected, thus, when reading a Story at level Myths, one can directly transfer to level Art with the Story’s related Artworks highlighted, and vice versa; from a selected Artwork, one can directly transfer to level Myths and the Story that this Artwork illustrates.

Artworks are organized on a “chronological timeline” since the period of their creation is known. They are classified into three categories: Sculpture, Pottery, and Various, with the possibility of further enriching this categorization, depending on the available material to be integrated in the future.

3.2. Showcasing the Information - The Three Dynamic Windows

In COSMOS, we recognize three basic elements of information in Myths and, respectively, three basic elements of information in Art.

In Myths:

1. the Stories as text,
2. the Characters that participate in the Stories,
3. the Locations that the Stories evolve.

In Art:

1. the Artworks, in digital format (image),
2. the Characters that are depicted in the Artworks,
3. the Locations, that the Artworks were found, or exhibited.

Separate windows showcase the above-described elements. Myths level contains (see Figure 1):

1. the Stories window,
2. the Characters window,
3. the Locations window,

accordingly, Art level contains (see Figure 2):

1. the Artworks window,
2. the Characters window,
3. the Locations window.

The three windows are dynamic; a selection in one window will display the linked information in the other two. This technique showcases the myth's or artwork's "structural" elements as parts, while, at the same time, the user can compose these parts as a whole.

3.3. Revealing the Relations

COSMOS helps the user discover relationships that are not obvious, such as:

1. influences between different Stories e.g., connections based on elements that play a key role in the evolution of the Story,
2. a set of different Stories that
 - a. have a shared Character,
 - b. occur in a shared Place

To achieve the visualization of the above relations, the structure of COSMOS is as follows:

3.3.1. Node

In COSMOS, myths are divided into small, autonomous Stories. Each autonomous Story is depicted as a node, which contains the Story's narrative as a text. These small, autonomous Story-nodes are part of a broader narration, similar to the vertebrae of a spinal column. For example, the 12 Labours of Heracles could be divided into 12 nodes. These 12 nodes belong to an even more extensive story that begins with the hero's birth and ends with his apotheosis and ascension to Mount Olympus, after his death in the fire.

In the same manner as the Story, any element in COSMOS, i.e. Character, Place, and Artwork, is visualized as a node in the respective window, containing all the related information.

3.3.2. Thematic

As Stories have at least one protagonist, the main Character, the Story-nodes are organized in a character-

oriented structure, called Thematic. Therefore, the Stories are narrated through the Heroes' and Gods' lives. In this sense, there is the Zeus Thematic, Heracles Thematic, Theseus Thematic, and consequently, the Jason Thematic, instead of the Argonauts Campaign, the Odysseus Thematic, instead of the Odyssey, etc. In the latter, the Odyssey is a group of Story nodes (e.g., Odysseus in the land of the Cyclopes, Odysseus in the land of the Lotus Eaters, etc) within the Odysseus Thematic, which begins with the birth and ends with the death of the hero.

3.3.3. Connection Types

In accordance with the above, Story nodes sharing the same main Character belong to the same Thematic and, thus, the first connections emerge, called (a) thematic connections (see Figure 3). The Thematic Connections are always visible to facilitate the discernment of the Thematics from one another.

In some cases, though, there are Stories that have more than one protagonist. These Story-nodes appear (as duplicates) in more than one Thematics, and these duplicate nodes are connected with the (b) equal connections (see Figure 4). For example, the Story "The Birth of Zeus" has two main Characters: Cronus and Zeus. Consequently, the Story exists as a separate node in each of the two corresponding Thematics, and these two nodes are connected with an equal connection. The rule of creating separate but connected nodes in different Thematics -rather than having different Thematics sharing nodes- makes the Thematics well-defined visually and more comprehensible to the user. At the same time, equal connections manage to showcase the crossing of the Thematics in events that are of major importance to their main Characters.

By splitting the narrations into smaller pieces (Story-nodes), it is easier, and therefore more comprehensible, to visualize the relations between Stories due to shared elements. These relations are visualized with two different types of connections. The (c) primary connections (see Figure 5), created due to shared elements that influence the evolution of the Stories (e.g., how an event/element of a Story from Thematic A influences, or reappears, in a Story from Thematic B). The (d) secondary connections (see Figure 6), created due to shared Characters or Places. In the same manner, Artworks can also be connected with Secondary Connections, due to shared depicted Characters or Places of Exhibition (museums).

