CIAO-WPS
Automatic and Intelligent Orchestration of Geospatial Web Services using Semantic Web (Web 3.0) Technologies

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Abstract: Current geospatial datasets and web services are disparate, obscure and difficult to expose to the world. With the advent of geospatial processes utilizing temporal data and big data, along with datasets continually increasing in size, the problem of under-exposed datasets and web services is amplified. Current text search capabilities do not sufficiently expose web services and datasets for use in on-the-fly geospatial use cases. End users are required to know the exact location of these online resources, their format and what they do. For example, to locate an OGC (Open Geospatial Consortium - http://www.opengeospatial.org)-compliant WPS (Web Processing Service) that performs flood modelling, a Google Search for "Flood Modelling WPS" is insufficient to find relevant results. This paper proposes the integration of semantic web concepts and technologies into geospatial datasets and web services, making it possible to link these datasets and services via functionality, the inputs required and the outputs produced. To do so requires the extensive use of metadata to allow for a standardised form of description of their function. There are already ISO (International Organization for Standardization - www.iso.org) standards in place (ISO 19115-1:2014) that specify the schema required for describing geographic information and services. The use of ontologies and AI (Artificial Intelligence) then allows for the intelligent determination of which web services and datasets to use, and in what order they are to be used to achieve the desired final output. This research aims to provide a method to automatically and intelligently chain together web services and datasets to assist in a geospatial analyst's productivity. A simple prototype termed CIAO-WPS (Chet's Intelligent, Automatically-Orchestrated Web Processing Services) is created as a proof of concept, using the Python programming language. The prototype seeks to reinforce ideas in regards to pathing and cost constraints, as well as explore overlooked designs.

1 INTRODUCTION

ACIL Tasman (ACIL Tasman, 2008) determined that inefficient access to geospatial data is estimated to have reduced the direct productivity impacts in certain sectors by around \$0.5 billion, and that reductions in these inefficiencies will contribute to Australia's economic, social and environmental development goals. This is not only due to the current exposure issues of geospatial datasets and web services, but also the manual processing and workflows involved in chaining together these resources to achieve a task.

Current geospatial workflows that include geospatial web services (for example, flood prediction within a given area) are manual, requiring the chaining together and intervention between the running of processes to be manually performed to ensure the relevant output is generated. The possible introduction of human error as a result of manually processing and searching the datasets and/or web services also increases the probability that the output generated is based on out-dated or even irrelevant data.

There are currently many inefficiencies with processing and using geospatial data. Yu and Liu (Yu and Liu, 2013) have documented these similar inefficiencies in their attempts to implement a new system that republishes real-world data as linked geo-sensor data. Janowicz (Janowicz and Blomqvist, 2012) has also observed in their survey of semantically-enabled DSS (Decision Support Systems), that the users of said system still require a lot of work in increasing the efficiency and productivity of the intelligent system. The research outcomes of this project aligns with the conclusions of the survey.

The ability to automatically and intelligently orchestrate multiple geospatial web services to provide intelligent and useful output from a complex user

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query will greatly assist a geospatial analyst's efficiency, accuracy and productivity. Being able to orchestrate geospatial datasets and WPS to achieve a task will be adaptable to other fields as well. Integrating Semantic Web concepts and technologies into various non-geospatial datasets and Web Services will allow for automatic orchestration and hence, increased productivity. As an example, Kauppinen (Kauppinen et al., 2014) has documented how semantic technologies are being integrated within Brazilian Amazon Rainforest data, that has led to increased productivity and efficiency in that area.

To advance automated and intelligent orchestration, certain features and specifications must be added to the current WPS standard to allow for machine interpretation of these Web Services, to be able to effectively and reliably determine which Web Services are appropriate for completing a given task. Critical information that paves the way for automatic orchestration are currently not defined in the WPS specification and this research aims to set an example for the addition of metadata and functions that allow for automatic orchestration as the next logical step for WPS.

