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creative learning

Creative Emotional Reasoning Computational Tools Fostering Co-Creativity in Learning Processes

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DIAGRAMMATIC REASONING COMPUTATIONAL TOOLS

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EXECUTIVE SUMMARY

C²Learn at a glance

C²Learn (www.c2learn.eu) is a three-year research project supported by the European Commission through the Seventh Framework Programme (FP7), in the theme of Information and Communications Technologies (ICT) and particularly in the area of Technology-Enhanced Learning (TEL) (FP7 grant agreement no 318480). The project started on 1st November 2012 with the aim to shed new light on, and propose and test concrete ways in which our current understanding of creativity in education and creative thinking, on the one hand, and technology-enhanced learning tools and digital games, on the other hand, can be fruitfully combined to provide young learners and their teachers with innovative opportunities for creative learning. The project designs an innovative digital gaming and social networking environment incorporating diverse computational tools, the use of which can foster co-creativity in learning processes in the context of both formal and informal educational settings. The C²Learn environment is envisioned as an open-world 'sandbox' (non-linear) virtual space enabling learners to freely explore ideas, concepts, and the shared knowledge available on the semantic web and the communities that they are part of. This innovation is co-designed, implemented and tested in systematic interaction and exchange with stakeholders following participatory design and participative evaluation principles. This happens in and around school communities covering a learner age spectrum from 10 to 18+ years.

About this document

Deliverable D3.2.2 reports on the final version of the Diagrammatic Reasoning Computational Tools that will be used within creative activities designed in C2Learn, in order to foster Diagrammatic Lateral Thinking, as it is defined by the C2Learn theory for creativity. The document provides information on the different types of computational tools, indicates their conformance with the underlying reasoning theories, presents details on their implementation, and discusses the measures taken towards ensuring Content Safety and Quality. Furthermore, the document reports on performance improvements carried out in relation to the first version of the tools.

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LIST OF TERMS AND ABBREVIATIONS

Term/Abbreviation	Definition
CER	Creative Emotional Reasoning
LT	Lateral Thinking
LTC²	C²Learn's Lateral Thinking
DLT	Diagrammatic Lateral Thinking

1. INTRODUCTION

C2Learn's Lateral Thinking (LTC2) theory is built on Lateral Thinking and Brainstorming Techniques. The term Lateral Thinking (LT) is invented in 1967 by Edward De Bono [1]. As he elucidates:

"The brain as a self-organizing information system forms asymmetric patterns. In such systems there is a mathematical need for moving across patterns. The tools and processes of lateral thinking are designed to achieve such 'lateral' movement. The tools are based on an understanding of self-organizing information systems."

"In any self-organizing system there is a need to escape from a local optimum in order to move towards a more global optimum. The techniques of lateral thinking, such as provocation, are designed to help that change."

In deliverable D2.1.x (Creative Emotional Reasoning), three kinds of LT are suggested: Semantic, Diagrammatic, and Emotive. In the context of the present deliverable, we elaborate on the Computational Tools related to Diagrammatic Lateral Thinking.

1.1 THEORETICAL BACKGROUND

Diagrammatic Lateral Thinking (DLT) comprises a family of techniques that use pictorial disruptors in order to facilitate creative thinking via the usage of visual representations as stimuli.

The following subsections provide a brief analysis of the elements and techniques of Diagrammatic Lateral Thinking, with respect to the process of identifying the type of computational tools needed to support them within a digital environment. For further details on the techniques, cf. deliverable D2.1.2, Creative Emotional Reasoning.

1.1.1 DIAGRAMMATIC REPRESENTATIONS

For the purposes of Diagrammatic Lateral Thinking, the following visual representations are taken into account:

- Analogue: The analogue representation is characterized by a strong resemblance to the represented entities.
- Abstract: In this case, the resemblance with the represented object is not as strict as the analogue representation. Rather, the visual features are abstractly – but still schematically clearly – presented in the depiction.
- Schematic: The schematic representation does not aim to act as a facsimile of the represented entity, but rather communicate its essence.
- Conceptual: This type of representation aims to showcase non-visual concepts- as well as possible interrelations between them - in a diagrammatic way.