3.4. Placing the Stories Along the Mythological Timeline

In the same manner as level Art, where the Artwork-nodes are organized in a chronological timeline, as described previously, in level Myths, Story-nodes are organized in a "mythological time sequence" based on the course of "events". In contrast to the Artwork-nodes, the Story-nodes' organization is indicative, and since absolute time does not exist in Mythology numerous "temporal paradoxes" can be spotted. As a result, the Story-nodes placement is generated with the help of certain Landmark Stories (such as births or deaths of mythical Characters,

marriages, battles) that can define other Stories that either preceded or followed them in time. Moreover, a general time-sequence overview is achieved on a macroscopic level by comparing the Thematics deployment along the mythical timeline. For example, the Cronus Thematic, which evolves around the beginning of the mythological times, precedes all the

rest. On the other hand, the Thematics regarding the heroes of the Trojan War, which evolves around the end of the mythological times, are located towards the end of the mythical timeline and run parallel to each other, as they narrate shared events and have equal connections.

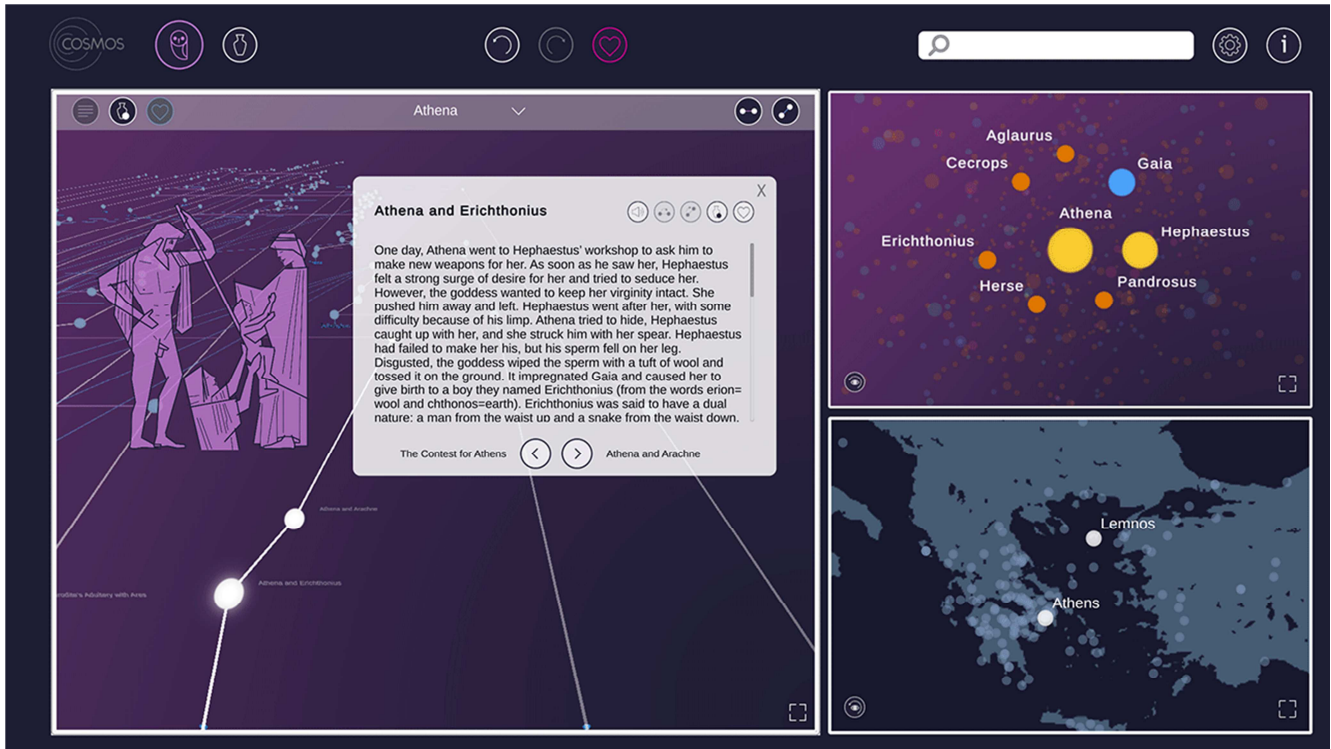


Figure 1. The three dynamic windows in Myths level. The Story "Athena and Erichthonius", the participating Characters and the Places the Story evolves.

