

A Portal for the State of the Art on Content Negotiation

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Abstract. Resources on the Web are identified by Uniform Resource Identifiers (URIs), and can be accessed using web protocols such as HTTP. A resource can have several representations varying along a set of dimensions, forming a set of variants. Content negotiation (CN) is the mechanism for selecting the appropriate variant that conforms to a set of preferences (constraints). Over the years, various dimensions of CN, styles of CN, as well as ways to convey constraints have emerged to satisfy new requirements and solve new use cases. This paper presents a new resource called Content Negotiation Theoretical Framework (CNTF): a website that collects knowledge about CN use cases, styles, dimensions, etc., and organise it according to an ontology. CNTF aims to highlight existing solutions if available, or suggest plausible ways to satisfy common requirements. It is intended to be used to disseminate our future proposals for advancing CN, making it a sustainable and up-to-date digital survey of CN.

Keywords: Content negotiation · Style of negotiation · Dimension of negotiation · Constraint · Ontology.

1 Introduction

Open, distributed, accessible, and heterogeneous are some of the fundamental characteristics of the Web [5]. Although these characteristics greatly contributed to its world-wide adoption and development, the abundance and constant development of Web resources and data formats make it challenging to provide the best representation to each client. A simple example is that of two people speaking different languages accessing the same resource, the server should be able to provide each client with an understandable version. To remedy this, a solution was devised from the start, with a negotiation layer between the client and the server [3]. Negotiation, as a concept, is a back-and-forth communication intended to reach an agreement when two or more parties have common and opposing interests [8, p. 1]. Applied to the Web, it then becomes “Content Negotiation” (CN), the mechanism for serving the most appropriate representation

of a web resource. CN is described in the Architecture of the World Wide Web W3C Recommendation as one of the essential components of Web design [12, section 3.2].

Resources on the Web are identified by Uniform Resource Identifiers (URIs), and can be accessed using web protocols such as HTTP. One resource may have different alternatives representations that we call variants as in [6]. To request a specific variant a client would use CN. Thereby, CN is the mechanism of choosing the best variant from among a set of alternative representations of a resource available on the Web by accessing its URI. The client may accompany its request with a set of constraints that the origin server (or some proxy server) uses to serve the adequate response. The sequence and type of exchanged messages vary according to the CN style, CN dimension, constraint conveyance technique, and the employed web protocol.

Over the years, various dimensions of CN, styles of CN, as well as ways to convey constraints have emerged to satisfy new requirements and solve new use cases. The broad application of CN has led to fruitful research results in recent years.

However, there is no general and comprehensive state of the art on this topic. This paper presents a new resource called Content Negotiation Theoretical Framework (*CNTF*): a website that collects knowledge about CN use cases, styles, dimensions, etc., and organise it according to an ontology. To the best of our knowledge, CNTF provides the first digital state of the art about existing CN approaches and features. We identify the used CN feature in each contribution, and categorise them in order to classify existing contributions on CN. CNTF aims to highlight existing solutions if available, or suggest plausible ways to satisfy common requirements. To summarize, the contributions of CNTF are the following:

- A digital state of the art about CN in the form of a website.
- A reference point for CN categories and concept groups to enable classification.
- An ontology data model for CN knowledge.
- A graphic visualisation and navigation.

CNTF is open-source <https://github.com/youctagh/cntf> with permanent URL <https://w3id.org/cntf/> and DOI <https://doi.org/10.5281/zenodo.6504504>.

The remainder of this article is organised as follows. Section 2 presents the state of the art on CN, followed by Section 3 which provides an overview of related problems and resources. Section 4 describes three use cases and the requirements for the CNTF resource. The Section 5 presents the characteristics of the resource. In Section 6, we present the relevance of CNTF for the Semantic Web community. Finally, we conclude the paper and suggest future directions in Section 7.

2 State of the art

In HTTP, constraints are called preferences and can be expressed and transmitted as mentioned in [7, section 5.3], which offers in addition to the retrieval and transmission of information, the possibility of selecting more specific formats and languages.

The question of how/who makes the decision in the CN selection process has led to the emergence of several CN styles that denote a particular manner or technique by which the CN process is conducted. This includes how the negotiation is conducted and which of the CN parties makes the choice of which variant to select. One can find among others: proactive CN, where the server chooses the representation to provide to the client, reactive CN, where the client chooses the representation from a list provided by the server, and transparent CN, which makes visible to intermediate parties (proxies) all variants that exist in the origin server. [11].

