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Foundations of Digital Twins, Information modeling and Information Architecture

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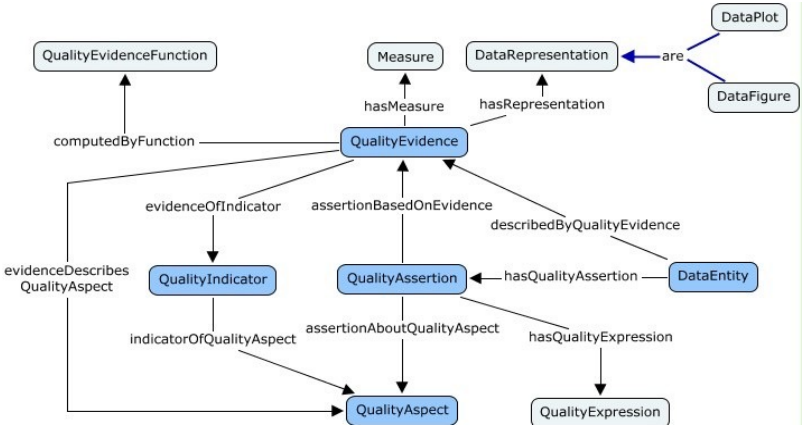
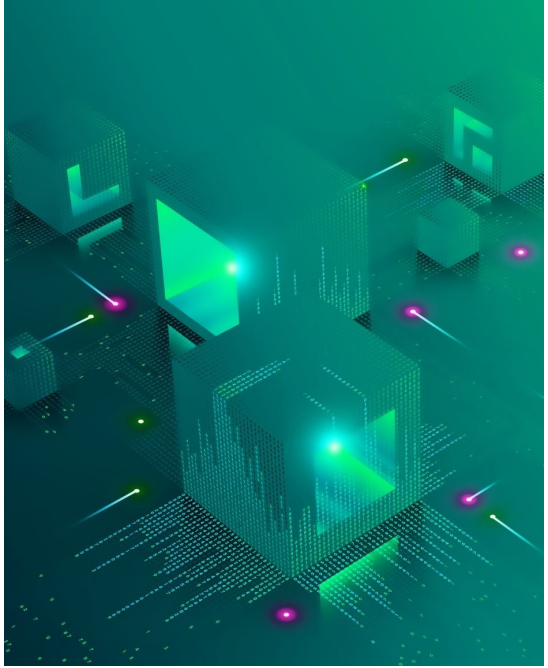




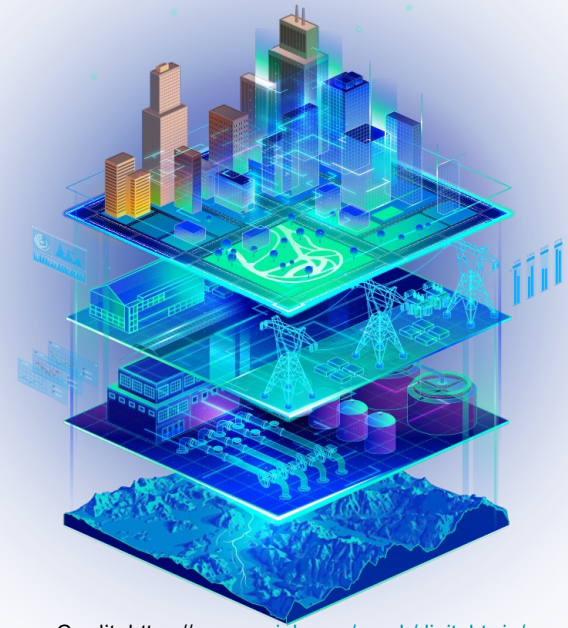
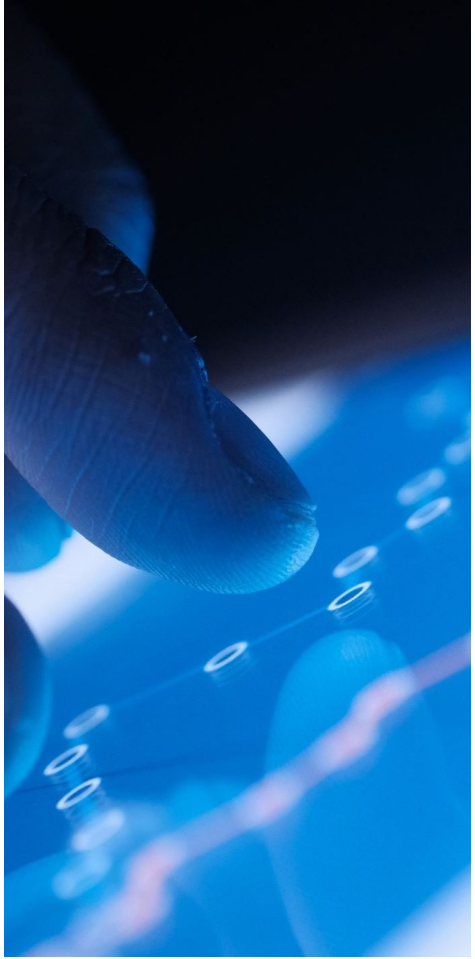