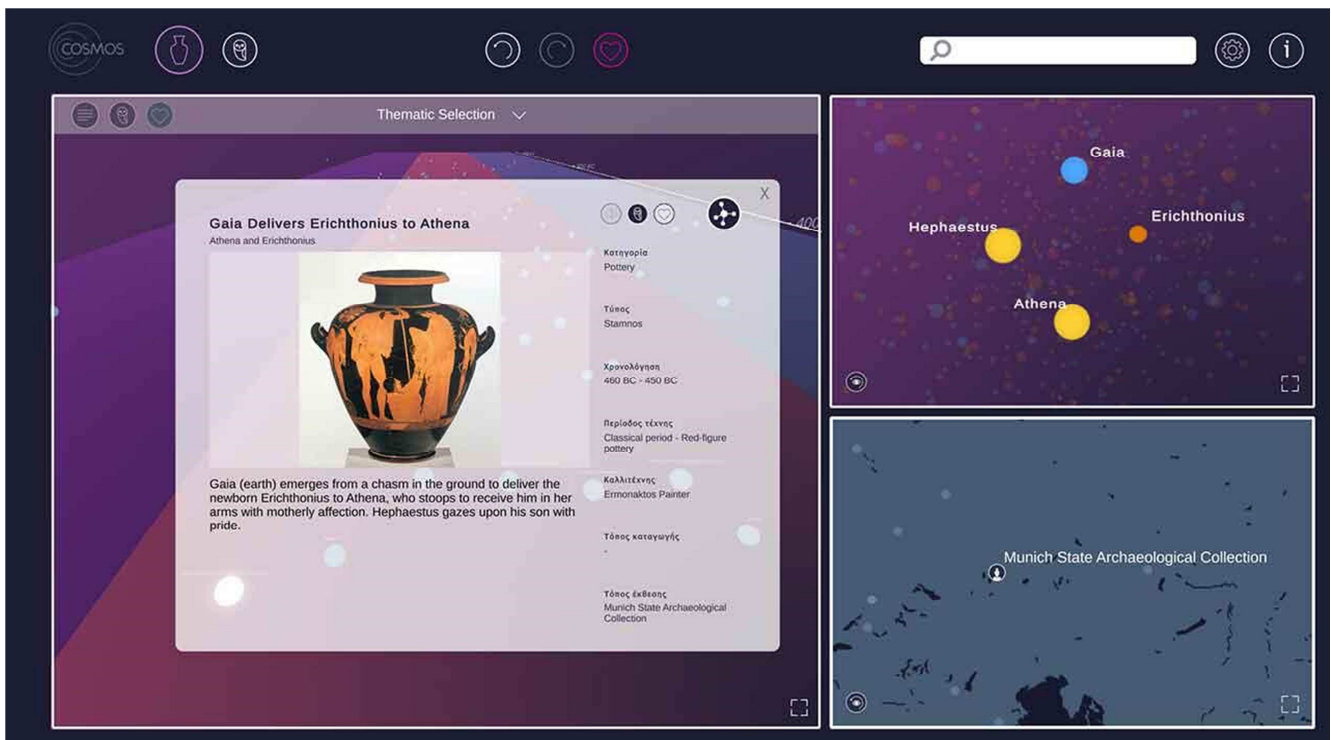


Figure 2. The three dynamic windows in Art level. The Artwork "Earth delivers Erichthonius to Athena", the depicted Characters and its Exhibition Place.