For a long time, the negotiation of format, language and encoding was sufficient using *accept*, *accept-language* and *accept-encoding* respectively, and has been adopted for various use cases such as sending the appropriate alternative on email-based fax services [14]. The HTTP memento framework enabled a Time-Based access to the versions of the resource [20]. Ever since, HTTP users applied content negotiation using various ways from using the *prefer* header [19] and *profile* link [27] to creating custom headers as *accept-presentation* to negotiate RDF presentations, *accept-lowering-rule* to negotiate lowering rules [13], and *accept-schema* header for meta data schema negotiation [21]. Recently, a new approach called Client Hints was introduced to support agent-based content negotiation [10]. A server sends an *accept-ch* response header to indicate to user agents that it is using the request headers for proactive content negotiation.

Another application area of content negotiation is Universal Multimedia Access (UMA), where the objective is to provide multimedia content under certain constraints and conditions. The work [16] is an example of an approach to address this problem by using Pareto's multi criteria optimisation theory to formally describe the characteristics of a content negotiation process for evolving bitstreams with multiple quality dimensions. Also, with the introduction of phones of different sizes and capabilities (colour, characters, ect.) one had the need to express the constraints of these devices. This motivated the creation of UAProf by the WAP forum [18] and CC/PP by the W3C [15]¹, to be able to negotiate representations adapted to these devices [4].

On the Web of Linked Data, with RDF as the framework for describing resources, it is common that resources have different representations, potentially with different RDF vocabularies or shapes. The HTTP *accept* header is commonly used to negotiate RDF document syntaxes. However no simple solution exists to negotiate a representation with a specific vocabulary or shape.

¹ Example of a Nokia UA Profile: <http://nds1.nds.nokia.com/uaprof/N6230ir200.xml>

This problem was also pointed out about other formats such as JSON in “Your JSON is not my JSON” [25]. JSON Hyper-Schema is a proposition intended to facilitate HTTP content negotiation [1] in that direction.

The profile vocabulary [2] is a new way of defining the validation rules or semantic interpretation to be applied to a representation. A new header *accept-profile* has been introduced in [22,23] to allow the client to convey its preference for a profile to the server which enables CN by profile.

3 Related problems and resources

Efforts were done to encapsulate the available techniques and characteristics of CN, but to the best of our knowledge this only took the form of a related work section in specifications using CN such as [22, Section 5] or web page documentation such as in Mozilla Developer Network Web Docs².

Our recent non-peer-reviewed contribution was a state of the art on CN [24]. CNTF attempts to assemble all the information gathered in this article into a website and extends it by providing more information and new exclusives which we describe in detail in the Section 5.

A related problem is personalised information retrieval (PIR) that aims not only to assist users in finding information from the myriad of information resources available on the Web as in traditional information retrieval field, but takes into account user preference and the history of their interactions with the system with the main objective to increase user satisfaction. A survey was conducted and proposed a classification of PIR systems [9].

The idea of a digital state of the art is not new; others have already proposed similar resources, either in the form of web pages, or in the form of a web site dedicated to a topic like the one for the complexity of reasoning in logic of description <http://www.cs.man.ac.uk/~ezolin/dl/>.

4 Use cases & Requirements for CNTF

In this section, we discuss the potential impact of CNTF as a resource. To this end, we present different use cases that motivate its creation. We highlight the challenges that these use cases reveal, and obtain a set of requirements for CNTF to address these challenges.

Use case 1 Jane is a researcher and John is a developer, they are both interested in CN. While Jane is preparing a PhD in relation to that subject, John has a task to develop a CN mechanism for its company to serve different archived versions of their content served via an API. Both Jane and John *have to search different websites* for the old methods of CN or the most modern ones (C1). It would also take them *ages to come up with a coherent understanding of the relationship between the different approaches*

² https://developer.mozilla.org/en-US/docs/Web/HTTP/Content_negotiation

(C2), especially because *one term may have different meanings in different communities of researchers*. One of the goals of CNTF is to provide a digital catalogue of everything one needs to know about content negotiation.

Use case 2 Paul has an idea for a new approach to do CN, and although he already has a use case to motivate it, he wants to compare it with existing approaches, and to know what style, dimension, and negotiation requirement his use case fits into. For now, the lack of a resource categorising the different concepts of CN makes it difficult to compare with other approaches. The task of Paul would be eased by *a categorisation and grouping medium* (C4) and *assistance and guidance to select a classification* (C5). CNTF aims to address these.