Image Credit: https://www.esriuk.com/en-gb/digital-twin/overview

What is a Digital Twin

- Digital Twin is a virtual replica of a physical system, product, process, or service.
- It is a software-based model that enables the visualization, analysis, and simulation of real-world objects or systems.



Why do we need DT?

- The main purpose of Digital Twin is to create a real-time or Near-Real-Time (NRT) simulation of a physical system that can be used for predictive maintenance, performance optimization, and monitoring.

Where are Digital Twins applied?

Digital Twins can be used in a variety of applications area, including:

- Manufacturing,
- Aerospace industry,
- Energy infrastructure and management,
- Healthcare,
- Transportation.

Framework for Digital Twins

A framework to create and integrate digital twins:

- It is more than just a visualization,
- a digital twin can accelerate innovation, build consensus,
- Can save time and money by iteratively modeling changes,
- Conduct testing how components or systems function, and troubleshooting malfunctions inexpensively in a virtual world.

Michael Grieves introduced this in his 2002 white paper *Digital Twin: Manufacturing Excellence through Virtual Factory Replication*.

Framework for Digital Twins

A framework to create and integrate digital twins:

Dr. Michael Grieves posited the use of computer-aided design for developing digital objects, creating virtual factories to produce them, and running simulations to test plant operations.

6 Questions with Michael Grieves on the Future of Digital Twins:

https://www.asme.org/topics-resources/content/6-question-with-Michael-grieves-on-the-future-of-digital-twins

- Advancement in computational capabilities and the advent of the Internet of Things (IoT) have closed the gap between the promise of the digital twin and its reality.
- Although originally pioneered to improve the operations of manufacturing plants, the use of digital twins has been expanded to applications such as supply chains, wind farms, and even cities.

Reference/Resource: https://www.esri.com/about/newsroom/arcuser/digital-twins-enable-innovation-and-savings/