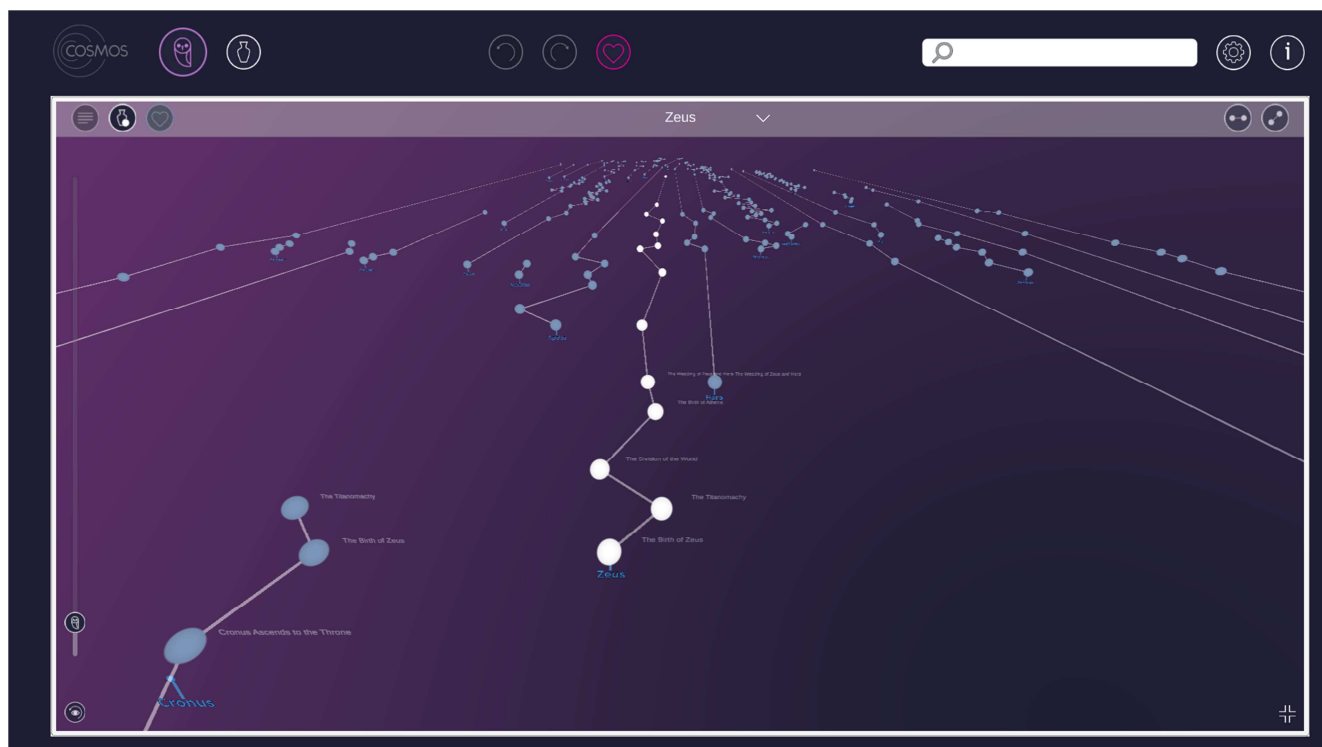


Figure 3. Thematic connections - Highlighted is the selected Zeus' Thematic.

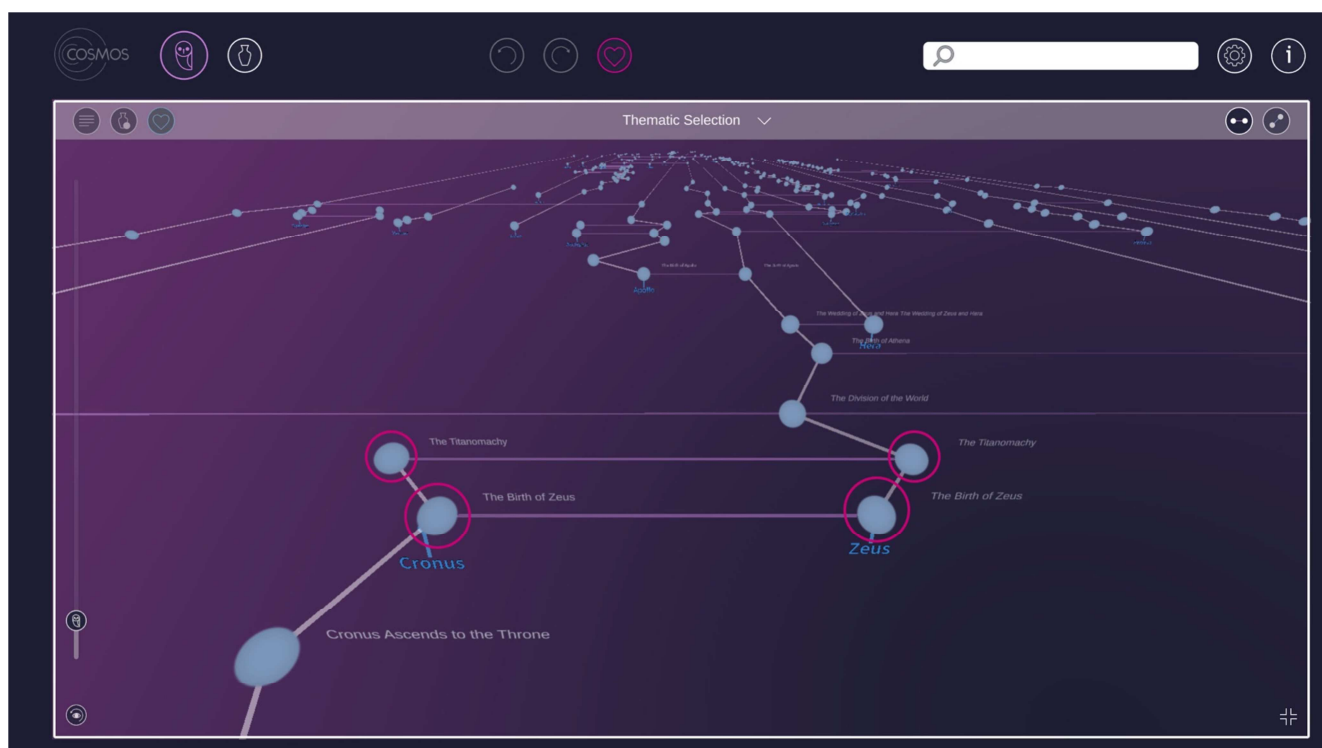


Figure 4. Equal connections (purple) - the common Stories "The Birth of Zeus" and "The Titanomachy" (in a circle), that are shared by the Cronus' Thematic and the Zeus' Thematic, and their equal connections.