Use case 3 Alice is a semantic web researcher involved in a project for which there is a plan to use CN and she is interested in learning more about this topic. While UC#1 contains resources and data, UC#2 allows for grouping and categorisation. As a semantic web scholar she would be interested in *a model of how everything is related, with each of the content negotiation concepts represented with all of its relationships* (C6). Also, *a visual explanation for perceiving these relationships if possible* (C7), and *a procedure for graphically navigating from one concept to another* (C8). This is what CNTF intends to provide.

From these use cases, we identify requirements that the CNTF should meet:

- R₁ Navigable design** The CNTF should have a navigable design that includes interlinking through hyperlinks to help users categorise their use cases (C5), and a graph following the resource model (C7), with clickable nodes to navigate from one concept to another (C8).
- R₂ Extensible** One of the main contrasts between a traditional survey paper and the CNTF resource is that it should support extensibility by allowing the addition of new content negotiation concepts, e.g., a new dimension (C1), and to be up to date with different terminology and definitions (C3).
- R₃ Categorisable** The CNTF should provide the means to categorise the different content negotiation use cases and techniques (C4) to allow for comparative evaluation. It should also have a well thought out grouping (C2) and modelling (C6) of the different content negotiation concepts to facilitate understanding.
- R₄ Maintainable** The CNTF should promote maintainability by adjusting the model used, e.g., community-recommended vocabularies (C6), and by taking into account feedback provided by resource users to clarify and rectify content (C1).

Table 1 summarises the relationship between the challenges (C_i) and the requirements (R_j).

Use cases	Use case 1			Use case 2		Use case 3		
Challenges	C1	C2	C3	C4	C5	C6	C7	C8
Requirements								
R ₁ : Navigable design					✓		✓	✓
R ₂ : Extensible	✓		✓					
R ₃ : Categorisable		✓		✓		✓		
R ₄ : Maintainable	✓					✓		

Table 1: Relationships between the challenges (C_i) and the requirements (R_j)

5 A Portal for the State of the Art on Content Negotiation

CNTF is a web site designed to help the web community: either newcomers to the field of content negotiation who want to explore it, or indigenous who want to keep up with the latest techniques.

In this section, we present the architecture behind CNTF, followed by the accompanying features and functionalities, and show that it meets the requirements presented in Section 2.

The system has been designed as a website, so no installation process is required. In addition, it allows users to always have the latest version without having to perform an update at each release. CNTF is built with the Angular Framework ³ with cross-browser compatibility. Figure 1 shows the home page of CNTF.

5.1 CNTF as a State of the Art Literature Review of CN

As mentioned in the introduction content negotiation could be achieved using different styles, CNTF collects these styles and gives:

- A description of the style.
- An example of content negotiation using that style.
- The use cases from the bank of use cases in CNTF using that style.
- Pointing the advantages and disadvantages of this style.
- Relevant references where the style was introduced or mentioned.

Over the year the preferences of the client/server in content negotiation have been referred to with different designations “constraints”, “features” etc, in CNTF we group them in a category named content negotiation dimension and for each of these dimensions we deliver:

³ <https://angular.io/>

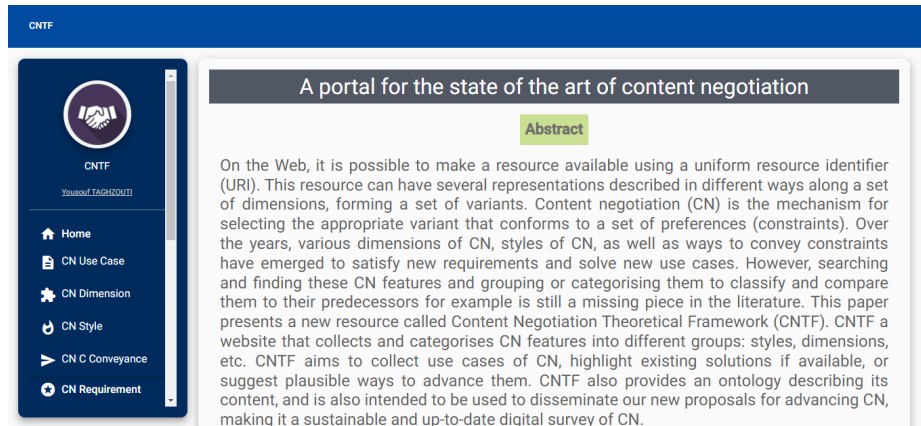


Fig. 1: CNTF home page.