The computational tools that will support Diagrammatic Lateral Thinking should be able to handle information provided in each of these representations.

1.1.2 DIAGRAMMATIC LATERAL THINKING PROCESSES

Three processes comprise the core of all diagrammatic techniques:

- Identification: The process of identification refers to the understanding of the core meaningful constituents of a diagrammatic representation, which can be used for opening up new thinking directions towards solving a problem or handling a task.
- Re-mapping: The process of re-mapping essentially culminates to the provision of a lateral thinking path by forming an abstraction of a diagram’s pictorial elements and applying these abstraction to a given problem solving procedure.

– Exploratory Transformation: This process relies on the inherently dynamic, evolvable nature of a diagram. In this regard, the process aims to discover meaningful changes and alterations that can be applied over the diagram in order to find and follow lateral paths, which may lead to new transformations and result in a solution approach clearly divergent from the ones expressed or implied by the initial diagram.

1.1.3 DIAGRAMMATIC LATERAL THINKING TECHNIQUES

The aforementioned processes are used by specific DLT techniques, in order to lead to creative thinking and problem solving. This subsection provides a brief description of the different techniques foreseen within CER. These are the following:

– Creative Re-presentation: The specific technique employs an Identification phase, followed by a Re-mapping phase in order to use the core elements of the diagram over a specific problem or task within a creative activity.
– Creativity Icons: This technique focuses on the production of a pictorial representation of a concrete or abstract entity. The technique is applied to an initial diagrammatic input accompanied by a verbal stimulus. The actors are then called to identify the core elements of the diagram related to the stimulus, and transform it to a different picture that evokes the meaning of the stimulus in a visual manner.
– Picture Talk: This DLT technique builds on the usage of diagrams as an alternative means for verbal communication. In this case, diagrams are regarded as a grammatical constructs of a visual grammar, and the core idea is to communicate the intended verbal message not by the content of the diagrams but by their visual properties.
– Juxtaposition: The Juxtaposition technique is used for the enhancement of diagrammatic stimuli, by their augmentation with elements of different modalities (linguistic, audio, etc.). To this end, an exploratory transformation process is carried out for identifying these augmentative elements, followed by a re-mapping stage, where the newly introduced elements are interpreted within the context of the task / problem at hand.
– Mixed-initiative Co-creation: The Mixed-initiative Co-creation, that is, the process of constructing a solution via the usage of elements constructed collaboratively by human or automated actors, is a Diagrammatic Lateral Thinking technique in the context of C2Learn, as the provision of alternate paths is realized through visual elements.

2. DIAGRAMMATIC REASONING COMPUTATIONAL TOOLS

This section discusses the rationale behind the design and implementation of the C2Learn Diagrammatic Reasoning Computational Tools, with respect to the underlying theories for CER.

The following table summarizes the Computational Tools that were designed and implemented as assistive technologies for the Diagrammatic Lateral Thinking techniques presented in the previous section. There are three (3) tools that are actively integrated in the process of creative thinking with the purpose of fostering idea conception and expression; the Image Finder, the Concept Finder, and Relation Finder tools.

The Image Finder pertains to the Creative Re-presentation technique, where the provision of a disruptor for encouraging Lateral Thinking is directly related to a diagrammatic input from the supporting tool.

The Concept Finder and Relation Finder tools are closely associated with the Juxtaposition DLT technique. They aim to provide ways for altering / enhancing a concept graph, that is, a diagram accompanied by semantic information.

The Picture-talk DLT technique has the intricacy that all the information representation and manipulation is pictorial. Thus, no Computational Tool support is applicable to the specific technique, as the lack of associated semantics does not allow any automated analysis of the diagram's meaning and features.

Additionally, the Mixed-initiative Co-creation technique is not supported by Diagrammatic Reasoning Computational tools. In the context of C2Learn, AI support for the particular DLT technique is provided by the Mixed-initiative Procedural Content Generation components, developed in the context of WP4, and reported in deliverable D4.3.x, Mixed-initiative Procedural Content Generation.

