**Data Visualisation**

In our increasingly data-driven world, it’s more important than ever to have accessible ways to view and understand data.

Data visualization is the graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.

**The importance** of data visualization is simple: it helps people see, interact with, and better understand data. Whether simple or complex, the right visualization can bring everyone on the same page, regardless of their level of expertise.

**Advantages** - Our eyes are drawn to colours and patterns. Data visualization is a form of visual art that grabs our interest and keeps our eyes on the message. When we see a chart, we quickly see trends and outliers. If we can see something, we internalize it quickly.

**Disadvantages** - When viewing a visualization with many different data points, it’s easy to make an inaccurate assumption. Sometimes the visualization is just designed wrong so that it’s biased or confusing.

**Types**

* **Chart:** Information presented in a tabular, graphical form with data displayed along two axes. It can be in the form of a graph, diagram, or map.
* **Table:** A set of figures displayed in rows and columns.
* **Graph:** A diagram of points, lines, segments, curves, or areas that represent certain variables in comparison to each other, usually along two axes at a right angle.
* **Geospatial:** A visualization that shows data in map form using different shapes and colours to show the relationship between pieces of data and specific locations.
* **Infographic:**A combination of visuals and words that represent data. Usually uses charts or diagrams.
* **Dashboards:**A collection of visualizations and data displayed in one place to help with analysing and presenting data.

<https://www.tableau.com/learn/articles/data-visualization#:~:text=Data%20visualization%20is%20the%20graphical,outliers%2C%20and%20patterns%20in%20data>.

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**28/09/2023**

**Real-Time Monitoring**

Real-time monitoring is the delivery of continuously updated data about systems, processes, or events. Such monitoring provides information streaming at zero or low latency, so there is minimal delay between data collection and analysis.

<https://www.techtarget.com/whatis/definition/real-time-monitoring#:~:text=Real%2Dtime%20monitoring%20is%20the,performance%20issues%20and%20critical%20events>

Real-time monitoring is the process of collecting and storing performance metrics for data as it traverses your network. It involves polling and streaming data from infrastructure devices so that you know how your networks, applications, and services are performing. It’s the process of continuously gathering data that you can use to quickly jump into action when problems arise. But there wasn’t always a need for this.

**Advantages -** Being able to get real-time information about your IT infrastructure will help you find and fix problems faster. E.g. Minimized Breaches**,** Reduced User Complaints**, and** Confident Network Knowledge.

**Disadvantages -** As mentioned above, no network is perfect. And no monitoring is perfect either. Real-time monitoring does have its drawbacks. E.g. May Lead to Complacency, Lots of Troubleshooting

<https://www.netreo.com/blog/real-time-monitoring/>

**Importance -** This critical gap between the time to report and the time to take action can cost you a lot of money. Real-time monitoring helps fill this gap by giving you real-time data, alerts, and notifications so you can take the timely discourse to deal with any issue. - <https://www.virtualmetric.com/blog/why-real-time-monitoring-so-important>

**Types of real-time data:**

* Central processing unit (CPU) and memory utilization.
* Application response time.
* Service availability.
* Network latency.
* Network security.
* Web server requests.
* Transaction times.

**Example:** Fleet management - Fleet operations can use real-time data collection through vehicle fleet management software to catch reckless, sleepy, and impaired drivers, as well as maximize fleet use.

<https://www.techtarget.com/whatis/definition/real-time-monitoring>

**29/09/2023**

**Communication Protocols:**

A communications protocol is a set of formal rules describing how to transmit or exchange data, especially across a network.

You can use standardised communication protocols to make your data available, for example:

* from a web server via HTTP using a browser
* from a file server via File Transfer Protocol (FTP) using an FTP client application
* through a well-documented Application Programming Interface (API).

**Types** – File Transfer Protocol (FTP), TCP/IP, User Datagram Protocol (UDP), Hypertext Transfer Protocol (HTTP), Post Office Protocol (POP3), Internet Message Access Protocol (IMAP), Simple Mail Transfer Protocol (SMTP).