- A description of the dimension.
- Some references to the pertinent use cases.
- Some examples of the content negotiation process.
- Some relevant references on the state of the art.

Each domain comes with a set of terms, for a newcomer to find and grasp the definitions of all these terms is a tedious task, that's why CNTF has a terminology section that lists and keeps track of the meaning of the terms related to content negotiation, and since different communities might differ on the meaning of a term, we present them with their respective communities references. Also, since some terms are prone to confusion, CNTF has a dedicated section to provide more clarity, e.g. "Media type vs MIME type vs format".

Since another type of users of this resource is developers, the CNTF has an "Additional Info" section that lists implementations of content negotiation using some of the available technologies. Figure 2 represents a CN dimension example.

5.2 CNTF as a Bank of CN Use Cases

A difficulty faced by someone making research in a new subject area is to contextualise the usefulness of the material learned. CNTF attempts to solve this problem for the CN domain by collecting use cases from other documents and websites. Being an open-source project, the community may contribute with other use cases. In each of the use cases one finds:

- A description of the use case.
- Potentially some references to the primary source the use case was inspired from.
- The requirements extracted from the use case.
- Potentially a solution section with relevant references or preliminary solutions.

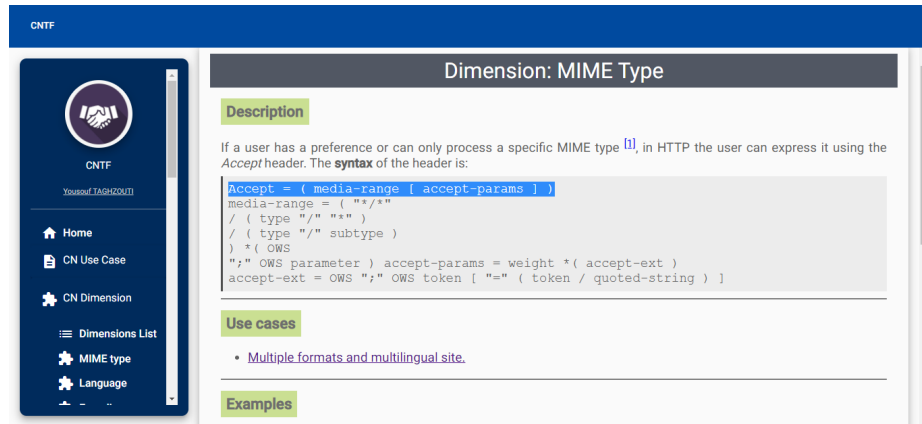


Fig. 2: CNTF MIME dimension example.

Each of these use cases must satisfy a set of requirements that could be found in the “CN requirement” section. Figure 3 shows the use case list page.

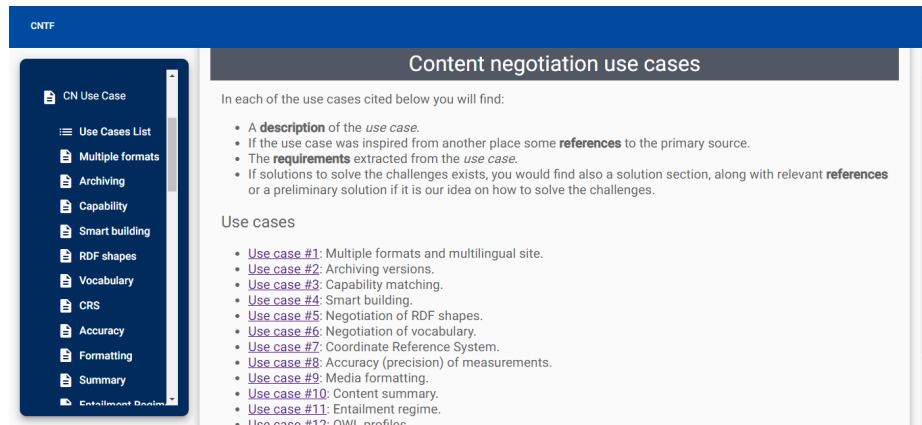


Fig. 3: CNTF use case list page.

5.3 CNTF as a Categorisation and Classification Medium

CNTF is organised in categories, which favours categorisation and classification. A user may check all the concepts of content negotiation: styles, dimensions, etc., and select those that best fit his/her use case. A table with the same structure as Table 2 is found in the “Classification” section in CNTF, where each row of the table is accompanied by a summary to aid understanding. For example the row in Table 2 has the summary:

“Istex is a French scientific archive [26]. The clients have the possibility to have the representation in several formats and for that, as mentioned on the site, an ARK is used. If we request the resource without specifying the media type, we receive a JSON file describing the existing variants and therefore we can consider it a reactive negotiation. The dimension is the media type and the transmission in ARK using the HTTP protocol.”