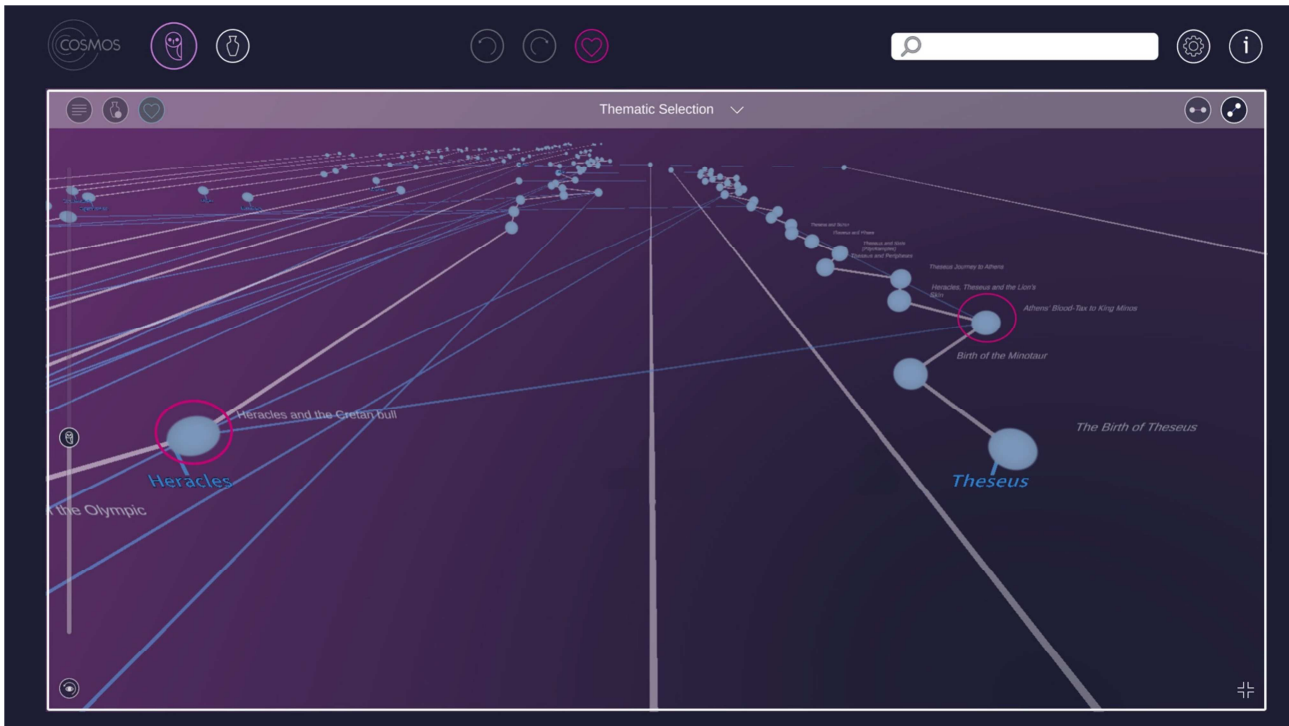


Figure 5. Primary connections (blue) - among others, there can be spotted the connection between the Stories "Heracles and the Cretan Bull", of the Heracles Thematic, and "The Athenian tax on Minos", of the Theseus Thematic (in a circle). The common element that influences both Stories is the Cretan Bull.

