On the Use of Cloud and Semantic Web Technologies for Generative Design

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Abstract. The emergence of the Cloud has transformed the way we approach data. It created a convergence of heterogeneous data and an opportunity to link data at scale. This transformation came with challenges; some related to the migrating of historical data, some with the adoption of service-oriented architecture. In this work[1], we introduce three challenges that we addressed with semantic web technologies during the recent development of Generative Design services for manufacturing.

Keywords: Semantic web · Generative design · Cloud · Data convergence · Linked data · Simulation.

Introduction. Generative Design(GD) is a relatively new concept. It challenges traditional design processes by automatically generating valid designs through computation. Each of these designs fulfills given desired goals and complies to specified rules and constraints. As a whole, they provide a broad view over the space of valid solutions to substantially complex problems that would otherwise be resource-exhaustive through traditional approaches.

Context. In our domain of interest, Computer Aided Design(CAD) for manufacturing, GD accelerates the design cycle by generating new shapes, geometries or assemblies that are digitally validated for a specific environment. At the core, there are traditional numerical simulation solvers such as the ones for structural, thermal, and fluid analysis. The GD process generates an initial set of designs with noticeable variations and optimizes each design using the simulation solvers towards compliance. The whole process uses simulation at scale which is inherently provided by Cloud technologies. During the composition of our GD services, we faced three challenges that were resolved using Semantic Web Technologies.

The first challenges is related to the unification of data sources. Autodesk has a rich portfolio of historically independent CAD and simulation software; each with its own data sources. Now located on the Cloud, these data sources are centralized and easy to maintain. However, these data sources often have

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commonalities; for example, sources on material properties or manufacturing specifications. The first challenge was to unify these data sources to take advantage of the aggregated knowledge. For this purpose, we developed a service using ontology as an intermediary taxonomy to correlate sources and aggregate data without interfering with the original formatting of the data sources[2].

The second challenge is related to data validation. The creation of a GD problem is a complex step by step operation which can benefit from regular validation of user-provided data. The types of validation vary from simple logic to complex mathematical transformations that are usually best distributed over dedicated computing units. This challenge can be broken down in two parts. The first part was to offer the largest diversity of validation methods, for example, geometric analyses for early feasibility evaluation. For this purpose, we stored our knowledge base in ontology to leverage descriptive logic, executed simple validation locally, and connected to Cloud service-meshes through plugins for advanced processing. The second part of the challenge was to structure the knowledge base in a re-usable fashion to support commonalities between the various forms of Generative Design applied to different disciplines. For example, most geometric validations are shared between GD for manufacturing and GD for building construction. To support these commonalities, the knowledge base was split in two layers; one for applications and one for domain-specific content consumed by the application layer.

Finally, the third challenge relates to the storage and management of GD content. Simulation data was historically encapsulated for consistency and portability. It often led to very large files or groups of files. The GD process naturally scales up this storage requirement. Moreover, in GD, the individual simulations often share content whether geometries, material properties, boundary conditions or process parameters which leads to redundancies. The third challenge which is still under investigation, tackles the design of an efficient architecture to store GD data by optimizing content distribution and reducing redundancies. This management of data is a switch from managing all-encompassing files to managing metadata pointing to smaller content. In this context, semantic web technologies are suitable for the coordination of metadata, the verification of content integrity, and the fast exploration and retrieval of data. Finally, this architecture is also an opportunity to integrate advanced analyses and automatic generation of knowledge to support the GD process.

Conclusion. Generative Design is a new design paradigm. It goes beyond traditional processes and has been made available to the masses through the emergence of Cloud technologies. This work is a report on the challenges that we encountered during the design and creation of GD services and how we used Semantic Web technologies to address those challenges.

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[2] Mercier, D., Cheong, H., Tapaswi, C.: Unified access to heterogeneous data sources using an ontology. In: Semantic technology: 8th Joint International Conference. pp.104-118 (Nov 2018)