Ref	Date	Style	Dimension	Transmission	Protocol
[26]	2018	Reactive	Media type	ARK	HTTP

Table 2: An example of the classification of a CN contribution

5.4 CNTF as a CN Knowledge Graph

Most of the content of CNTF is available in a knowledge graph (KG)⁴, describing among other: use cases, references, dimensions, requirements. the CNTF knowledge graph is modelled according to the “CNTF ontology” <https://w3id.org/cntf/ontology>, with an excerpt in Listings 1.1.

...

```
@prefix : <https://w3id.org/cntf/ontology#> .

: a owl:Ontology;
  dct:title "CNTF ontology"@en;
  dct:description "This is the ontology for the CNTF resource"@en .

:UseCase rdf:type owl:Class ;
  rdfs:comment "The class of use cases for Content
  ↳ Negotiation."@en ;
  rdfs:label "Use Case"@en .

:hasDimension rdf:type owl:ObjectProperty ;
  rdfs:subPropertyOf owl:topObjectProperty ;
  rdfs:domain :UseCase ;
  rdfs:range :Dimension ;
  rdfs:comment "Links a Content Negotiation use case to a
  ↳ dimension of Content Negotiation"@en .

:hasRequirement rdf:type owl:ObjectProperty ;
  rdfs:subPropertyOf owl:topObjectProperty ;
```

⁴ <https://w3id.org/cntf/kg>

```

rdfs:domain :UseCase ;
rdfs:range :Requirement ;
rdfs:comment "Links a Content Negotiation use case to one
↔ of its requirements."@en .

```

...

Listing 1.1: Excerpt of the CNTF ontology <https://w3id.org/cntf/ontology>

5.5 CNTF as a Medium for Visualisation and Navigation of CN Concepts

CNTF users can navigate with the traditional hyperlinks to move from one page to another in order to explore different concepts. Alternatively, the user can get a general view of the relationships between concepts through the CNTF ontology “visualisation” section⁵. WebVOWL [17] is used to render the visualisation as shown in Figure 4.

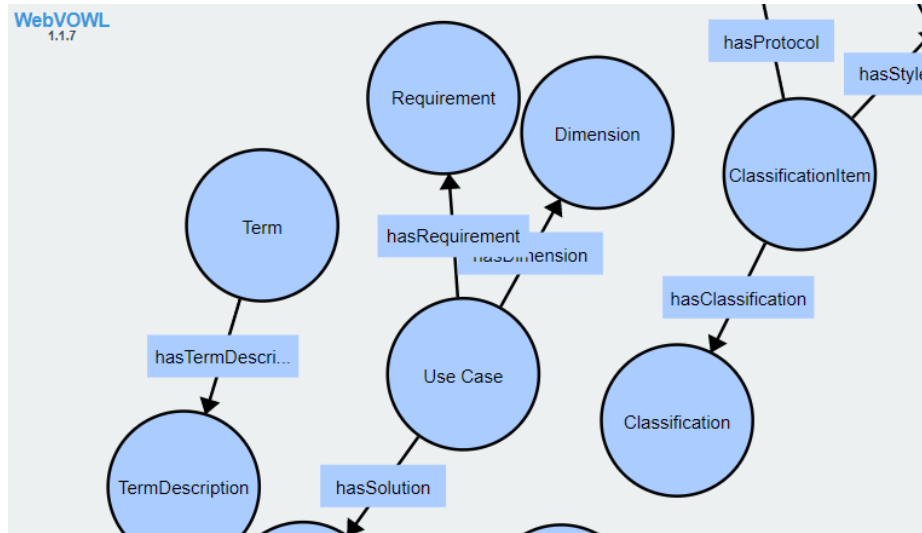


Fig. 4: A partial view of the CNTF ontology page.

5.6 CNTF as a Template for State of the Art Resources

CNTF is a website that represents a digital form of the survey on the CN domain but some components that represent generic parts could be reused to fit other

⁵ <https://w3id.org/cntf/visualisation>

domains such as: Use Cases, Requirements, Classifications (change the table columns with the used metrics), Terminologies, Abbreviations, References, etc., making it a candidate to be a model for digital surveys. Moreover, the same parts could be reused from the ontology.