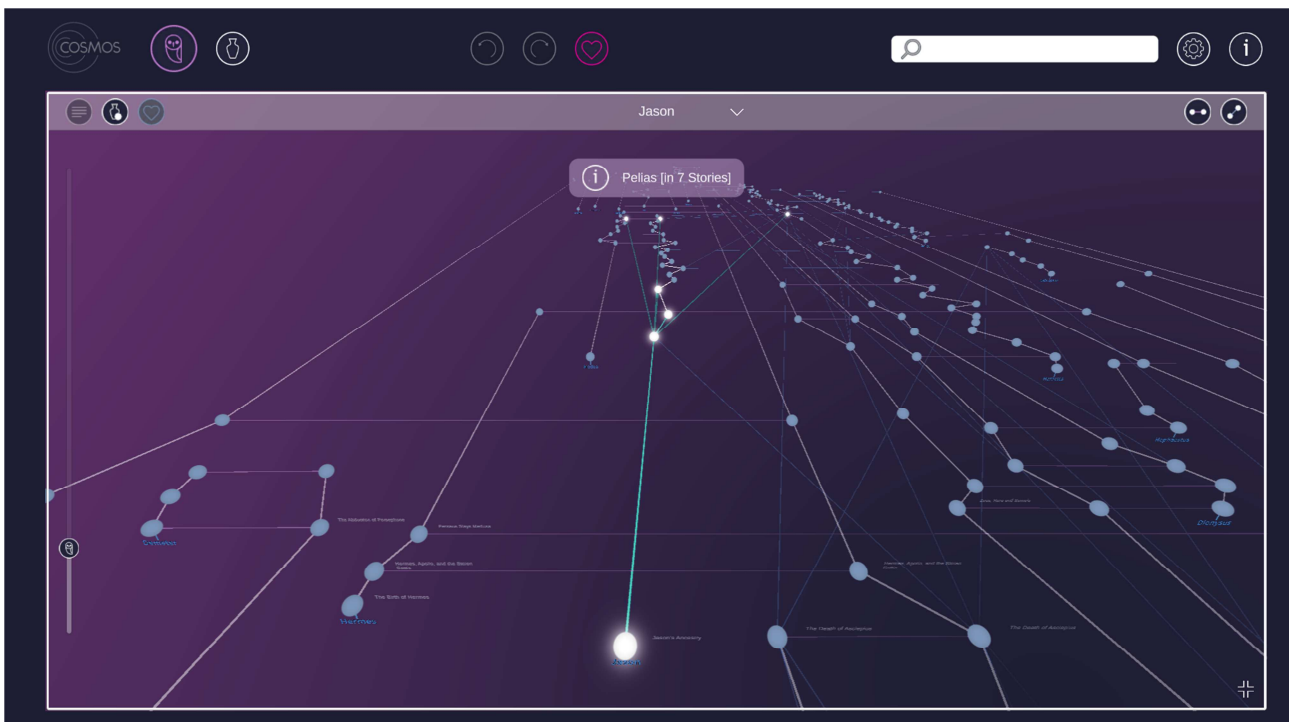


Figure 6. Secondary connections (green) - the common element in the highlighted Stories is king Pelias. The connections start from the originally selected Story-node "Jason in Pelion".

4. System Architecture [9]

4.1. Knowledge Organization System (KOS)

KOS is responsible for the automated extraction of

structured and machine-readable information from unstructured sources (e.g., mythology texts). This information is subsequently organized into correlation graphs, by means of which the myths are connected, according to shared attributes (e.g., characters, locations, artworks). KOS comprises the following two, independent, subsystems.

4.1.1. Information Extraction Subsystem (IES)

IES uses the unstructured mythology texts as input and creates the correlations between the myths, based on certain entities mentioned in the texts (e.g., characters, locations, other keywords). IES consists of:

COSMOS Document Store: A MongoDB [10] database, which contains the mythology texts in English and Greek, as well as the entities (locations, persons) in them.

Text Preprocessor: Takes the texts and entities stored in the Document Store and produces the annotated dataset to be used for the training and evaluation of the Named Entity Recognition (NER) [11, 12], NLP model.

NLP Model: This was developed using the NLP framework spaCy [13]. While spaCy provides pre-trained models for many languages, the Named Entity Recognizer's performance was insufficient. The pre-trained English model was further trained using the project's annotated dataset and evaluated against the gold standard. Table 1 illustrates the model's performance.

COSMOS Graph Generator: Takes the entities extracted from each text by the NLP model and generates a Neo4j [14] graph database, which contains the links between each mythology text.

Model development methodology: For the development of the NLP model a corpus of 129 Stories was used for training and testing and is currently included in COSMOS. Half of the mythology texts were used for the NLP model development and the other half was automatically processed by the trained model. The first half was manually processed, to extract the related metadata (entities, tags) and build the ground truth. Then, the raw texts, as well as the extracted metadata, were stored in the COSMOS Document Store database. To generate the corpus, the Text Preprocessor (a script in Python) was developed, which takes the raw texts and the metadata from the COSMOS Document Store and then produces the corpus in the format spaCy requires. For example, to train the Named Entity Recognizer, the training dataset must be in the following format:

'At a time when Minos was trying to establish himself as king of Crete, he asked Poseidon to send a sign revealing that the gods favored Minos and his ascent to the throne.'

{'entities': [(15, 20, 'PERSON'), (64, 69, 'LOC'), (80, 88, 'PERSON'), (136, 141, 'PERSON')]}

After generating the dataset, Transfer Learning was applied by starting from existing pre-trained representations (e.g., word vectors) and training them on the Greek mythology corpus. An amount of 80% of the dataset was used for training and the rest 20% for testing. A 20% dropout rate was applied to features to reduce overfitting. The results show that the COSMOS model, trained specifically on the Greek mythology texts domain, performs better than the pre-trained model which was trained on the OntoNotes [15] corpus (see Table 1). This was expected, as the COSMOS model has learned to recognize specific language patterns occurring in Greek mythology texts. At the same time, Location identification is not as good as Person identification, since the raw texts contain significantly more references to

Persons than Locations, making the identification of the Location harder to train.

Table 1. Performance metrics per entity type of the pre-trained model versus our trained model.