Regarding the Creativity Icons DLT technique, several elements of the process of formulating an icon can be supported by tools that handle and alter the underlying semantics of a diagram. To this end, a set of supporting tools, that are also used by the other Diagrammatic Reasoning Computational Tools and can also be evoked in different stages of the DLT process, have also been implemented. The following table summarizes the available Diagrammatic Reasoning Computational tools.

Type	Tool
Tools fostering Idea Conception	Image Finder
	Concept Finder
	Relation Finder
Supporting Tools	Search Engine Wrapper
	Concept Graph Equivalence Checker
	Concept Graph Abstraction Engine
	Concept Graph Polymerism Engine
	Fact Retriever

Table 1: C2Learn Diagrammatic Reasoning Computational Tools

The following subsections present in detail the different Diagrammatic Reasoning Computational tools, describing their functionality and providing details on the methodology and implementation of each tool.

2.1 DIAGRAMMATIC REASONING COMPUTATIONAL TOOLS FOSTERING IDEA CONCEPTION

This section provides details on the design and implementation of the C^{2}Learn Diagrammatic Reasoning Computational Tools for Fostering Idea Conception. All the tools are implemented as SOAP-based web services, and thus are able to be used by any client that follows the services' call definition. The WSDL definition of the C2Learn Diagrammatic Reasoning Computational Tools can be found at: *http://cru.iit.demokritos.gr:8080/c2Learn/C2learn?wsdl*

2.1.1 IMAGE FINDER

2.1.1.1 FUNCTIONALITY

The Image Finder aims to provide pictorial stimuli, having a varying semantic distance from an initial concept given as input. To this end, the service searches the web in order to discover and retrieve images that constitute a depiction of an alternate concept, which will lead the user to consider the implications and associations with the problem at hand.

2.1.1.2 IMPLEMENTATION

The input seed is given is randomized following the same process as the Thinking Seed Generator service (cf. deliverable D3.1.2, Semantic Reasoning Computational Tools) in order to retrieve a key string with some semantic distance from the input. Then, the Image Finder uses the Bing Search API [1] to collect images related to the generated search strings. It then randomly selects a specified amount (default 50) of images and gives the URL of the image to the calling agent. The tool support input in three languages (English, Greek, and German).

2.1.2 CONCEPT FINDER

2.1.2.1 FUNCTIONALITY

Given a concept graph, the Concept Finder service is used to identify additional concepts with certain associations to the concepts included in the graph. These new concepts can be used to expand the initial graph and provide new thoughts paths and alternate considerations on the problem at hand.

2.1.2.2 IMPLEMENTATION

The Concept Finder service accepts as input a literal denoting a concept in the graph, along with an integer value denoting the "difficulty" of the response in terms of the lexical and semantic distance of the results to be provided by the service. Furthermore, the service's input includes a string denoting the category to which the delivered additional concepts will belong. These categories are the following:

- Concepts similar to the initial concept
- Concepts that subsume the initial concept
- Concepts that supersume the initial concept
- Concepts directly or indirectly related to the initial concept

Similar concepts are discovered by discovering synonyms of the input concept in the WordNet [2] graph and by identifying equivalent concepts in previously created graphs via the usage of the Concept Graph Equivalence Checker supporting tool (see Section 2.4.2 of this document). This case does not use the difficulty parameter.

Subsumed and supersumed concepts are retrieved via the usage of the Concept Graph Abstraction Engine (see Section 2.4.3). In this case, the difficulty parameter defines the length of the path over the subsumption graph that will be followed in order to reach the concepts to be returned.

Similarly, the Concept Finder uses the Fact Retriever tool to find related concepts. In this case, the difficulty parameter defines the number of relations with different entities that will be followed until we reach the set of the concepts to be returned. Starting from the input concept, the service randomly selects a relation with that concept as the subject. It then retrieves relations of this relation's object as the subject, and repeats the process until the difficulty threshold is reached. The resulting set of concepts is then retrieved to the calling agent.