This paper explores automated orchestration methods of web services and data from multiple, disparate sources; in contrast to the current widespread method of supplying all the data and services to the end user and leaving it to them to manually analyse and process the vast amounts of varying kinds of data, and determine what processing needs to be executed. Natural language processors and ontologies are proposed to build the required Artificial Intelligence to automatically chain together the resources to produce useful output for the end user.

2 BACKGROUND

In the last decade, the Web has been moving towards Service-Oriented Computing architecture supporting automated use (Ameller et al., 2015) (Huhns and Singh, 2005). This architecture aims to build a network of interoperable and collaborative applications, independent of platform, called services (Papazoglou and Georgakopoulos, 2003) (Pugliese and Tiezzi, 2012). The geospatial world is also moving away from the traditional desktop application paradigm to processing and accessing data on-the-fly from the Web using Web Processing Services, as outlined by Granell et al. (Granell et al., 2012). As Web Service technology has matured in recent years, an increasing amount of geospatial content and processing capabilities are available online as Web Services (Zhao et al., 2012). These Web Services enable interoperable, distributed, and collaborative geoprocessing to significantly enhance the abilities of users to collect, analyze and derive geospatial data, information, and knowledge over the Internet (Zhao et al., 2012).

Current geospatial workflows and processes rely on manual human intervention in searching for the relevant and/or required datasets and Web Services (Granell et al., 2012). These workflows also require human analysis of the output at each stage of processing, and manual determination of which Web Processing Service to use next on the data to achieve the final required output (Granell et al., 2012). This has been observed to lead to inefficiencies in the accuracy and currency of the data as we are relying on a human user to search for these ill-exposed datasets and Web Services. For example, a human user will tend to have a bias towards a dataset or Web Service that he/she has used before, regardless of the currency of the data or the frequency of updating of the data, a phenomenon known as the Mere-repeated-exposure paradigm (Zajonc, 2001). Geospatial Web Services and datasets that may be vital in contributing to the final result may also be left unexposed due to current search technologies not being able to expose Web Services sufficiently. The way that Web Services are searched for is by functional and non-functional requirements as well as interactive behaviour (Wu, 2015a), which require more than simple keyword matching, as per current search algorithms.

2.1 The Semantic Web (Web 3.0)

The Semantic Web aims to create a web of information that is machine-readable and not just human-readable (Berners-Lee et al., 2001). This allows machines to automatically find, combine and act upon information found on the Web (Pulido et al., 2006).

The objective of the Semantic Web is accomplished by integrating semantic content into web pages that helps describe the contents and context of the data in the form of *metadata* (data about data) (Handschuh and Staab, 2003). This greatly improves the quality of the data so that a machine is able to understand what the data is for, what it can be used for and what other things are linked to it (Harth, 2004) (Berners-Lee et al., 2001). This allows the machine to process and use the data, instead of the current paradigm of relying on a human to interpret, process and understand data.

Ontologies are a core component of the Semantic Web, and are required by machines to be able to intelligently reason and infer data (Pulido et al., 2006). An ontology is a set of data elements within a domain that are linked together to denote the types, properties and relationships between them (Beydoun et al., 2014). Ontologies contribute to resolve semantic heterogeneity by providing a shared comprehension of a given domain of interest (Nacer and Aissani, 2014). In knowing the relationships that exist between data, search can be expanded to incorporate relationships that exist between the data as well as traditional string matching. The search is now a semantically intelligent search.

Put simply, the Semantic Web aims to create a web of knowledge and information that is both machine and human-readable (Pulido et al., 2006)(Berners-Lee et al., 2001). This consequently allows the capability for machines to automatically find, combine and act upon information found on the Semantic Web.

