Jul 12th, 2:30 PM - 2:50 PM

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Abstract: Interoperable software development uses principles of component reuse, systems integration, flexible data transfer, and standardized ontological documentation to promote access, reuse, and integration of code. While interoperability principles are increasingly considered technology standards in software engineering, adoption by the environmental modeling community has been slow. We created an Application Programming Interface (API) for the U.S. Environmental Protection Agency's Human Well-being Index (HWBI) model based on interoperability principles. The HWBI characterizes economic, social, and environmental services during years 2000-2010. For each county in the U.S., specific metrics (e.g., life expectancy, housing affordability, voter turnout) are used to calculate scores for eight domains of well-being: Connection to Nature, Cultural Fulfillment, Education, Health, Leisure Time, Living Standards, Safety and Security, and Social Cohesion. These eight domain values are then used to determine an overall HWBI classification for each U.S. county, state, and region. Interoperability best-practices are demonstrated through the reuse of the code and database for both a web application and a desktop application. The web application accesses the HWBI API services with a browser-based interface to encourage data exploration and obtain feedback from the public. Desktop access is enabled via a plug-in for an agent-based modeling system that uses the HWBI API for output calculations. Our software incorporates best-practices for front- and back-end design that includes automated code testing, data transfer standardization for efficiency and responsiveness, emerging documentation standards, and terminology services and controlled vocabularies to promote reusability.

Keywords: REST API; interoperability; web services; USEPA

1   INTRODUCTION

Traditionally, environmental models were custom-built to address specific research needs. During the 1980s and 1990s tightly-coupled software interfaces generated monolithic applications with complex, inaccessible, and inflexible code. Access to modeling tools and data was limited and alteration, extraction, and reuse of model code was tedious. Today, the broader software community recognizes the need to build flexible, modular, component-based software designed for reuse and interoperability. The International Organization for Standardization (ISO) International Electrotechnical Commission (IEC) (2001) defines interoperability as "the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units." However, component-based functional units are not typically integrated into environmental modeling despite being a software engineering standard (de Kok et al., 2015).

We implement a modern, interoperable software design as an example of interoperability best-practices by creating a REST (REpresentational State Transfer) API (Application Programming Interface) and applying Goodall's concept of model interoperability through web services (Goodall et al., 2013). Exposing the API

in this manner allows us to leverage the API for our own use cases and also permits others to integrate these services in novel applications (Goble et al., 2010). The web service approach is advantageous because it eliminates language, operating system, and platform barriers to interoperability. Using models as web services hinges on open access, minimal barriers to entry, and scalability (Nativi et al., 2013). Implementing these principles provides access to and promotes integration of environmental models (Castronova et al., 2013).

To demonstrate implementation of a web-services based interoperability strategy, an API for the Human Well-being Index (HWBI) model was created for consumption by a public-outreach visualization website and a desktop environmental modeling tool, Envision (Bolte 2012). The HWBI model and its REST API demonstrate interoperable software design to promote model discovery, evaluation, and integration while satisfying three primary objectives:
1) Create an HWBI REST API based on interoperability practices to enable consumption of the HWBI by multiple users;
2) Generate a website that consumes the HWBI REST API to support public access; and
3) Link Envision to the HWBI REST API to enable well-being calculation using land use change data.

2   IMPLEMENTATION

2.1   HWBI and Envision

The HWBI (Smith et al., 2013; Summers et al., 2014) processes more than 100 nationally-available data layers to assess economic, social, and ecosystem services across the U.S. at regional, state, and county levels for years 2000-2010. Input data consists of both subjective and objective information from sources such as the U.S. Census Bureau American Community Survey, the Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System, and others (Smith et al., 2012). A different set of regional input metrics was also considered to assess eight values for the "domains of well-being": Connection to Nature, Cultural Fulfillment, Education, Health, Leisure Time, Living Standards, Safety & Security, and Social Cohesion. These "service" and "domain" values were evaluated using multiple linear regression and relationship-function statistical techniques to identify correlations and calculate coefficient values for each service-domain relationship. The HWBI model uses the resulting coefficients to process 22 economic, ecosystem, and social services values to calculate eight values for the "domains of well-being," as well as a total HWBI score for each U.S. county.