<https://www.techopedia.com/definition/25705/communication-protocol#:~:text=Popular%20protocols%20include%3A%20File%20Transfer,Mail%20Transfer%20Protocol%20(SMTP)>

HTTP, originally designed for web page transmission, has evolved into a versatile protocol for exchanging various forms of information, notably through web APIs (Application Programming Interfaces). These APIs enable computer applications to seamlessly share and access machine-readable data across the internet, with the ability to operate from remote locations, relying on complementary network protocols. Notably, APIs can facilitate the selective sharing and retrieval of specific data subsets, a crucial feature for managing unwieldy or sensitive datasets. Many established APIs, such as OGC WMS for map images and OAI-PMH for repository metadata, are well-documented standards for data and metadata exchange. In cases where a standardized API doesn't exist for a particular type of data or metadata, software developers can create custom APIs.

<https://ardc.edu.au/resource/standardised-communications-protocols/#:~:text=A%20communications%20protocol%20is%20a,Hypertext%20Transfer%20Protocol%20(HTTP)>

**API**

An API, or application programming interface, enables interaction between software applications, systems, or platforms to send and receive data. An API is a messenger that delivers your data request to an external source and then returns their reply to you.

**Examples:** Social Media Login, PayPal Transactions, Price Comparison for Vacations.

**How It Works:** APIs act as the link between the user and the service provider, with the API software facilitating an exchange. Whether that is an information request, an e-commerce transaction, sending money to a bank account, or any other situation requiring a two-way data transfer. When you act on a website, the API will send online data related to your action to its server. Subsequently, the server receives and interprets the data, completes the necessary activity, and then returns the outcome to the application. The application interprets the outcome data and shows you the answer in an understandable format.

**Advantages:** Automation, Developer efficiency and innovation, Improved value proposition

**Disadvantages:** Security; Poor integration means that an API can be vulnerable to attacks.

<https://airfocus.com/glossary/what-is-an-api/#:~:text=APIs%20empower%20developers%20to%20be,interface%20with%20other%20developers'%20applications>

**04/10/2023**

**DIGITAL TWINNING**

A digital twin is a dynamic virtual copy of a physical asset, process, system, or environment that looks like and behaves identically to its real-world counterpart. A digital twin ingests data and replicates processes so you can predict possible performance outcomes and issues that the real-world product might undergo.

**How does a digital twin work? -** The power of digital twins comes from connecting real-world assets with real-world data, so you can better visualize them. Digital twins enable cross-functional teams to collaboratively design, build, test, deploy and operate complex systems in interactive and immersive ways. They help companies understand the past, view present conditions, and prevent future problems. They inform decision-making through sales and marketing insights, analysis, 3D visualization, simulation, and prediction.

**History:**

**Benefits:** With digital twin deployments, customers immediately realize improved access to data. As a digital twin matures, other benefits include reduced maintenance costs, more informed process change decisions with large potential savings, and improvements in maintenance and operational efficiency. Having better designs from the start pays dividends over a project’s lifetime, as 80–90% of costs incurred during the production, use, and maintenance of a facility are determined at the design stage.

Using digital twins in the design industry has improved multiuser collaboration and communication. Preconstruction clients experience seamless aggregation of data and trade coordination.

The safety training, quality assurance, and quality control that’s possible with digital twins have significantly reduced accidents and mistakes in the construction industry. When digital twin initiatives are used for maintenance and operations, the benefits include optimized operations, reduced downtime, and decreased maintenance and personnel costs.

The ability to interact with data in real-time is changing the way people make design, operations, and maintenance decisions. The power to visualize and simulate complex operations in real-time 3D has elevated how people interact with their assets, transforming the way every physical space and asset on the planet is created, built, and operated.

**Challenges:** It's one thing to gather extensive data, but it's quite another to consume it in an intelligent way. The best decisions are made using data, but your data is only as good as your ability to bring it to life to simulate and predict business scenarios.