The Concept Finder currently supports input in the English language, as the Fact Retriever natively provides relations in English.

2.1.3 RELATION FINDER

2.1.3.1 FUNCTIONALITY

As the Concept Finder, The Relation Finder service operates over a concept graph. The service examines the relations between the concepts included in the concept graphs and proposed additional or alternative relations between the existing concepts. In this way, the concept graph is enriched with information that provides a different perspective for the associations between the core concepts and ideas included or implied by the diagram at hand.

2.1.3.2 IMPLEMENTATION

The Relation Finder accepts a string list, denoting two concepts and their relation in the concept graph, as well as, a parameter denoting the "difficulty" of the response, in terms of the semantic disassociation of the newly found relations compared to the initial one. Furthermore, the service accepts a string denoting the desired association between the initial concepts and the concepts to be analyzed (subsumption or supersumption).

The Relation Finder uses a higher or lower abstraction of the action denoted by the relation, following the verb hierarchy defined in WordNet. It then uses the Fact Retriever supporting tool to find entities linked with this relation and proceeds to discover additional relations between such entities or entities related to them via a hierarchical connection (equivalent, more abstract, more specific), in accordance with the association input parameter. The lexical descriptions of the relations found via this process are then returned to the user.

As the Concept Finder, the current version of the Relation Finder tool supports content in the English language.

2.2 SUPPORTING DIAGRAMMATIC REASONING COMPUTATIONAL TOOLS

The supporting computational tools do not fall in the aforementioned categories and are not directly used by client applications. Rather, they have been implemented as they are necessary for the providing the functionality of the other Diagrammatic Reasoning Computational tools.

2.2.1 SEARCH ENGINE WRAPPER

The Search Engine Wrapper's implementation is described in deliverable D3.1.2b, Semantic Reasoning Computational Tools. For the purposes of the Diagrammatic Reasoning Tools, the only differentiations is that the service is called with an additional parameter for the Bing API, which indicates that the URLs to be retrieved should correspond to images, instead of Web pages. The Search Engine Wrapper supports the retrieval of content in three languages (English, Greek, and German). Furthermore, the tool incorporates content safety and quality mechanism for ensuring the suitability of the delivered content, as described in Section 3 of this document.

2.2.2 CONCEPT GRAPH EQUIVALENCE CHECKER

The Concept Graph Equivalence Checker is responsible for identifying correspondences between the concepts and relations of two distinct concept graphs. To this end, the concept graphs are treated as simplifications of an ontology, and ontology alignment techniques are employed in order to find mappings between the concepts and relations of the compared graphs. The techniques included in the first version of the service are the following:

COCLU. This is a string matching technique. It is realized by a partition-based clustering algorithm, which divides the examined data (strings in our cases) into clusters and searches over the created clusters using a greedy heuristic [3]. The clusters are represented as Huffman trees, incrementally constructed as the algorithm generates and updates the clusters by processing one string at a time. The decision for adding a newly encountered string in a given cluster is based on a score function, defined as the difference of the summed length of the coded string tokens that are members of the cluster and the corresponding length of the tokens in the cluster when the examined string is added to the cluster.

VSM. This is a Vector Space Models-based method [4], computing the similarity be-tween two documents. In the case of mapping tasks, the pseudo-documents to be compared are constructed as follows: Each document corresponds to a concept or relation and comprises words in the vicinity of that element, i.e. all words found in the synset of the word and (b) relations for this concept. The produced documents are represented as vectors of weighted index words. Each weight is the number of words' occurrence in the document. We apply cosine similarity to measure the similarity between two vectors.

LDM Alignment. This method uses unstructured textual information retrieved from the Web, in the form of extracted relation triples [5]. The method performs web searches, using lexical information from the concepts and relations included in the concept graph. The web documents returned from the web searches are pre-processed in order to derive their textual information, and relation tuples are extracted from each document. The sets of relation tuples associated with each class are compared, and classes' similarity is assessed.