Envision is a Geographic Information System (GIS) and modeling desktop tool for integrated planning and environmental assessment (Guzy et al., 2008). Envision uses spatially-explicit environmental data layers and policy rules to drive an agent-based model (Bolte et al., 2006). A query-based framework dictates how individual land manager "agents" use policy rules to guide parcel-level land use change over time. The model has been applied to various study areas (e.g., Oregon, Puerto Rico, and Florida) (Nolin 2012; Yee et al., 2014). In addition, plug-ins including the Terrestrial Ecosystem Services (Terr-ES) enable quantification of spatiotemporal patterns in ecosystem service provision associated with different land cover types. Envision is often used for comparative environmental modeling under varying climate and policy scenarios.

2.2   REST API

REST APIs allow flexible access to databases and are often considered the "connecting glue between modern applications" (Open API Initiative, 2016). Modern implementations of REST API principles use HTTP (Hypertext Transfer Protocol) to manipulate and access resources such as models, services, and components (Granell et al., 2013). Relying on HTTP behavior allows a Uniform Resource Identifier (URI) to interact with a database. Rather than specifying the function of interactions, HTTP methods such as POST, GET, PUT, and DELETE are used to read or edit resources (Fielding, 2000). Use of HTTP standards

suggests that the API has been built for consumption by a browser, however, other endpoints can also access the resource.

While there are no accepted Request for Comments (RFC) specifications or World Wide Web Consortium (W3C) standards for REST protocols, certain best practices are currently proposed by the community of users (Hazelwood, 2016). In general, interoperable design of REST APIs involves thoughtful construction of resources. In environmental modeling, resources are often data values or model results -- the resource can be a single value (instance resource) or group of values (collection resource). Well-designed resources are coarse-grained for generalizability, avoiding the need to create complex remote procedure calls. REST APIs are architecturally styled for use-case scalability.

Well-documented return data with metadata and resource-location information is an essential attribute of well-written REST APIs. If a PUT request creates a resource, a "201 created" return indicates the request was successful. The response should also return the location header of the newly created item. A GET or POST request will return standard "200 ok" as well as a response body. It is valuable to incorporate a metainfo tag within the response body that describes the request, indicates a version number, and provides a timestamp of data creation and update times using the ISO 8601 UTC protocol (Figure 1). Version should also be indicated in the media-type response code (e.g., application/json; v=1).

Hypermedia as the Engine of Application State (HATEOAS) (Alarcon et al., 2010) specifications guide and constrain REST application architecture. HATEOAS-compliant APIs are structured to promote discoverability of actions by providing a direct link to each resource location and listing the HTTP method actions that can be taken to interact with that resource. Content negotiation is also essential since it allows users to request specific return formats and data version. Content negotiation can be accomplished through HTTP method input filtering (e.g., GET /data/42?output=xml or GET /data/42?output=json), resource extension (e.g., GET /data/42.xml vs. GET /data/42.json), or acceptance headers (e.g., HEADER Accept: application/json GET /data/42).

```json
{
  "metainfo": {
    "status": "Finished",
    "timestamp": "2016-02-22 09:27:08",
    "service_url": "http://qed.epa.gov/rest/hwbi/locations/GA/Clarke"
  },
  "inputs": [
    {
      "state": "georgia",
      "county: "clarke",
    }
  ],
  "services": [
    {
      "ServiceID": "S01",
      "ServiceName": "Capital Investment",
      "Description": "Capital Investment",
      "ServiceType": "Economic",
      "Score": 0.5858767309
    },
    {
      "ServiceID": "S02",
      "ServiceName": "Consumption",
      "Description": "Consumption",
      "ServiceType": "Economic",
      "Score": 0.5130107144
    },
```

Figure 1. Example HWBI REST API GET response body. A successful content negotiation will return a JSON response that contains metainfo, the provided input, and the associated outputs.