Every enterprise going through a digital transformation risk drowning in raw data before finding a way to process and leverage it. Today, capturing raw data is less of a challenge than processing it, filtering the useless parts, combining it, and transforming it into information that makes sense to the user in the context of their application.

The main challenge is unlocking the power of information. Enterprise and IoT data have been buried in databases, spreadsheets, and models (CAD, BIM, GIS). Real-time 3D digital twins can bring that data to life.

**How are digital twins and Internet of Things (IoT) related?** Digital twins are visualizations built from conceptual models (e.g., BIM, CAD, or GIS) or scans of physical entities (e.g., manufactured products or facilities). The Internet of Things (IoT) refers to a network of physical objects that possess unique identifiers (UIDs) and contain embedded technology. This enables them to communicate and interact with other objects over the internet, collecting real-world and real-time data. When digital twins integrate with IoT data, they can provide insights into the performance of an asset at specific points in time, and help users evaluate potential outcomes and plan resolutions.

With access to IoT sensors and data, digital twins can capture a holistic view of the virtual model to unlock deeper operational intelligence. For example, a digital twin of an engine might contain information about its performance characteristics and allow engineers to run simulations to test new designs or measure the impact of future changes.

While there are many different types of digital twins, they all share several common characteristics. They use digital representations of physical objects and systems, contain UIDs so that they can be easily identified by devices on the internet, and allow for bidirectional communication between themselves and physical IoT devices to exchange information and coordinate actions.

**Future of digital twins:** Increasingly, products, equipment, factories, buildings, and cities are no longer merely things in the physical world – they have accurate virtual counterparts. Even people have digital twins. We will experience the next iteration of the internet – and the connectedness of systems, devices, and people – in the metaverse via real-time 3D.

The metaverse is unlocking a new economy with countless opportunities - such as 3D marketing - for immersive experiences in cross-digital and hybrid reality spaces, whether it’s to manage facility updates or customize a vehicle purchase.

<https://unity.com/solutions/digital-twin-definition#digital-twin-challenges>

**Use Cases**

**Aerospace:** Digital twins aid in product development, simulation, training, maintenance, and marketing, enabling teams to work more efficiently and make informed decisions in real-time 3D environments.

**Architecture:** Architects use digital twins to streamline design reviews, visualize design concepts, and communicate design intent effectively in immersive AR and VR experiences.

**Automotive:** Digital twins facilitate 3D car design, HMI development, autonomous driving simulation, training, and sales and marketing, helping save time and resources by addressing issues early in the design process.

**Construction:** In the construction industry, digital twins assist in visualizing designs in real-time, streamlining virtual design and construction workflows, offering immersive safety training, and improving project close-out and maintenance.

**Energy:** Digital twins are utilized in design visualization, learning, training, field service, and site operations and maintenance to enhance decision-making in energy operations and infrastructure.

**Infrastructure:** Digital twins help stakeholders understand and optimize infrastructure by combining and visualizing key data, simulating mobility patterns, and improving sustainability outcomes in smart cities and infrastructure management.

**Government:** Government agencies employ digital twins for flight and vehicle modeling, team-based situational training, guided maintenance and repair, and developing cutting-edge applications, reducing risks and costs.

**Luxury Goods:** Luxury brands leverage digital twins for real-time 3D product configurators, photorealistic marketing imagery, virtual try-on experiences, and interactive showrooms to enhance the shopping experience.

**Manufacturing:** In manufacturing, digital twins are used for factory design, robotics simulation, operator training, and monitoring and maintenance, resulting in improved innovation and collaboration.

**Retail:** Retailers apply digital twins for design and planning, sales and marketing, and operational enhancements, creating virtual experiences for customers and improving overall efficiency.

These digital twin applications revolutionize industries by enhancing decision-making, reducing costs, and improving user experiences.