There are currently well-defined, open standards in place for moving towards Web 3.0, where resources and ontologies are shared (World Wide Web Consortium, 2001). The advantage of this is that there is no reinvention of the wheel, however there is still significant development required in integrating Semantic Web techniques into spatial applications. To aid in the movement towards semantic spatial data manipulation, the OGC has established standards for storing, discovering and processing geospatial information (Janowicz et al., 2010). Having these standards (W3C -World Wide Web Consortium and OGC - Open Geospatial Consortium) to work with creates the ability to simplify any data collected from multiple sources that are usually stored in their own unique proprietary formats, and create a standardised format of the spatial data and processes for use both in research and in industry.

2.2 The OGC WPS Standard

Web Processing Services, as their name suggests, provide services over the Internet to consumers, be it data access or processing. They are client-side platform-independent and have standardized input and output protocols so that consumers are able to utilize these Web Services (Wu, 2015b).

It is not uncommon for a company website to be converted into an interactive, completely-automated, web-based application (such as those for stock trading, electronic commerce, on-line banking, travel agencies, etc) (Kovács and Kutsia, 2012). It is worth noting that to achieve reliable application development, appropriate specification and verification techniques and tools are required. Systematic, formal approaches to the analysis and verification of a web service or application can deal with the problems of this particular domain by automated and trustworthy tools that also incorporate semantic aspects (Kovács and Kutsia, 2012).

In the geospatial world, the OGC is the main standards body for geospatial data and technology. The standard published by the OGC in regards to Web Processing Services is currently in its second iteration (v2.1), that brings about enhanced features to improve the functionality of web services, especially in regards to asynchronous operation and error handling. However there has been little work on the orchestration of Web Services. This research requires the adding of functionality to the standard.

The OGC WPS standard sets out the groundwork for exposing features, inputs and outputs and processing of a geospatial web service (Lopez-Pellicer et al., 2012). Loosely defined, it simply describes the syntax and minimal requirements of a geospatial Web Processing Service.

An example of a WPS is a service that provides polygon intersection capabilities. A user provides two or more polygons as input to the WPS and receives a polygon of their intersections as output, or a NULL value if the polygons provided do not intersect. The WPS is specific as to what format and coordinate reference systems are used in the polygons that it processes.

Using and extending the WPS specification for orchestration within a workflow is not a foreign concept in the geospatial community. For example, a partially manual system of orchestrating PyWPS (A Python implementation of WPS) within Taverna has been proposed to assist in their efforts to assess modelling in urban areas (De Jesus et al., 2012). This workbench for mapping business processes and workflows to chains of web services to complete geospatial tasks shows promise and feasibility.

By integrating Semantic Web concepts in the form of ontologies and metadata tags, as well as improvements and expansion of the OGC WPS standard (and possibly other open standards as seen fit), it is possible to expose all these useful datasets and Web Services that the user hasn't considered through better metadata and linking them through ontologies. The use of Semantic Web technologies allows us to look for meaning, rather than simple keyword matching. While this has been achieved to a certain degree in generic, publically-available search engines such as Google by utilizing semantic analysis algorithms (Cilibrasi and Vitányi, 2007), there has been little development in the geospatial area.