For the HWBI, two REST API endpoints are available to interact with the database (Figure 2). The qed/rest/hwbi/locations endpoint takes state and county names as input and provides pre-calculated HWBI database values for each U.S. county. The qed/rest/hwbi/calc endpoint takes thirty user-supplied input values: twenty-two service scores and a "relative importance value" for each of the eight domains. The "relative importance values" are used to weigh domain scores based on user preferences. For example, some users may give greater importance to "Education" while others give greater importance to "Health". The qed/rest/hwbi/calc endpoint then uses these inputs and model equations to calculate 8 domain values and a total HWBI score. Both REST API endpoints return metadata information, as well as a complete list of input and output data values: service scores, domain values, domain weights, and overall HWBI scores. GET requests can be made directly through the Uniform Resource Identifier (URL) string, and POST requests can be made using the request body to specify input values. For our purposes, acceptance headers were used for content negotiation and the state transferred between machines is formatted as nested JavaScript Object Notation (JSON) by default. HATEOAS-compliant resource structure hierarchies were implemented to promote method discoverability. Open source Swagger 2.0 (Open API Initiative, openapis.org) was used to build an interactive representation of the HWBI API for documentation and discoverability.
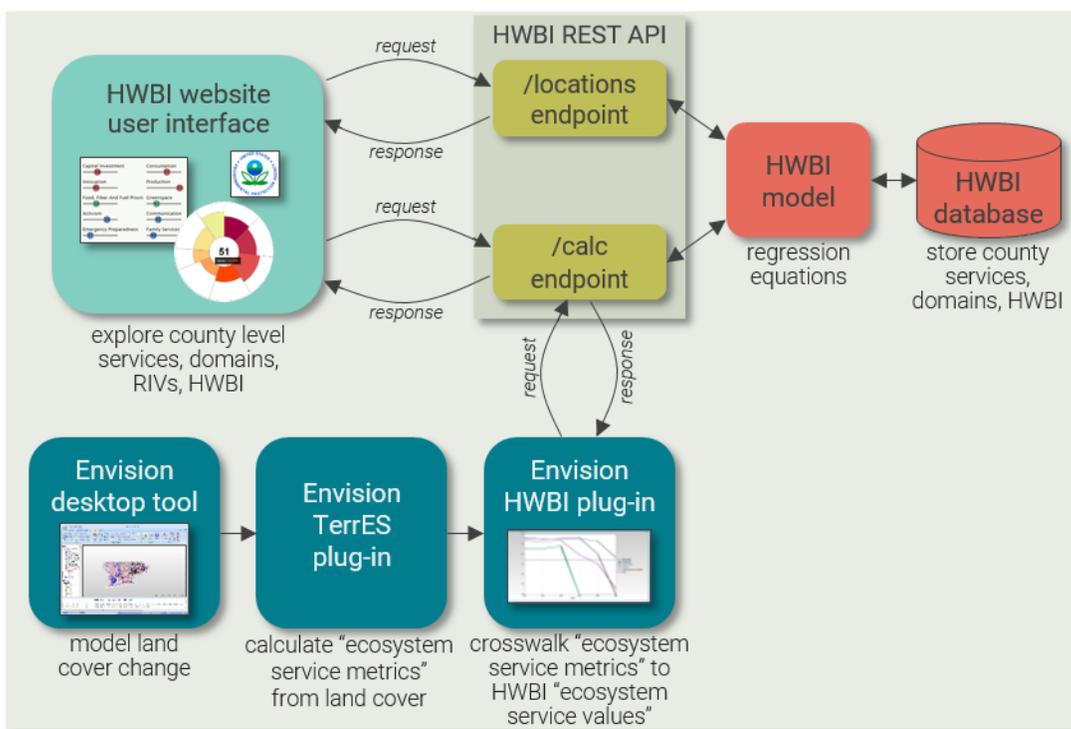

Figure 2. System architecture. The HWBI API uses coefficients to process 22 economic, ecosystem, and social services values in order to calculate values for 8 "domains of well-being" and provide a total HWBI score for each U.S. county. This API is used by a web application that includes a description of the HWBI, documentation of model equations, and an interactive interface that explores services, domains, and overall HWBI scores for each county in the U.S. The same API is used by the desktop application Envision to assist with analysis of ecosystem services and associated variations in human well-being based on changing land cover.