<https://unity.com/solutions/digital-twin-applications-and-use-cases>

**16/10/2023**

**Digital Twin Object:** Digital twin objects build a one-to-one mapping virtual model in Unity 3D, synchronize data with the physical model, and conduct real-time evolution by receiving the data returned by the physical model, so as to keep consistent with the operation status of the physical model. (Reword)

CASE STUDY: DIAMND

The DIAMND (Diagnostics and Monitoring for Navigating Data) system stands as an indispensable cornerstone of the crane management domain, serving as a critical platform for data visualization and diagnostics. Developed using the Windows Presentation Foundation (WPF) language, DIAMND operates as the central nexus for crane monitoring, diagnostics, and data presentation. However, the system's significance in enhancing crane operations is marred by its unattractive user interface, which is plagued by issues of information overload and excessive noise in data representation. The application's aesthetic shortcomings are evident in the accompanying images (see below), which illustrate the stark disparity between its functionality and its visual appeal. This aesthetic deficiency not only impacts the user experience but also makes it arduous for operators to distil meaningful insights from the data it provides. Despite these challenges, the DIAMND system remains intricately woven into the daily fabric of crane management, offering a comprehensive solution as a one-stop shop for diverse metrics and statistics. It sources data from various origins, including the crane's Programmable Logic Controller (PLC) through SignalR and OPC servers, trace files, feedback arrays, and port 6000-5000 PCPIP collections, amassing data at a staggering rate of approximately 35,000 signals per hour. This data is subsequently processed and directed to a client-server architecture and stored in SQL databases to construct job and load statistics tables.

A 3d model of a crane

Description automatically generatedA screenshot of a computer

Description automatically generatedA screenshot of a computer

Description automatically generated

### Data driven simulation models

Recent studies have addressed the longstanding challenge of generating adaptive simulation models that are responsive to the project dynamic changes during the construction stage. Recent efforts took advantage of tracking technologies to capture trucks and [excavator](https://www-sciencedirect-com.mtu.idm.oclc.org/topics/engineering/excavators) motions and enhance the detection of equipment state [[34]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580516300930#bb0170), [[35]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580516300930#bb0175). Song and Eldin [[44]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580516300930#bb0220) highlighted the ineffectiveness of using statistical input data for simulation models to analyze look-ahead schedules, which, for precision, require the most recent project performance data on a real-time or near-real-time basis. The authors proposed an adaptive real-time tracking and simulation of heavy construction operations using sensors to constantly capture and feed the dynamic site condition changes into the simulation for more accurate look-ahead scheduling. Akhavian and Behzadan [[45]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580516300930#bb0225), [[46]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580516300930#bb0230) employed data mining methods to extract contextual knowledge from heterogeneous field data that are captured through ubiquitous sensors to automatically generate and refine a simulation model. Further, the authors used built-in smartphone sensors to detect data other than positional information to recognize construction equipment activities [[47]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580516300930#bb0235). Although, all such studies provided means of realistic input data for simulation models, their utilization for simulation driven visualization is limited with one-way data flow; hindering the full benefit of real-time visualization models.

(ElNimr et al., 2016)

ElNimr, A., Fagiar, M. and Mohamed, Y. (2016) ‘Two-way integration of 3D visualization and discrete event simulation for Modeling Mobile Crane movement under Dynamically Changing Site Layout’, *Automation in Construction*, 68, pp. 235–248. doi:10.1016/j.autcon.2016.05.013. Available at: https://library.ittralee.ie/ (Accessed 23 November 2023).

5.2. Suspension model

This section introduces the principle of constraint-based rigid body dynamics and describes how to formulate the motions of the suspension model using this principle. It is mainly used for simulating the physical motions of articulated objects. The articulated objects can be treated as systems with specific types of constraints among connected joints and contact planes. These constraints represent the limitations of motion and place restrictions that cause the virtual objects to act as they would in the real physical world. For example, the constraints can be formed as the movement range of joints, contact points which exhibit spring-like or stiff reactions, and even the behaviors of motors.