BIM+IoT+AR+VR+GIS

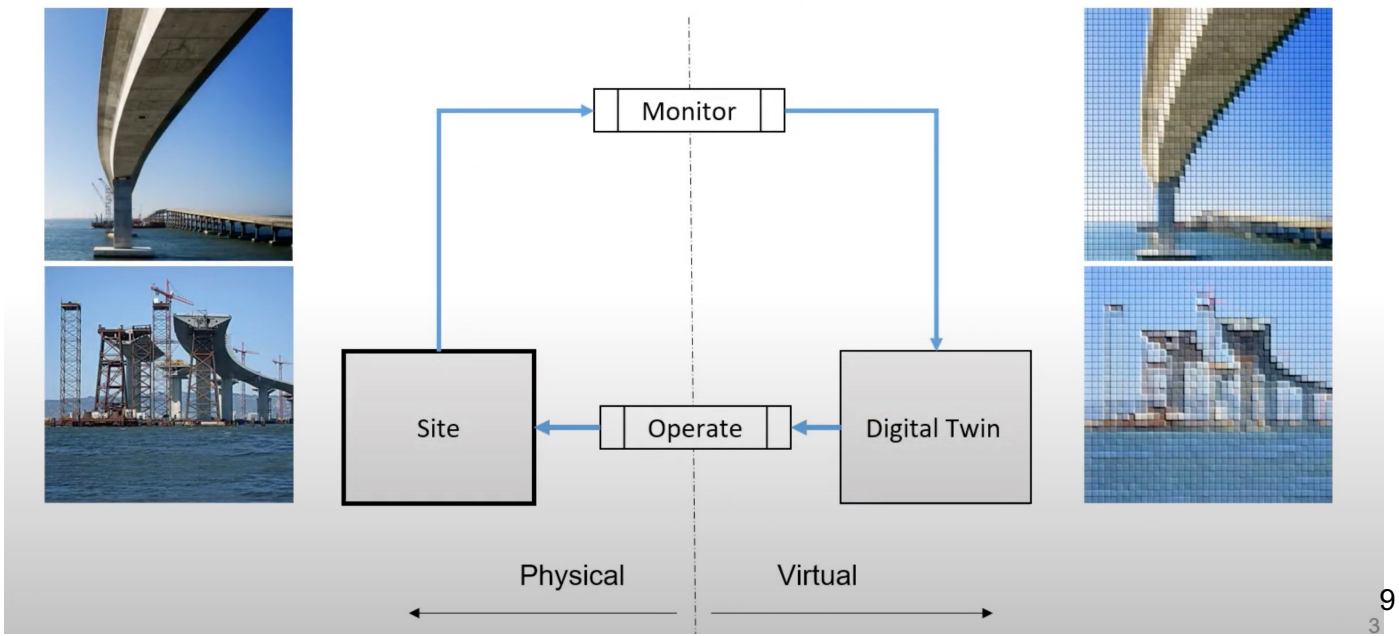
- With its 3D and spatial analysis capabilities and the evolving integration of technologies such as **building information model (BIM), augmented reality (AR), and virtual reality (VR), GIS offers tremendous benefits for modeling impacts and improving operations through the use of digital twins by government and industry** for activities such as:
- Viewshed delineation
- Solar radiation assessment
- Shadow modeling
- Urban analytics
- Modeling sea level rise
- Space-time analysis

The Evolution of Smart Communities

Digital Twin Helps Airport Optimize Operations

Reference/Resource/ Image Credit: https://www.esri.com/about/newsroom/arcuser/digital-twins-enable-innovation-and-savings/

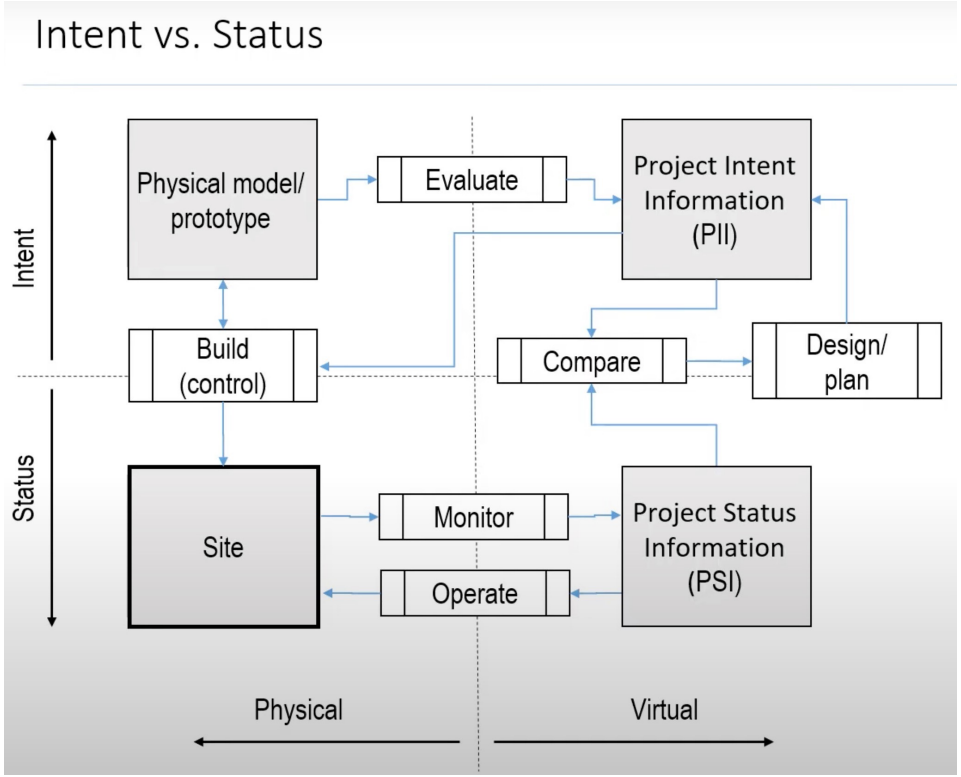
Physical Vs Virtual (Digital)