2.3   HWBI QED Web Application

To demonstrate integration of the HWBI REST API, a web application hosted on the United States Environmental Protection Agency (USEPA) Quantitative Environmental Domain (QED, http://qed.epa.gov/hwbi) was created. The site includes a description of the HWBI, documentation of model

equations, a list of references, quality control quality assurance (QAQC) descriptions, and an interactive interface (Figure 3) that explores services, domains, and overall HWBI scores for each county in the U.S. To enhance public understanding of the model, the interface uses intuitive, interactive elements and incorporates data visualization design principles. The D3.js JavaScript library was used for visualization (Bostock et al., 2011).
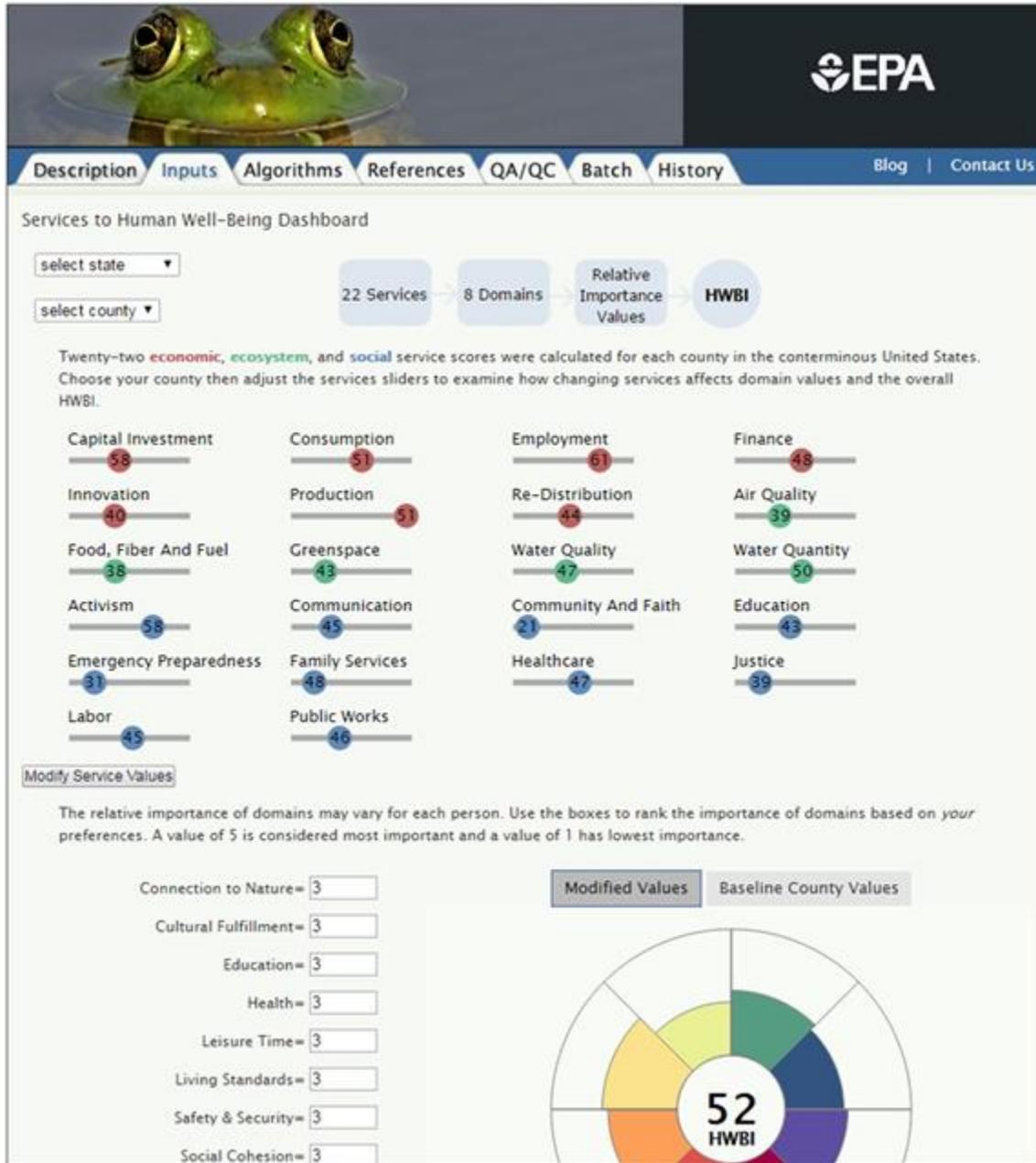