In this research, the joint descriptions of the suspension model are identified. We use the methodology of formulating the constraints, followed by applying constraint-based rigid body dynamics. The basic idea for formulating all kinds of constraints is to represent them in a matrix form. First, we take the ball-in-socket joint as an example. The detailed formulating procedures can be referenced from previous works [[15]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580510000488#bib15) and other references [[16]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580510000488#bib16), [[17]](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580510000488#bib17). Second, we explain how the model of the suspension part of the crane is constructed.

The number of degrees of freedom (DOFs), which is the minimum set of parameters needed to describe the motion of a rigid object in the system, is the key part of the constraints formulation. A free moving body has six DOFs: three parameters, *x*, *y*, and *z*, to describe its position and three parameters, ω, ψ, and κ to describe its orientation. If there are two bodies *Bi* and *Bj* in the system, we have twelve DOFs. The general form *P* for describing these two bodies can be represented as follows:



A fixed connection between two rigid bodies *Bi* and *Bj* reduces the number of DOFs of the system to six. Similarly, if rigid bodies *Bi* and *Bj* are connected together by another kind of joint, some of the DOFs can be removed, the number depending on the type of connection. However, the maximum number of DOFs that can be removed is six.

Assume that the *l*'th joint is a ball-in-socket joint between the two bodies *Bi* and *Bj* as represented in [Fig. 4](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580510000488#fig4). With equality in the *x*, *y*, and *z* dimensions at the common point we can formulate three equations as follows:

A math equations on a white background

Description automatically generated

*Pi* and *Pj* are the position vectors of *Bi* and *Bj* respectively, *Ri* and *Rj* are the corresponding rotation matrices of each body's orientation, and *Pi*anc and *Pj*anc are the anchor vectors which represent each body's center of mass to the connected point. By formulating these three constraint equations, three DOFs can be removed from the joint.

A diagram of a joint

Description automatically generated

Fig. 4. Constraint formulation for a ball-in-socket joint.

If we reorganize these formulations, the constraint equations can be represented by the following vector form:

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By using the same rules for other types of joints, we can find the same expression Φ(*P*) but with a different row *m*, which represents the number of constraints or removed DOFs. The removed DOFs imply restrictions on the movement capability of the joint.

Now we explain how the suspension model of the crane is constructed. We built the suspension model of the crane by imitating the relationship of connections between each piece. The cable and hook on the suspension model present dynamic motions and are easily influenced by wind force, suspended objects, and so on. To simulate the natural properties of these components, we use ball-in-socket joints and slider joints to represent the DOFs potentially required on the model. [Fig. 5](https://www-sciencedirect-com.mtu.idm.oclc.org/science/article/pii/S0926580510000488#fig5) illustrates the configuration of joints on the suspension model. The ball-in-socket joints attached between the hook and the cable or the cable and the top of boom represent the relative movements during a swinging situation. Following the same idea, we divide the cable into several pieces and consider the ball-in-socket joints as connectors within each part. For extension and shortening movements, we also attach slider joints on the cable. Thus, the flexibility of the cable can be simulated to provide physical suspended actions during an erection simulation.

A diagram of a swing and a hook

Description automatically generated

Fig. 5. The connection relationships of the suspension model: (a) illustration and joints configuration in static condition; (b) illustration and joints configuration in swinging condition.

(Chi & Kang, 2010)

Chi, H.-L. and Kang, S.-C. (2010) ‘A physics-based simulation approach for cooperative erection activities’, *Automation in Construction*, 19(6), pp. 750–761. doi:10.1016/j.autcon.2010.03.004. Available at: https://library.ittralee.ie/ (Accessed 23 November 2023).

(Hung & Kang, 2013)

Hung, W.-H. and Kang, S.-C. (2013) ‘Configurable model for real-time Crane Erection Visualization’, *Advances in Engineering Software*, 65, pp. 1–11. doi:10.1016/j.advengsoft.2013.04.013. Available at: https://library.ittralee.ie/ (Accessed 23 November 2023).