Train dataset		
	Model type	
	Pre-trained model	COSMOS model
Precision (Person)	86.70	100
Recall (Person)	48.35	100
F1 (Person)	62.08	100
Precision (Location)	23.42	100
Recall (Location)	10.48	100
F1 (Location)	14.48	100

Test dataset		
	Model type	
	Pre-trained model	COSMOS model
Precision (Person)	89.54	94.43
Recall (Person)	49.62	98.23
F1 (Person)	63.85	96.29
Precision (Location)	37.50	79.41
Recall (Location)	15.51	93.10
F1 (Location)	21.95	85.71

4.1.2. Information Retrieval Subsystem (IRS)

IRS is responsible for searching and retrieving the information that the end-user is looking for and consists of:

COSMOS Web Service: A RESTful API developed in NodeJS [16] using the Fastify framework [17]. The API provides endpoints to query and retrieve data stored in the COSMOS Document Store and the COSMOS Graph Database.

COSMOS Graph Database: A Neo4j graph database containing the links between each mythology text. The entity-relationship queries to the graph database are implemented in Cypher [18], Neo4j's query language.

When a system component, such as the Knowledge Presentation System, wants to access the linked information stored in the graph database, it performs an http request to the appropriate endpoint of the COSMOS Web Service. The service queries the graph database through the Cypher API and returns the results to the system component.

4.2. Knowledge Presentation System (KPS)

The Knowledge Presentation System (KPS) is the interface via which the user interacts with the Knowledge Organization System. KPS uses 3D graphic technologies, to deliver the linked information in an original and interactive way. To achieve that, a system of nodes has been developed (1352 nodes in total: 277 Stories, 612 Characters, 252 Places, 211 Artworks), which are connected both among the three visualization windows, as well as between the two levels.

5. Comparison with Existing Applications

To better evaluate COSMOS standing in the current market situation and to identify the features that distinguish it,

rendering it competitive to existing applications, a Feasibility Study was assigned to a Consulting Services company. This study examined 22 applications about Greek mythology based on their characteristics, e.g., Greek Mythology - Gods & Myths, Greek Mythology & Gods Offline, Greek Mythology.

The outcome showed that these applications are limited in content. They are mainly structured around an index of the most prominent gods and heroes, through which one can read their related myths. The texts contain hyperlinks that connect myths and characters (e-book), while none of the applications includes connections to the locations or related artworks. As a result, they fail to present mythology dynamically, being limited to a linear reading of mythology. Based on the above-mentioned, COSMOS has an undeniable competitive advantage over the existing applications, both in content and presentation, usability, and interconnection of the available information.

6. COSMOS Evaluation Results

In September 2021, the project partners invited the audience to test and evaluate the features, the content, and the overall experience using the COSMOS application. During this event, COSMOS was demonstrated in the most up-to-date version, close to the completion of the project. The purpose was to evaluate certain technical and quality application features and to assess whether it meets the objectives set at the beginning of the project.

The COSMOS version, subject to testing, was composed of the two levels (Myths and Art), including 30 Thematics,

277 Stories, 612 Characters, 252 Places, and 211 Artworks, 69 Artists, 53 Exhibition Places and 12 Places of Origin. Initially, a group of researchers from the collaborating partners presented the project, from the concept through the implementation process. The audience was provided with a brief analysis of the available features and the User Interface, to use, explore and further discover the application. The recorded presentation, the online version of the application, and the evaluation questionnaire remained available to the public for the following six days.

During the event, a total of 113 participants registered, categorized by age as follows: 18-29 (20%), 30-39 (20%), 40-49 (31.11%), 50-59 (11.11%), over 60 (17.78%). 91.11% of them have completed higher, 6.67% secondary, and 2.22% compulsory education. 82.22% have extensive familiarity with digital applications, and 17.78% moderate. Their knowledge of Greek mythology ranges from limited (6.67%) to extensive (28.89%), with the largest percentage evaluating themselves as having moderate knowledge (64.44%). The time dedicated to using COSMOS varied, as the registered participants could revisit the application throughout the duration of the event. However, indicatively, the average time was estimated to be 35 '- 45', while some users spent up to 2 hours.

The questionnaire results reflect the overall positive response of the audience and validate the fulfillment of the project objectives (see Table 2). The element considered to be the most interesting was the original way of presenting the available information (65.91%). The Thematics, the "mythological time sequence" configuration, the relations among myths, and the direct connection between Myths and their relative Artworks were additional positive features.

Table 2. The evaluation results, in response to the objectives (Obj).

