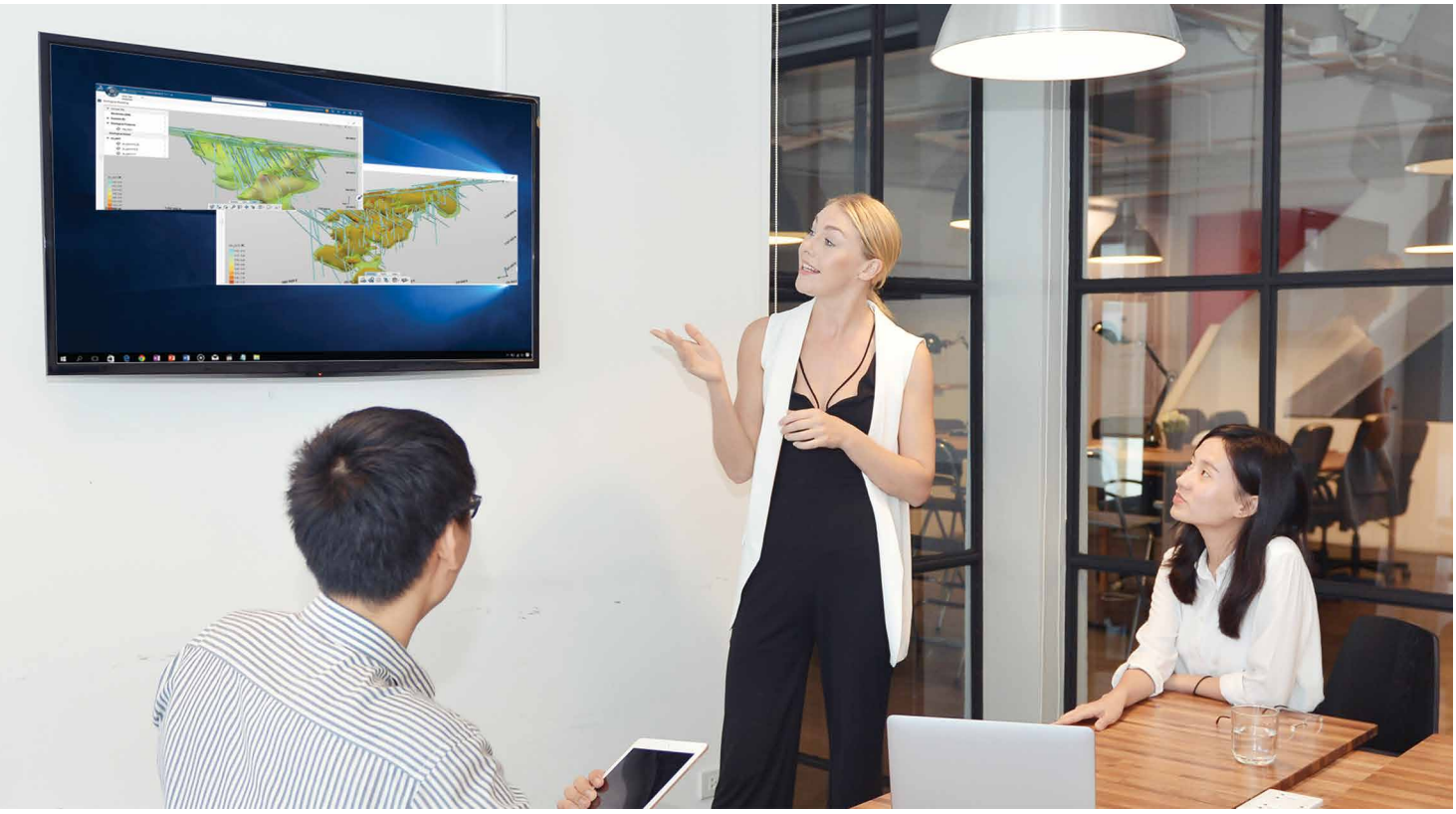
NEXT GENERATION OF RAPID IMPLICIT GEOLOGICAL MODELING

White Paper



INTRODUCTION

The mining industry is entering a period of disruptive transformation using digitalization, information transparency, data governance, data portability and process innovation. Mining companies can now deploy a variety of different sensors throughout their process that can provide real time data of mining exploration and operations that together are referred to as the "Mining Internet of Things" (MIoT).

Business decisions that today can take days or weeks using manually modeled data will be made in minutes from a fusion of estimated and actual data. This decision making will be supported by automated processes and informed by simulation of possible scenarios and their consequences upstream and downstream. This results in substantial time savings and improvements in accuracy, transparency and business agility by making informed decisions in a timely manner. But this vision can only become reality when based upon a new generation of software applications that are structured on a modeling language that can be shared, processed and understood by both machines and people.