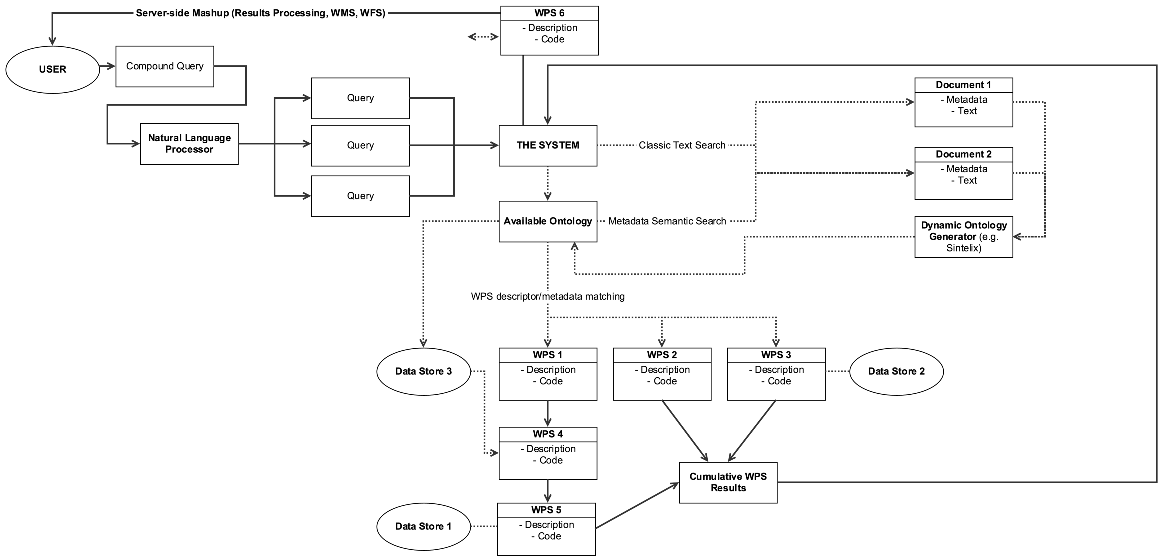

Figure 1: A system flow diagram of how a user query is processed through CIAO-WPS.

3 APPROACH

To automate the orchestration process, there are several essential aspects that must be developed to assist in this regard.

Firstly, NLP (Natural Language Processing) methods require investigation to determine the meaning of a user query and semantically search for information using ontologies. In situations where a relevant ontology is not available, a classic text search may be executed and an ontology dynamically generated on-the-fly from the search results using an off-the-shelf product. In this scenario, ontologies may be used akin to a workflow, where information and process interdependencies are linked.

Secondly, Artificial Intelligence is explored that utilizes ontologies to determine what Web Services and datasets are required to generate an accurate result to the user's query. Ontologies may then be used to link together the functions, inputs and outputs of the web resources allowing the AI solution to determine which order the web services will run in to achieve an output that will satisfy the end user's query.

Finally, we identify enhancements for the OGC's open standard for WPS by adding functionality and supporting metadata to allow for automatic orchestration by the AI system developed under this research.

An overview of such a proposed system can be seen in Figure 1.

The user firstly feeds a complex query in natural language to the system. The query is then broken down to simple, modular queries for ease of understanding using the NLP. These individual queries are then searched for in any available ontologies, and if the available ontologies are not available, the dynamic ontology generator is used to create ontologies on-the-fly using documentation and expert domain knowledge from trusted sources, obtained via classic text search from the Internet. Alternatively a system can also be put in place to query the user for additional information and details that will help complete the search.

With multiple ontologies on-hand and ready-to-use, information in regards to the user's original query can be searched within the ontologies to obtain links for, and between datasets and relevant web services. Using rules of inference and logic processing via AI, we are able to obtain a chain of Web Services and datasets in order to satisfy the user query. The sequence in which these datasets and Web Services are invoked in is also important; this is catered for by the AI. Multiple pathing and costing options can also be provided for the user to determine the most cost-efficient path to the end result (processing time or payment to use). An example of how multiple paths may lead to the same outcome is shown in Figure 2.

The end result, however, may not always be in the most relevant form to be utilized by the user. If that is the case, we can rely on Web Services to transform the final output to a more usable form. For example, a table of rainfall predictions is not as readily-usable to a human user in comparison to a percentage chance of rain in an area, drawn on a map using a WFS (Web