Obj-1: Wide diffusion and reviving of Greek mythology & Art
1. 88,89% consider that COSMOS may address to the general audience but also to experts, educators and researchers
2. 93,33% found the information about Art to be useful for the average reader who seeks for general information on Greek Mythology
Obj-2: Better understanding and overview of the available information
1. 82,22% considers the application to offer direct correlation of the myth with the characters, the places and related artworks
2. 71,11% were assisted by the thematic and chronological branching of the myths, in better understanding the relations among the different mythological Thematics
Obj-3: Creation of an easy-to-use, reference and search tool
≈93% of the audience
1. found the application easy to use
2. found the navigation straightforward
3. searched and located the desired information easily
4. understood the function of the 3 windows
Obj-4: Connecting research with the market
1. 72,09% would buy COSMOS
2. 97,78% would recommend COSMOS to a friend

Regarding the application use, the audience mainly navigated through the nodes (91.11%) instead of the search field, usually used as an index in other applications. The browsing experience was original (60%) and enjoyable (35.56%). A multiple-choice question's answers show that drawing information from the three windows, triggered the audience to visit related myths (88.89%) and was also considered to enrich the knowledge provided by the descriptive text (64.44%). 80% found the "Visualization of

the connections and relations among the myths" to be a competitive application element. The aforementioned validates that COSMOS responds to the need to interconnect the information and present it non-linearly, through the application's innovative design and features.

In response to the question "What does the application offer compared to other means of digital information on Greek Mythology?", 82.22% answered, "Direct connection of the myth with the characters, the places, and the related Artworks"

while the other two windows "act as a trigger for the transition to other myths" (68.89%). It is, thus, confirmed that the two levels complement each other, and this innovative combination (a feature not met in other competitive products) is essential for a complete narrative experience.

The online event results comply with the positive results gathered in the first pilot testing event, which took place in February 2020. At that time, the level "ART" was not developed yet. An interesting observation has arisen comparing the responses to the question "What additional content would you like to see in the application?". In the first event, 66.67% answered that they would like to see "Illustrations of myths and characters", while in the online event, this percentage was reduced to half (34.88%). This reduction could be due to the level "ART" addition (including the corresponding images and their descriptive texts), which realizes the direct connection of each story with related visual representations. Consequently, the need to visualize the narratives seems to have been met, at least partially, via the inclusion of related Artworks.

7. Expected Results and Application Uses

COSMOS development and distribution aims at a wide range of results, with social, economic and cultural impact.

First and foremost, it constitutes a unique opportunity for a combined recording and digitization of Greek Mythology, both in its written and visual forms. This procedure fosters the identification, localization, and interconnection of related ancient Greek artworks, on a worldwide level. Moreover, this project creates an opportunity for the wide dissemination of this important part of Greek intangible cultural heritage [19], and for the better understanding and overview of such a complex and monumental work, thus raising awareness around Greek civilization internationally, employing an attractive, user-friendly, and easily accessible product. This new product will have a positive impact on the digital transformation [20] of traditional publishing houses, such as the collaborating partner Ekdotike Athenon reinforcing the company's competitiveness in the market.

COSMOS intends to reach a broad market audience. Indicatively, it can be used: a) by the average reader who wants to gather information and deepen his knowledge on Greek Mythology and the related Art, b) for educational purposes, as a support tool to be used by teachers to further engage students, as schools are stepping into the digital era, c) as a reference tool in the field of the Social Sciences and the Humanities, for the production of research projects (a tool produced by Research, to be offered to Research anew), and d) as a scientific documentation tool, and as an artworks registry, where cultural institutions may address for the organization of exhibitions, presentations, workshops, or other events about mythology and art.

8. Conclusion

The evaluation outcomes show an extensive interest of the

general audience and scholars in this new approach of presenting Mythology. This positive feedback paves the way for developing equivalent applications combining other Mythologies with their related Art, such as Celtic, Norse, Chinese, Hindu, etc. A challenging project would be the cross-linking among elements deriving from different mythologies, employing research that has been carried out in the field of comparative mythology [21]. Moreover, the methodology and the mechanisms developed in the bounds of the COSMOS application, in particular, could be adopted in producing other applications that will include different content, namely history, folk tales, fairy tales, music, etc.

The COSMOS project offers the opportunity to advance new interdisciplinary collaborations between the social sciences, the ICT sector, and the cultural and creative industries, to produce innovative products. Consecutively, the know-how acquired during the development of the specific project can foster further advancements in the research on the revival, exhibition, and dissemination of other cultural heritage forms, through the development of cutting-edge applications.

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The present paper uses minor text and part of the work (see 4. System Architecture) published in COSMOS. Cultural Osmosis – Mythology and Art. In: Ioannides M., Fink E., Cantoni L., Champion E. (eds) Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. EuroMed 2020. Lecture Notes in Computer Science, vol 12642. Springer, Cham. doi: 10.1007/978-3-030-73043-7_30. The present paper provides an updated, more comprehensive description of the project and its methodology. It is enriched with the second pilot testing evaluation results, as well as images from the final product.

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