6 Relevance of CNTF for the Semantic Web Community

6.1 Impact

CNTF reviews the available literature and compiles it into a single resource so that users interested in CN can easily find relevant materials. It addresses the problem of CN and attempts to identify new ways to better solve the available use cases. The resource covers the basics of CN: use cases, dimensions, styles with the advantages and disadvantages of using one over the other, and existing ways of conveying constraints. One can compare it to other resources dealing with CN, such as: MDN Web Docs⁶, Wikipedia⁷, or CN implementations in specific technologies and contexts^{8,9}, each of these resources mentions only some of the features listed above, but the CNTF brings them together and links them to give a coherent view of the problem that will be the basis for addressing the semantic CN problem. Another example of its use is that if a developer finds that the use case under consideration matches one of those identified in the resource, the proposed solutions could be used to provide a better service and, in turn, increase end-user satisfaction. Finally, recommending solutions that leverage semantic web technologies for the collected use cases would generate interest in using semantic web technologies, e.g., leveraging SHACL as a way to express the threshold of CN constraints¹⁰.

6.2 Reusability

Explanations are provided in the resource itself to aid user browsing. A concise documentation is also provided in GitHub for standard handling of the source code. The user can reuse some components in other state of the art digital resources as explained in the Section 5.6. CNTF has a potential for extensibility to meet future requirements. Thanks to the component architecture, one can add a navigation bar menu item and then create a component with the desired functionality. An example of such feature is mentioned in the future work in Section 7.

⁶ https://developer.mozilla.org/en-US/docs/Web/HTTP/Content_negotiation

⁷ https://en.wikipedia.org/wiki/Content_negotiation

⁸ <https://docs.microsoft.com/en-us/aspnet/web-api/overview/formats-and-model-binding/content-negotiation>

⁹ <https://www.playframework.com/documentation/2.8.x/ScalaContentNegotiation>

¹⁰ See the use case: Negotiation of RDF shapes in CNTF.

6.3 Design & Technical quality

CNTF proposes an ontology describing its content, and reuses higher-level ontologies such as: dct, foaf, biblio etc. CNTF as illustrated in Section 5 is able to meet the use cases and requirements described in Section 4. Finally, the content of CNTF is by default available in a human-readable format (HTML) and also in a machine-readable form (RDF).

6.4 Availability

CNTF is available at a persistent URI using w3id¹¹. Citations are given in the GitHub¹² repository in BibTeX or RDF along with the creators contact, CNTF is under the GNU General Public License v3, and the source code is available in the GitHub open code repository and in Zenodo¹³. If new CN use cases or solutions are proposed, they can be added to the resources and linked to already available elements of the resource, e.g. the CN dimension used. Finally, feedback is welcome, either via GitHub issues or as mentioned in the “maintenance” section of CNTF.

7 Conclusion and Future work

Content negotiation is a cornerstone of the Web architecture and a powerful mechanism for selecting the best representation from multiple available alternatives, but over the years, no single resource has collected *everything one needs to know* about it in one place. In this paper, we introduced CNTF, which is designed to meet a set of requirements extracted from three use cases: (I) Navigable design, (II) Extensible, (III) Categorisable, (IV) Maintainable. We explained how CNTF meets these requirements. We then illustrated the characteristics of CNTF and its relevance to the semantic community.

The future work of CNTF involves a number of initiatives, one of which is the ongoing collection of use cases for content negotiation, dimensions, etc., in particular the new content negotiation by profile. We plan to have an implementation of this approach to facilitate its adoption by having an experimental space, this space would give users the opportunity to test different content negotiation styles, dimensions and solutions to some of the use cases without having to implement them themselves.

Another future update is to be able to visualise the RDF data graph describing CNTF and interactively follow the links of interest. The graph would allow navigation from one concept to another. For example the user starts from a CN use case and navigates to the CN dimension associated with it. From there, the user can get additional information about the references of that CN dimension: who the authors are? in what year the publication was published? The list of upcoming features can be found on the resource “updates” page.

¹¹ <https://w3id.org/cntf/>

¹² <https://github.com/YoucTagh/CNTF/blob/master/README.md#citation>

¹³ <https://doi.org/10.5281/zenodo.6504504>

Resource Availability Statement: Source code for the CNTF website and ontology used in Section 5.4 are available on Github <https://github.com/youctagh/cntf>. The Resource is available in Zenodo <https://doi.org/10.5281/zenodo.6504504> and at the permanent link <https://w3id.org/cntf/>.

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