Resource/Reference/ Image Credit: Rafael Sacks et,al

Interaction of Lean and **B**uilding **I**nformation **M**odeling (BIM) in Construction : https://ascelibrary.org/doi/10.1061/%28ASCE%29CO.1943-7862.0000203 (Rafael Sacks; Lauri Koskela; Bhargav A. Dave; and Robert Owen)

Intent Vs Status



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Three Types of Information with respect to Digital Twins

What is the Philosophy of Information?
~By Luciano Floridi

https://www.academia.edu/3491627/What_is_the_Philosophy_of_Information

Physical or factual
Information as reality
e.g. fingerprints, tree rings

Instructional
Information for reality
e.g. algorithms, commands

Semantic
Information about reality
train timetables, maps

Resource/Reference/ Image Credit: Rafael Sacks et,al

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Data, Information, Knowledge Eco-System

Big Data, new epistemologies and paradigm shifts:

By : Rob Kitchin

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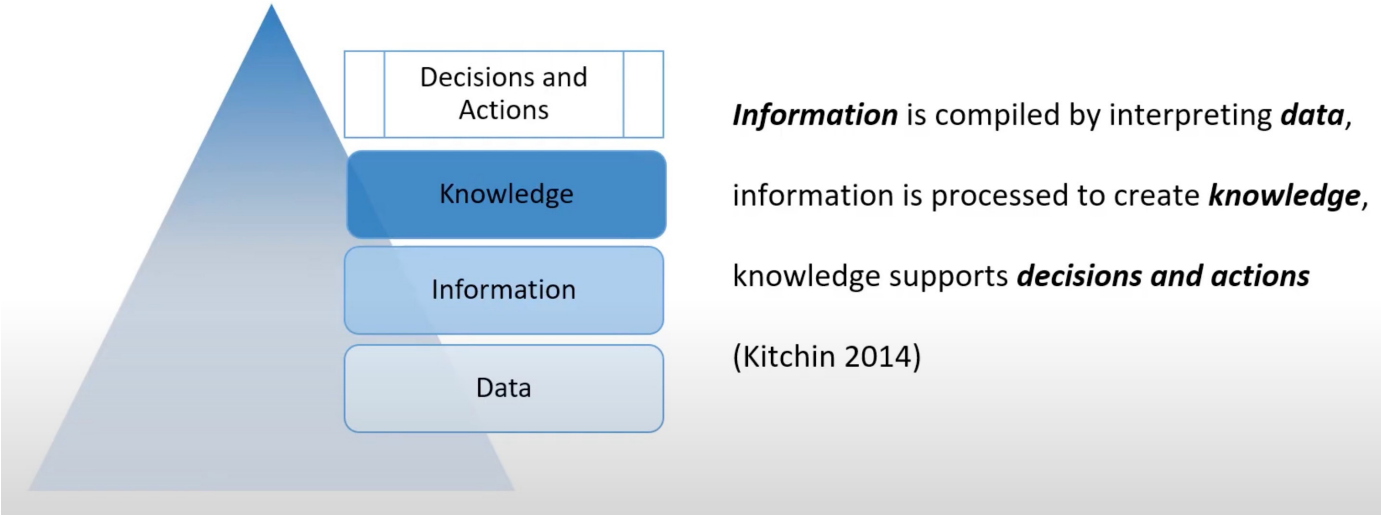