Figure 3. HWBI front-end web application. The site provides an intuitive, interactive interface that incorporates data visualization design principles. The application allows for exploring relationships between environment, sustainability, community resiliency, and human health metrics, the web tool reveals the complex interactions between society, economy, and environment.

While the primary goal of this project is to identify and implement interoperability software standards, the website also promotes data-sharing and encourages public participation in the USEPA HWBI. The web tool increases community involvement in the HWBI assessment process. The web platform utilizes responsive data visualization and includes an interactive capability to both inform and empower communities by cultivating user feedback. By exploring relationships between environment, sustainability, community resiliency, and human health metrics, the web tool reveals the complex interactions between society, economy, and environment.

2.4   Envision and HWBI API

The Envision model is designed to encourage creation of plug-in tools (Bolte, 2012). The model includes an HWBI plug-in created by the USEPA Environmental Modeling and Visualization Laboratory (EMVL) to assist with analysis of ecosystem services and associated variations in human well-being based on changing land cover. However, the original EMVL version of the HWBI plug-in did not use a dynamically updated HWBI database. Based on initial plug-in architecture, Envision users had to manually obtain HWBI scores for each county in their study area in a csv file format and then upload the data by modifying pathnames in an xml file. In addition, Envision users needed to download and install a new version of the plug-in if HWBI model equations were improved or altered. To avoid issues with outdated software, updates, and re-installation requirements, EMVL is linking the HWBI plug-in to the HWBI REST API web-service. This simplifies data retrieval and ensures that calculations of HWBI based on Envision-modeled land cover will always use the most recent, quality-assured, and peer-reviewed HWBI equations available. It must be noted that there are also disadvantages when relying on web services for data access. Users are dependent on an internet connection and may experience performance issues such as slower data download compared to local machine data requests. However, for the HWBI the benefits of using web services (dynamically updated database and model) outweigh minimally slower data retrieval. Driving models with REST API inputs extends model functionality and demonstrates interoperability (Peckham and Goodall, 2012).

3   SUMMARY AND CONCLUSIONS

The HWBI integrates social, economic, and ecological data to holistically characterize human well-being at multiple scales. The constructed HWBI API implements interoperability software standards and practices in the context of a model that performs science, enabling data sharing and public interaction with the tool. This approach encourages broad dissemination of results and collaboration across multiple government agencies and inherently increases access to modeling systems and data by the public.

ACKNOWLEDGMENTS

REFERENCES

Alarcon, R., Wilde, E., Bellido, J., 2010. Hypermedia-driven RESTful service composition. In Service-Oriented Computing (pp. 111-120). Springer Berlin Heidelberg.