The Concept Graph Equivalence Checker supports concept graphs that provide lexical descriptions in either of the three languages supported by C2Learn (English, Greek, and German).

2.2.3 CONCEPT GRAPH ABSTRACTION ENGINE

The Concept Graph Abstraction engine aims to provide generalizations of the concepts included in a concept graph, by identifying subordinance and superordinance relationships with other concepts and superimposing the new concepts over the given graph.

To this end, the service exploits the hyperonymy and hyponymy relations defined in the WordNet graph. Given a string denoting an entity in the graph, the service stems the string corresponding to the entity, and identifies terms with the same stem in WordNet. It then retrieves the hyponyms and hypernyms of the different terms and returns the results term sets to the calling application.

2.2.4 CONCEPT GRAPH POLYMERISM ENGINE

The Concept Graph Polymerism Engine aims to provide specializations of the concepts included in a concept graph, by identifying new concepts that have a complimentary relation to the concepts originally included in the concept graph.

To this end, the service exploits the meronymy relations defined in the WordNet graph. Given a string denoting an entity in the graph, the service stems the string corresponding to the entity, and identifies terms with the same stem in WordNet. It then retrieves the meronyms of the different terms and returns the results term sets to the calling application.

2.2.5 FACT RETRIEVER

The Fact Retriever service is used for discovering associations between concepts. It accepts as input an existing association and produces a list of additional relations that comprise the following cases:

- Relations with the same or equivalent object
- Relations with the same or equivalent subject
- Additional relations between the existing subject and object, or equivalents of them

The service relies on the fact database of the Read the Web initiative [6]. Read the Web uses the NELL system to process web information, by matching to an extensive ontology the content of 500 million selected web pages in order to discover relations between known or newly discovered entities.

The Fact Retriever server accepts as input a string denoting an entity, and its intended role in possible existing relations (i.e. whether the client calling the service desires to find relations with the entity as the subject or the object of the relation, or the entity is the relation itself). It then accesses the knowledge base built by NELL, and examines the existence of the entity or lexically close entities in different relations. The service finally returns the complete set of found relations.

2.3 LANGUAGE COVERAGE

The C2Learn Diagrammatic Reasoning Computational tools operate on content in all three languages supported by C2Lean (English, German, and Greek). However, the complexity of some of the operations require specialized linguistic resources that are not available in all languages. To this end, language support for some of the tools is not native, but rather relies on automatic translation components integrated in the services.

Image Finder: The Image Finder natively supports the three languages, via the usage of the Search Engine Wrapper with the appropriate configuration. In the case of the Bing Search API, a parameter is provided that sets the language to be used for performing Web searches. In the case of the other search engines integrated in the Search Engine Wrapper, the fragFINN search engine returns web pages in German, while DMOZ returns pages in Greek.

Concept Finder and Relation Finder: The Concept Finder and Relation Finder rely on more complex linguistic resources, like WordNet and the Read the Web knowledge base. Currently, such resources are available only for English and there are no similar resources for the other two languages supported by C2Learn (German and Greek). To overcome the issue, the two computational tools employ automatic machine translation components in order to be able to use the richer linguistic information available in English. Thus, the flow of the tools' functionality for German and Greek is modified as follows:

1. The services propagate their input to the machine translation component, which returns the English translation of the terms at hand.
2. The translated descriptions are used from the services to produce their respective output.
3. The output is translated back to the language of the original input and returned to the calling application.

3. TECHNIQUES FOR ENSURING CONTENT SAFETY AND QUALITY

As some of the services implementing the C2Learn Diagrammatic Reasoning Computational Tools deliver unregulated Web content, a major concern and requirement for the tools is the aspect of content safety, and particularly for the targeted age groups (K12 education). Hence, the tools should incorporate content quality control mechanisms, for ensuring the suitability and safety of the presented information. The actual tool that provides all the relevant components with Web information is the Search Engine Wrapper. As the Search Engine Wrapper delivers URLs of web resources (and specifically images) via external search engines, it is an in principle unsafe service. To ensure the delivery of safe web content the service incorporates various measures.