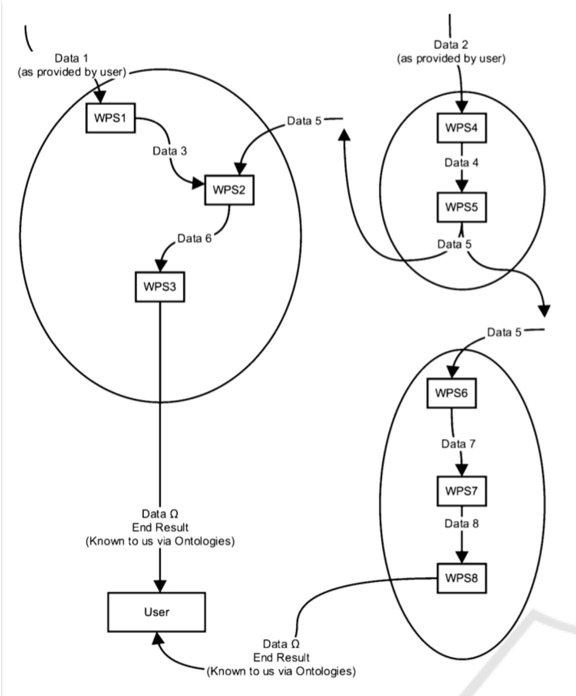

Figure 2: Different paths for the same outcome.

Feature Service) or WMS (Web Map Service) derived from the table data to show different rainfall chances in different areas of the map via heat layers.

4 USE CASE SCENARIO

A typical scenario that shows how CIAO-WPS may be utilized is shown in Figure 3. The following paragraphs will guide the reader through the diagram.

In this example, the user feeds a complex, natural-language query into the system. NLP breaks the query down into three separate sections. "What are the chances", "of flooding" and "in my area".

Based on "in my area", CIAO-WPS realizes the statement implies location of the user and therefore the first step would be to obtain the location of the user as this will provide very important context for the other queries. This could use simple GPS on the user's smart phone/device.

With an ontology such as the SWEET (Semantic Web for Earth and Environmental Technology) ontology readily available to CIAO-WPS, the system looks up "flooding" within the ontology, that will give links to elements such as "rain", "water", "severe weather condition". These elements will further give links to information such as links to BOM (Bureau of Meteorlogy) severe weather warning services or flood prediction Web Services, for example. As for the "in my

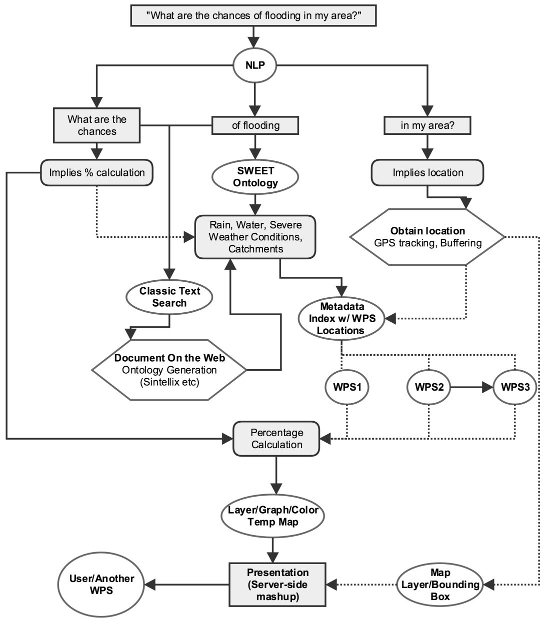

Figure 3: A sample use case scenario of CIAO-WPS.

area" section, the location of the user becomes extremely important at this point as CIAO-WPS will focus on the vicinity of the user.

"What are the chances" prompts CIAO-WPS that this is most likely a percentage/likelihood calculation. This contextual information is fed into the search for related Web Services and datasets.

With the query broken down, CIAO-WPS will attempt to use traditional text-search tools or further delve into more specialized ontologies to obtain more information and methodologies to obtain the relevant Web Services and datasets. This in turn could reveal more critical information such as workflows that provide a more authoritative source of guidance as to what Web Services and what datasets to access in what order.

Using AI and OWL-DL, CIAO-WPS attempts to obtain a path that fits in with user-defined restrictions and will fulfill the user's query. If a section or piece of information along the path is unavailable, CIAO-WPS will notify the user and fallback into a semi-supervised mode, in which the user may provide the needed information or direct which path CIAO-WPS should take.