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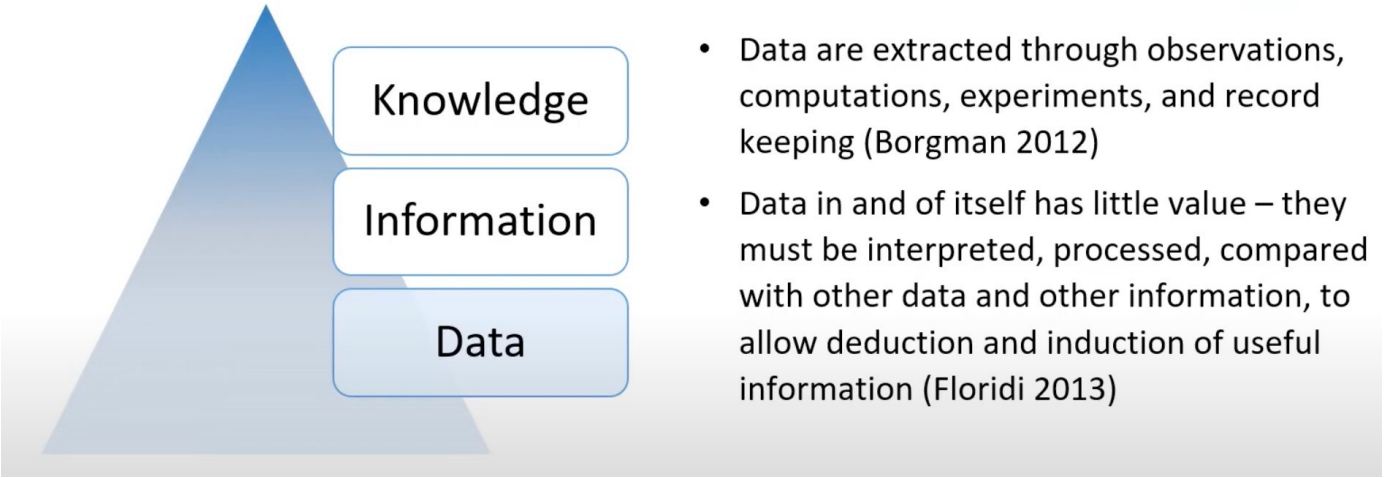

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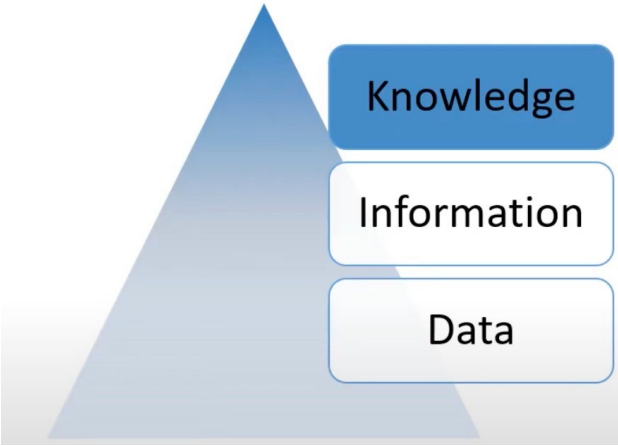

- Functions of knowledge include description, explanation and prediction of the behaviour of phenomena (Losee 2001)
- Knowledge also has a prescriptive function (de Figueiredo and da Cunha 2007). Production theories have to guide improvement of practice and provide means to validation (Koskela 2000)

