From Concepts to Production: Semantic Technology Solves Real Life Sciences and Healthcare Challenges

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Summary

While semantic technologies have been around for quite some time, real proof of being able to deliver on its promise has been lacking and therefore life science companies and clinical centers of excellence have been reluctant to implement it. With the advent of translational research and science harmonization, multiple information domains, a dynamic, flexible, and extensible solution has become more necessary than ever to cope with the demand for knowledge management and data sharing across disciplines. As data from countless disparate sources (new instruments, files, images, database, and web content) are generated in ever-changing formats, new approaches are needed. This paper outlines how the transition to a semantic data integration, where data are in context with other data, has changed the playing field.

Using real-life challenging scenarios (a. Discovery of genomic & proteomic biomarkers for toxicity classification in a NIST/CLDA setting, b. Development of species-independent disease markers for FDA VET to minimize animal experiments, c. Compound purity and excipient influence on drug stability at Pfizer, d. Comparative treatment effectiveness assessment for prostate cancer at the Prostate Cancer Centre at UBC and e. Predictive decision support for organ failure in transplant patients at the PROCF Centre for the Prevention of Organ Failures) we will demonstrate, that semantic technology not only provides the toolset required for the new information age in life sciences and clinics as it harmonizes synonyms and nomenclature, but also allows for relationship mining, inference, and reasoning in a systems approach – leading to informed decision-making with high confidence.

The presented solutions using dynamic, flexible and scalable RDF triple stores, SPARQL endpoints, and “linked open data” initiatives are key in research demanding global collaborations. Graph representations of merged data correlation networks and mechanistic reference networks have successfully demonstrated implementations are testimonials for capabilities, power and effectiveness of semantic technology not only provides the toolset required for the new information age in life sciences and clinics as it harmonizes synonyms and nomenclature, but also allows for relationship mining, inference, and reasoning in a systems approach – leading to informed decision-making with high confidence.

These successfully demonstrated implementations are testimonials for capabilities, power and effectiveness of semantic technologies to cope with “imprecise connections” across multiple relevant dimensions on drug safety and efficacy, but also allows for relationship mining, inference, and reasoning in a systems approach – leading to informed decision-making with high confidence.

Challenges

- Complexity of coherent data integration: different types, sources, taxonomies, ontologies, and non-standardized vocabularies.
- In many cases, data relationships are not a priori contained in the data sets.
- Experimental correlation networks do not necessarily align with mechanistically driven functional biology.
- Reluctance in implementation of relatively new semantic tools for network graph analysis and query in life sciences and clinical production environments.

Considerations

- Modern triple stores resolve most previous scalability and performance issues.
- Security, provenance, regulatory compliance (HIPAA) need to be addressed.
- Ease of use of tools is essential for broad adoption.

Methodology

- Map to a common local / formal ontology
- Explore network, reduce its complexity
- Build model using SPARQL queries
- Test and refine model
- Use Applied Semantic Knowledgebase for screening

Results

- Toxicity classification: Genomic and metabolic markers to detect different types of toxicity and SPARQL arrays characterizing them have been developed.
- Species-independent disease markers: Genomic, proteomic and imaging endpoints have been analyzed across different animal species for biomarker and marker applicability to human diseases.
- Effective treatment with minimal side effects: Multi-platform genomic and proteomic approaches have been undertaken to characterize the effectiveness of prostate cancer treatment.
- Purer, more stable drug formulations: Semantic integration of multiple data sources across imprecise connections allows assessing impact of excipient and compounding purity on stability of drug formulations.
- Life-threatening organ failure prevention: Screening of heart transplant patients for likelihood of organ failure bases on combinatorial biomarkers.

Discussion

Applying semantic technology to integration of data and knowledge networks results in:

- Faster, less expensive, dynamic and extensible solutions.
- Meaning, reasoning and inference provide actionable knowledge.
- Interconnected data make research more effective: information access keeps pace with data generation.
- "The Big Picture" from all data in context accounts for more accurate predictive models for complex diseases.

"Query by Meaning" changes the way we search: imprecise connections can be used to infer non-obvious relationships.
- Linked data collaborations drive knowledge expansion in life & medical sciences.

Implications for Life Sciences / Healthcare IT

The presented cases exemplify the immediate value across the full cycle from bench to clinic and back to pharmaceutical development. Early tailing in drug discovery (biomarkers for toxicity classification), reduction of animal experiments and confidant applicability to characterize human diseases (species-independent disease markers), effective treatment with minimal side effects (comparative cancer therapies), purer, more stable drug formulations (excipient influence on impurities), and life-threatening organ failure prevention (transplant rejection) commonly save time, money and lives. Establishing widely applicable and future-proof solutions. More generally:

- The understanding of biological mechanisms provides effective, patient-centric personalized medicine.
- The technology is broadly applicable in life sciences and healthcare.
- Semantic technology-based systems are now production solutions, not just research.

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References

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Fig. 1: Data integration framework: From multiple data sources to a experimental network

Fig. 2: Toxicity biomarker model refinement (Visual SPARQL)

Fig. 3: Species independent disease markers

Fig. 4: Comparative prostate cancer treatment effectiveness

Fig. 5: Compound purity and excipient influence on drug stability

Fig. 6: Decision support for likelihood of organ failure in transplant patients