In this case, we assume that all information is obtained successfully within the user's set parameters. The results are accumulated by CIAO-WPS. However what the system has obtained is simply polygons in the vicinity with a percentage chance of flooding attached.

This would not be useful to the user and therefore

CIAO-WPS draws the polygons on a map, while coloring in the chances of flooding with different intensities using a heat scale. This is much more useful to a human user than presenting the user with a table of numbers and coordinates for the edges of the polygon.

5 PROTOTYPE

A proof-of-concept model of CIAO-WPS has been built, with focus mainly on the chaining of WPS via metadata added outside of the OGC WPS standard. An Agile approach has been used for software development used in developing CIAO-WPS, prototypes and proof-of-concepts of modules of the system are continuously built and discarded to serve as reality and logic checkers for the research. At the moment the working proof-of-concept is currently available at http://research.haxx.net.au/cwps

The prototype was created in Python using classes to serve as "dummy" WPS with input and output formats and their parameters. Additional information such as response time and algorithmic complexity were added as well to explore these ideas further.

In Figure 4, we see a dummy WPS that is a Fire Modelling WPS, with appropriate metadata in its GetCapabilities section and its input (US date in the format mm/dd/yyyy). It outputs a polygon in vector format of the predicted fire area. This WPS has metadata that states that it has a high cost but a quick response time and a relatively simple algorithmic complexity.

In Figure 5, we see another dummy WPS that also

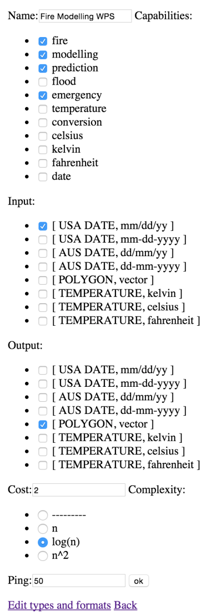

Figure 4: Dummy Fire Modelling WPS 1.

performs fire predictions, with appropriate metadata in its GetCapabilities section and its input (US date in the format mm/dd/yyyy), similar to the first fire modelling WPS. It outputs a polygon in vector format of the predicted fire area. The metadata of this version states that it has no cost but a slower response time and a relatively more complex algorithmic complexity. In Figure 6, we see a dummy WPS that is a date

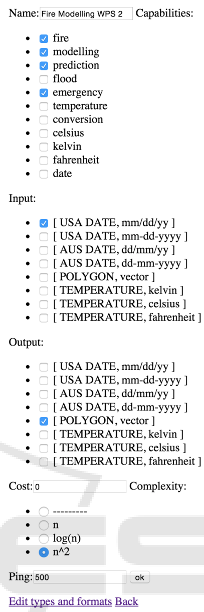

Figure 5: Dummy Fire Modelling WPS 2.

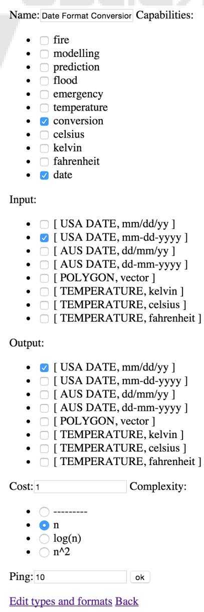

Figure 6: Dummy Date Format Conversion WPS.

format conversion WPS, with appropriate metadata in its GetCapabilities section and its input (American date in the format mm-dd-yyyy). It outputs an American date in the format mm/dd/yyyy.

In Figure 7, we see a dummy WPS that is a regional date conversion WPS, with appropriate metadata in its GetCapabilities section and its input (Australian date in the format dd-mm-yyyy). It outputs an American date in the format mm-dd-yyyy.

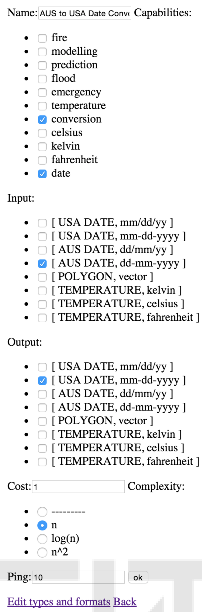

Figure 7: Dummy AUS to US Date Conversion WPS.