At the first stage, the Search Engine Wrapper examines the value of its safety parameter. If it is set to ***false***, the service uses the Bing Search Engine to perform the desired Web search. On the other hand, if the parameter is set to ***true***, the Search Engine Wrapper activates children-oriented search engines for searching the web. We examined various Safe Search Engines in terms of their suitability and connectivity, such as AgaKids1, FragFinn2, Quintura for Kids3, KidRex4, KidsClick5, etc.

It was determined that we should incorporate a different search engine depending on the desired language, as the examined engines did not provide content in all the languages covered by C2Learn. To this end, the Search Engine Wrapper invokes the DMOZ[6] search when the request refers to content in English or Greek. DMOZ, historically known as the Open Directory Project (ODP) is the largest human-edited directory of the Web. It is constructed and maintained by a global community of volunteer editors. One of the categories edited and maintained by the community is the "Kids and Teens" section, which is the one accessed by the Search Engine Wrapper. When the request refers to content in German, the service invokes the fragFINN[7] search engine. fragFINN started in 2007 as part of the initiative "A Net for Children". It uses a whitelist approach for ensuring that the accessed content is safe and child-friendly. Additionally, the service make use of blacklists and whitelists of web sources (sites) in order to avoid malicious and adult-oriented sites before processing content from them. Finally, the service examine the presence of content labels when visiting a page, and ignore the pages for which the labels indicate the presence of mature or offensive content.

4. PERFORMANCE IMPROVEMENTS

The final version of the C2Learn Diagrammatic Reasoning Computational Tools Suite incorporates measures for improving the performance and response times of the involved services. This section summarizes the performance improvements of the relevant tools and services.

4.1 IMAGE FINDER PERFORMANCE IMPROVEMENTS

The Image Finder incorporates techniques for pruning the search space and traversing the WordNet graph during the seed randomization phase. Furthermore, the retrieval of images is realized via a thread pool in order to minimize the time required for acquiring the whole set of discovered images.

4.2 SEARCH ENGINE WRAPPER PERFORMANCE IMPROVEMENTS

The Search Engine Wrapper incorporates caching techniques for reducing the delays caused from accessing the discovered web pages. Furthermore, improvements were made to the parsing features of the Search Engine Wrapper in order to speed up the content cleaning and text extraction functionalities of the tool.

4.3 CONCEPT GRAPH EQUIVALENCE CHECKER

As described in the relevant section, the Concept Graph Equivalence Checker employs different matching techniques for discovering equivalences between entities in the compared concept graphs. In the final version of the Diagrammatic Reasoning Computational Tools, the service has moved to a

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[1] http://aga-kids.com/

[2] www.fragfinn.de/kinderliste.html

[3] http://quinturakids.com/

[4] www.kidrex.org/

[5] www.kidsclick.org/

[6] http://www.dmoz.org/

[7] https://www.fragfinn.de/kinderliste.html

threaded architecture, so that the distinct matching methods perform their operation in parallel, and their results are aggregated after each of the corresponding threads is completed.

5. CONCLUSIONS

The presented C^2Learn Diagrammatic Reasoning Computational Tools aim to foster the Diagrammatic Lateral Thinking techniques as defined by the theory, within C2Learn gaming environments.

The tools are broadly categorized as (a) components that provide input for fostering Idea Conception and (b) components for performing assisting processes, providing the aforementioned tools fostering Idea Conception with the necessary information. The tools are to be used in activities implementing all the different DLT techniques for which such ICT support is applicable, namely, Creative re-presentation, Creative Icons and Juxtaposition. One of the provided tools, the Search Engine Wrapper, as it handles and produces non-moderated Web content, incorporates Content Safety and Quality measures to ensure that the presented content is suitable for the targeted age groups.

Some of the implemented services natively support content solely in English, as they require complex linguistic resources not available in the remaining languages supported by C2Learn (German and Greek). Towards resolving this issue, automatic machine translation components were incorporated in the services in order to transfer the analysis to English and be able to use the required resources.

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