Bolte, J.P., Hulse, D.W., Gregory, S.V., Smith, C., 2006. Modeling biocomplexity actors, landscapes and alternative futures. Environmental Modeling and Software. 22 (5): 570-579.

Bolte, J.P., 2012. A Guide to Application Development: Envision. Oregon State University. http://envision.bioe.orst.edu/Documents/Envision%20Developers%20Manual.doc

Bostock, M., Ogievetsky, V., Heer, J., D3: Data-Driven Documents. IEEE Transactions on Visualization and Computer Graphics. 17 (12), 2301-2309.

Castronova, A.M., Goodall, J.L., Mostafa, M.E., 2013. Models as web services using the Open Geospatial Consortium (OGC) Web Processing Service (WPS) standard. Environmental Modelling & Software. 41: 72-83.

de Kok, J.L., Engelen, G., Maes, J., 2015. Reusability of model components for environmental simulation – Case studies for integrated coastal zone management. Environmental Modelling & Software. 68: 42-54.

Elag, M., Goodall, J.L., 2013. An ontology for component-based models of water resource systems. Water Resources Research. 49(8): 5077-5091.

Fielding, R.T., 2000. Architectural Styles and the Design of Network-based Software Architectures. PhD dissertation, University of California (Irvine). <http://www.ics.uci.edu/~fielding/pubs/dissertation/top.htm>.

Goodall, J.L., Saint, K.D., Ercan, M.B., Briley, L.J., Murphy, S., You, H., DeLuca, C., Rood, R.B., 2013. Coupling climate and hydrological models: Interoperability through Web Services. Environmental Modelling & Software. 46: 250-259.

Granell, C., Schade, S., Ostländer, N., 2013. Seeing the forest through the trees: A review of integrated environmental modelling tools. Computers Environment and Urban Systems. 41: 136-150.

Guzy, M.R., Smith, C.L., J.P. Bolte, D.W. Hulse, Gregory, S.V., 2008. Policy research using agent based modeling to assess future impacts of urban expansion into farmlands and forests. Ecology and Society. 13(1): 37.

Hazelwood, L., 2016. Designing a Beautiful REST+JSON API. Presented at the 2016 DevNexus Professional Developers Conference, Atlanta, GA.

ISO/IEC, 2001. ISO/IEC 2382:2001 Information technology - Vocabulary Fundamental Terms Fundamental Terms. Geneva, Switzerland: ISO/IEC.

Nativi, S., Mazzetti, P., Geller, G.N., 2013. Environmental model access and interoperability: The GEO Model Web initiative. Environmental Modelling & Software. 39: 214-228.

Nolin, A.W., 2012. Perspectives on Climate Change, Mountain Hydrology, and Water Resources in the Oregon Cascades, USA. Mountain Research and Development. 32:S35-S46.

Open API Initiative, 2016. Linux Foundation Open API Initiative (OAI) 2.0 Specification. Retrieved from web March 2016, <https://openapis.org>.

Peckham, S.D., Goodall, J.L., 2013. Driving plug-and-play models with data from web services: A demonstration of interoperability between CSDMS and CUAHSI-HIS. Computers & Geosciences. 53: 154-161.

Smith, L.M., Smith, H.M., Case, J.L., Harwell, L.C., Summers, J.K., Wade, C., 2012. Indicators and Methods for Constructing a U.S. Human Well-being Index (HWBI) for Ecosystem Services Research. United States Environmental Protection Agency. Office of Research and Development, Gulf Ecology Division, Gulf Breeze, FL 32561. Report # EPA/600/R-12/023.

Smith, L.M., Case, J.L., Harwell, L.C., Smith, H.M., Summers, J.K., 2013. Development of Relative Importance Values as Contribution Weights for Evaluating Human Wellbeing: An Ecosystem Services Example. Human Ecology. 41(4): 631-641.

Yee, S.H., Carriger, J.F., Bradley, P., Fisher, W.S., Dyson, B., 2014. Developing scientific information to support decisions for sustainable coral reef ecosystem services. Ecological Economics.