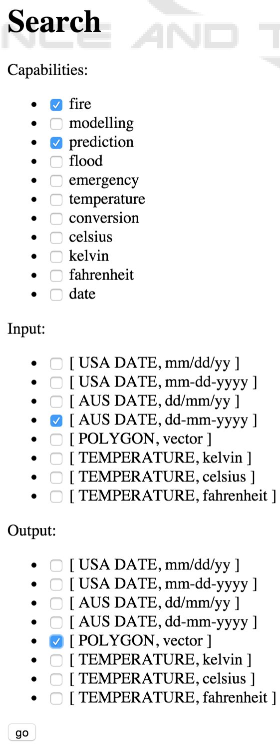

Figure 8: CIAO-WPS Proof-of-concept Search Interface.

The interface for this proof-of-concept can be observed in Figure 8, where the user wants to do “fire modelling”, but only has an Australian date in the format dd-mm-yyyy as input.

Finally in Figure 9 we have the results displayed. CIAO-WPS does a custom-tuned BFS (Breadth-First Search) to explore successful paths and choose the path that satisfies the user’s constraints. At this stage, the prototype will reveal multiple options for shortest, simplest, cheapest and most responsive paths. This idea translates to a semi-supervised operation in the final system.

6 CONCLUSION AND FUTURE PLANS

This paper has proposed the workings of a system in development that aims to automate the orchestration of WPS intelligently using Semantic Web techniques and concepts. The proof of concept shows the metadata required for orchestration that is not present in the WPS 2.1 standard. The advantages that CIAO-WPS hopes to achieve are increased productivity and efficiency, reduced manpower in locating resources, reduction and possible elimination of the manual, human analysis and linking of related datasets and WPS. CIAO-WPS, throughout its development, strives to improve itself from other attempts of orchestration by adding automation and intelligence.

Future plans for CIAO-WPS is the full integration and use of ontologies in the decision-making process of choosing paths and the order in which Web Services are run. Using OWL-DL will allow for more complex constraints such as file server location restrictions. Further improvements to the search algorithm are also planned for better efficiency when large numbers of WPS are involved. This ensures consistent response times for users in time-demanding applications. Finally, a learning algorithm that ranks paths based on past successful queries will also be explored.

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Path

Shortest Path

Path [<WPS: AUS to USA Date Conversion WPS>, <WPS: Date Format Conversion WPS>, <WPS: Fire Modelling WPS>] with cost 4, complexity O(n + n + log(n)), and ping 70.

Simplest Path

Path [<WPS: AUS to USA Date Conversion WPS>, <WPS: Date Format Conversion WPS>, <WPS: Fire Modelling WPS>] with cost 4, complexity O(n + n + log(n)), and ping 70.

Cheapest Path

Path [<WPS: AUS to USA Date Conversion WPS>, <WPS: Date Format Conversion WPS>, <WPS: Fire Modelling WPS 2>] with cost 2, complexity O(n + n + n^2), and ping 520.

Lowest Ping

Path [<WPS: AUS to USA Date Conversion WPS>, <WPS: Date Format Conversion WPS>, <WPS: Fire Modelling WPS>] with cost 4, complexity O(n + n + log(n)), and ping 70.

All Paths

- Path [<WPS: AUS to USA Date Conversion WPS>, <WPS: Date Format Conversion WPS>, <WPS: Fire Modelling WPS>] with cost 4, complexity O(n + n + log(n)), and ping 70.
- Path [<WPS: AUS to USA Date Conversion WPS>, <WPS: Date Format Conversion WPS>, <WPS: Fire Modelling WPS 2>] with cost 2, complexity O(n + n + n^2), and ping 520.

Figure 9: CIAO-WPS Proof-of-concept Results.

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