Resource/Reference/ Image Credit: Rafael Sacks et,al

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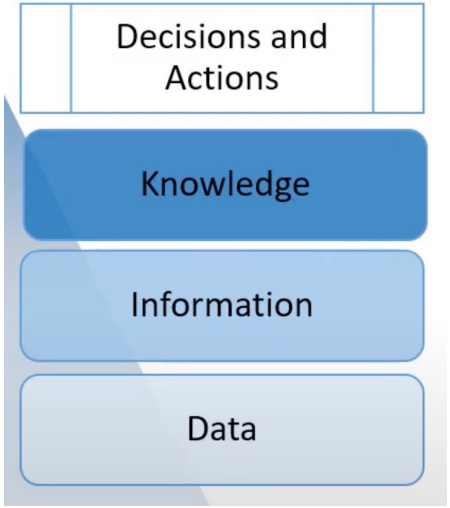
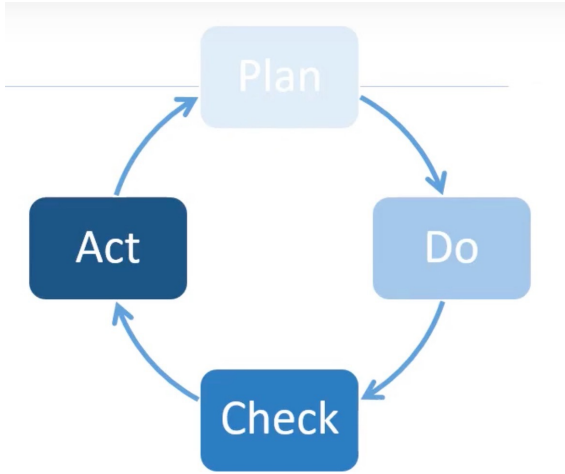
Plan, Do, Check, Act (PCDA):By Edward Demings 1982: https://en.wikipedia.org/wiki/PDCA





Resource/Reference/ Images Credit: Rafael Sacks et,al

DEMING CYCLE (PDCA)

Interaction of Lean and **B**uilding **I**nformation **M**odeling (BIM) in Construction : https://ascelibrary.org/doi/10.1061/%28ASCE%29CO.1943-7862.0000203 (Rafael Sacks; Lauri Koskela; Bhargav A. Dave; and Robert Owen)

https://link.springer.com/referenceworkentry/10.1007/1-4020-0612-8_229#:~:text=The%20Deming%20cycle%20(Plan%2C%20Do,Shewhart.

Two Dimensions in Digital Twin Construction

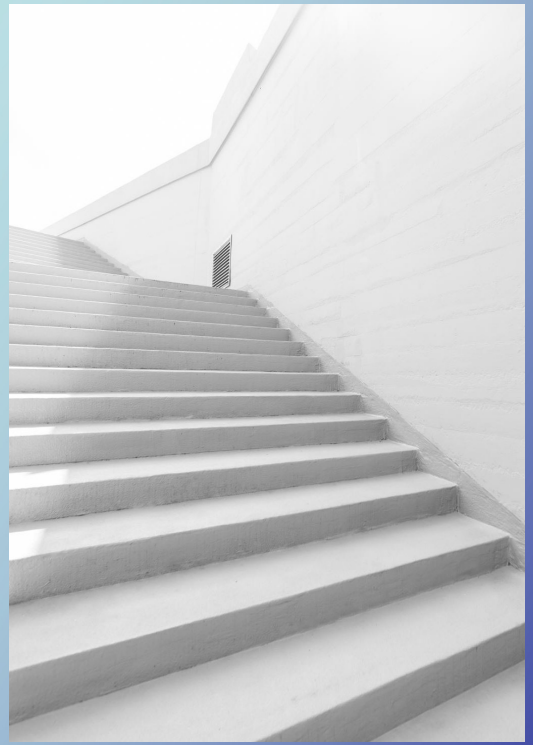
- **Information Dimensions:**
  - Virtual Vs Physical
  - Intent Vs Status

- **Process Dimensions:**
  - Information Life-Cycle
  - Plan, Do, Check, Act (PDCA)
  - Model, Build, Monitor & Interpret, Evaluate, Improve

Reference/Resource: IGLC 28 July 2020 Keynote: Digital Twins and Lean Construction by Rafael Sacks

Building a Digital Twin

- Building a Digital Twin involves several steps and requires expertise in the area and knowledge in different fields such as Data Analytics, how IoT or sensor networks work, and software development etc,.