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NEED FOR CHANGE

With the recent slowdown in demand and the resulting crash in commodity prices, the last seven years have seen many mining companies focus on productivity to achieve competitive costs and maintain a positive cash flow. However, productivity improvement programs and incremental applications of technology will go only so far and are reaching a limit. It is now apparent that the mining industry shares a common sentiment that the next step-change in cost reduction, and hence productivity, will be enabled through holistic implementation of technology across the whole mining value chain, underpinned by a challenging change management process.

Transformational change requires a shift in mindset involving people, culture, corporate organization and technology. Those companies that are first to adopt, adapt and master technologies and change will establish significant competitive advantage. Companies that are slow to adopt or resistant to change will see their cost curve stagnate and, in the long run, be out of business (e.g., Kodak, Blockbuster).

The mining industry is transitioning from a period when compartmentalized static desktop studies or plans were commonplace to more recently remote operation centers. However, we are going to a new world where every piece of data is mapped out, catalogued, connected and available on demand to model and simulate real life scenarios or situations for better decision making. In this new world, everything is connected—people to people, people to machines and machines to machines. Mining processes are carried out in a collaborative and dynamic manner to rapidly (in near real-time) capture value under changing conditions.

Dassault Systèmes' GEOVIA® brand is building the "bridge" to make that change with tools capable of bringing together plan and execution by combining the virtual world with reality. Rapid implicit geological modeling represents just the first of numerous applications to be built natively on Dassault Systèmes' **3D**EXPERIENCE® platform to enable this vision.

SEMANTIC MODELING

To harness the full potential of technology trends such as MIoT, machine learning and big data, a new software architecture and data organization using Semantic Modeling needs to be implemented.

Many existing web resources are understandable only by humans, since the mark-up language (HTML) only renders data for textual and graphical information intended for human consumption. The inventor of the World Wide Web, Tim Berners-Lee, therefore introduced the idea of the Semantic Web (Berners-Lee, Hendler & Lassila, 2001). The Semantic Web aims for machine-understandable Web resources, whose information can be shared and processed by both automated tools, such as search engines, and by human users.

The state-of-the-art knowledge representation language of the Semantic Web is the ontology description language (OWL), published by the World Wide Web Consortium (W3C). Its most common syntax is based on the Resource Description Framework (RDF), which describes meaning and relationships through a collection of triples each consisting of a subject, a predicate and an object. This "knowledge" is used by computers to "link the dots" in an autonomous fashion, without requiring human intervention.

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The concept of parametric modeling has been around for a number of years across disciplines such as computer graphics (Hughes et al., 2013), engineering (Reinschmidt, Griffs & Bronner, 1991), systems engineering, and design and styling (Aouad et al., 2013). Parametric modeling applies a parametric features-based approach to create solid models based on constraints, relationships and dimensions. These types of parameters drive the shape, size and output (how different pieces of geometry are combined). This is fundamentally different from the traditional CAD approach, where basic pieces of geometry (e.g., lines, polylines) are designed from scratch and manually combined to express the modeler's intent. In a parametric framework, the relationship between output and intent is inverted, as the intent is expressed first (through a set of parameters) to create 3D shapes that accurately represent the modeler's intent.

The use of Radial Basis Functions (RBF) to describe implicit surfaces in space given a set of data points is also not new in Analytic Geometry (Mittelman, 1983; Bloomenthal & Wyvill, 1997). It has been used since the late 1960s in the computer graphics field (Davis, Nagel & Guber, 1968). More recently, this concept has been applied in the natural resources sector to create 3D representations of geological features (Cowan et al., 2002). In the geological modeling space, the data-driven premise of implicit modeling not only reduces the subjective nature of the conventional modeling approach, but also enables a step-change in agility, repeatability and traceability.

The next generation of rapid implicit geological modeling that GEOVIA is introducing in 2018 continues to leverage RBF as the conduit for implicit modeling, but that is largely where the similarities end. The GEOVIA application introduces a variation of the traditional RBF engine with an innovative kernel and a novel marching tetrahedra algorithm, together with an implementation of the well-known Fast Multipole Method (Greengard & Rokhlin, 1987) for efficient handling of multi-million data challenges. The marching tetrahedra algorithm extracts the implicit functions and combines them with the semantic information to obtain a geological model that conforms to geologist's expectations. The approach also combines principles of parametric modeling through rules and relationships that determine how the different parts (data, model components) are assembled to form geological models, enabling the geologist to express modeling intent.

This next generation Geological Modeling solution also has the following characteristics:

Leveraging the Cloud

The application leverages the full potential of cloud computing, not only through license deployment, but also through processing within a true Software-as-a-Service (SaaS) framework. It is accessible to any device that is running a HTML5/WebGL compatible web browser, with no software to install and available from any place that can access the internet.

Linked Data

Consider the vision of autonomous mines with hundreds or perhaps thousands of machines equipped with millions of sensors communicating with each other. To make that happen requires a data format that can be processed by machines, and from which machines can infer new knowledge of existing information. Ideally, the machines will operate directly on the data format, with no additional transformation costs or potential information loss from the transformation. The philosophy of Linked Data with ontologies as underlying representation language enables exactly this scenario.

Interoperability

Interoperability among systems and their heterogeneous information must be the foundation of the next generation of applications. Ultimately, this will allow many separate knowledge sources to become Linked Data (Bizer, Heath & Berners-Lee, 2009) which is a central enabler for the Semantic Web. The data model of the coming GEOVIA application is aligned with standards from the Open Geospatial Consortium, such as GeoSciML. Since GeoSciML is not based on Linked Data principles, but still only an XML-based standard, GEOVIA has enriched the parts of the standard which are relevant to the application with semantic meaning by transforming them to ontologies. This allows all the benefits of Linked Data, including the ability to seamlessly communicate with other applications that use GeoSciML.

Semantics and Federated Search

Within the framework of the next generation of apps, every piece of information is stored as data in a unified repository and no longer embedded into files or databases in the traditional manner of managing data. The semantic data model (architecture) is the "glue" that holds the data together through the mapped out relationships and new inferred "knowledge" by machine learning algorithms.

Federated Search is the ability to discover and retrieve data across multiple searchable sources, independent of category. A semantic data model further enhances the capabilities of Federated Search, as the data is stored in a homogeneous database with associated metadata for every piece of information. This allows searching everywhere while at the same time exploring the inherent relationships of the data. To achieve this from a conventional relational database, all content would need to be indexed beforehand.

BUSINESS VALUE OF THE NEXT GENERATION OF IMPLIICIT GEOLOGICAL MODELING APP

Some of the business values that can be realized with the app are outlined below, along with the business drivers and the mechanism of delivery.

BUSINESS VALUE DRIVERS	BUSINESS VALUES	HOW IS IT DELIVERED?
• **Integrated** to Surpac and GEMS	• **Elimination** of data conversion **risks** • **Time savings**	• Seamlessly integrated with the Surpac and GEMS user interface
• Multi-user collaboration and central control of geological model data providing a **single source of the truth**	• Geologic models are always **up to date and shared** for business decisions • **Accessibility** to the right skills set through a collaborative modelling platform	• Store geologic models on secure cloud platform with version control and lifecycle management
• Geology Models are **parametrically modelled**, repeatable and auditable	• Business decisions can be validated • **Modelling consistency –** eliminating the subjective nature of explicit modelling	• Geologic models are stored in a "big data" data base, not as files. Model assumptions are recorded and results exactly reproduced
• Geology data is never moved from **secure server** to a client PC. Large models are **processed quickly** with most up to date data	• Data **integrity** and **security** • Speed to market for **timely decision making**	• HTML5 3D web user interface • Scalable cloud platform for fast computation
• **Geospatially and semantically indexed**, visualisation in a globe/map	• Business decisions can be taken witht the **right data**	• Data model allows geologic models to be positioned with reference to a geospatial reference system, indexed by EXALEAD®
• **Openess-**allows automation and integration with other enterprise solutions and workflows (e.g. measuring while drilling)	• **Interoperability** with automatic incorporation of new data from near real-time sensors • Integration to business workflows (e.g.approvals)	• Implemented with open standard web API's

CONCLUSION

The application discussed in this paper represents the first step in Dassault Systèmes GEOVIA brand's journey to the next generation of software that enables the vision of a truly autonomous mine. Although technology is a key enabler of such vision, change management is seen as the single most important component on this transformational path and, as such, must not be underestimated. For example, different skillsets and organizational structure may be required to solve challenges in a more collaborative, holistic and efficient manner.

To the mining industry, the vision of an autonomous mine represents a transformational change that requires a different mindset involving new ways to describe challenges and the innovative solutions to address them. The innovative software architecture of GEOVIA's new application is a revolutionary example of that. It represents a significant milestone for harnessing the full potential of the technology trends discussed above that in combination underpin the next wave of productivity improvements in the industry.

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