General steps to consider when building/implementing a Digital Twin

- Here are six general steps to consider when building a Digital Twin.
- Each step can have multiple sub-steps (sub-sections) based on the system you try to represent digitally.
- These six implementation steps can be considered as the basic foundational guidelines to begin with.
- Digital Twins are complex!

Steps for building a Digital Twin

1. **Define the purpose**: Before building a Digital Twin, it's important to define the purpose of the virtual model.

What are the goals you want to achieve with the Digital Twin?

Do you want to optimize a process? or

Monitor the performance of a system, or

Simulate different scenarios?

Steps for building a Digital Twin

2. **Collect data**: To build a Digital Twin, you need to collect data from the physical system.

This can be done using sensors, using IoT devices, or other data sources.

The data collected should be accurate, relevant, and comprehensive enough to create an accurate digital representation of the physical system.

Steps for building a Digital Twin

3. **Create a model**: Once you have collected the data, you can create a model. Frist, create a **conceptual model describing the concepts** and creating a **logical model which describe the logic/logical behavior of your system**.

You can use applicable software tools (flow-charts, wire- frames etc.) to design and implement those models that represent the physical system.

Those model should be as accurate as possible and include all relevant data points, parameters, and variables.

You need to clearly state any assumptions you make with your models and identify any possible limitation exist.

Steps for building a Digital Twin

4. **Integrate data sources**: Depends on the Digital Twin you try to implement based on the area, to make the Digital Twin more effective, you should integrate other relevant data sources such as weather data, traffic data, or social media data to provide a more comprehensive view of the system.

Steps for building a Digital Twin

5. **Implement analytics**: Using the data collected and using Near-Real-Time data, you need to implement tools for predictive analytics using AI and Machine Learning algorithms, statistical models, or other techniques on the system.

These tools can help you identify patterns, trends, and anomalies in the data, which can be used to improve the performance of the physical system.

Steps for building a Digital Twin

6. **Test and optimize**: Once the Digital Twin is built, you can use it to test various scenarios and analyze the potential impact of changes.

This can help you optimize the performance of the physical system and identify areas for improvement.

Implementing a Digital Twin for vector-borne disease outbreak monitoring in an urban environment (city)

Implementing a Digital Twin for vector-borne disease outbreak monitoring involves several steps, including:

1. **Define the purpose**: The purpose of the Digital Twin is to monitor and predict the outbreak of vector-borne diseases such as malaria, dengue, or Zika. The goal is to create a virtual model of the physical system, which includes data on the environmental conditions, mosquito population, and disease prevalence.
2. **Collect data**: Data collection is critical for building an accurate Digital Twin. The data can be collected from various sources such as weather stations, satellite imagery, ground based IoT sensor data (humidity, temperature etc..), and health records (confirmed cases). The data collected should include information on temperature, humidity, rainfall, mosquito population, human population density and disease prevalence.
3. **Create the model(s)**: Once the data is collected, you can use software tools to create a virtual model of the physical system. The model should include all relevant data points, parameters, and variables that influence the outbreak of vector-borne diseases.
4. **Implement analytics**: To analyze the data, you need to implement predictive analytics tools such as machine learning algorithms, statistical models, or other techniques. These tools can help you identify patterns, trends, and anomalies in the data, which can be used to predict the outbreak of vector-borne diseases.
5. **Test and optimize**: Once the Digital Twin is built, you can use it to test various scenarios and analyze the potential impact of changes. This can help you optimize the performance of the model and identify areas for improvement.
6. **Monitor and alert**: The Digital Twin can be used to monitor the physical system in real-time and provide alerts when there is a risk of a vector-borne disease outbreak. The alerts can be sent to public health officials, healthcare providers, or the general public to take appropriate measures to prevent the spread of the disease.

In summary, implementing a Digital Twin for vector-borne disease outbreak monitoring requires collecting data from various sources, creating a virtual model of the physical system, implementing analytics, testing and optimizing the model, and monitoring and alerting when necessary.

Digital Twin for vector-borne disease outbreak monitoring in an urban environment

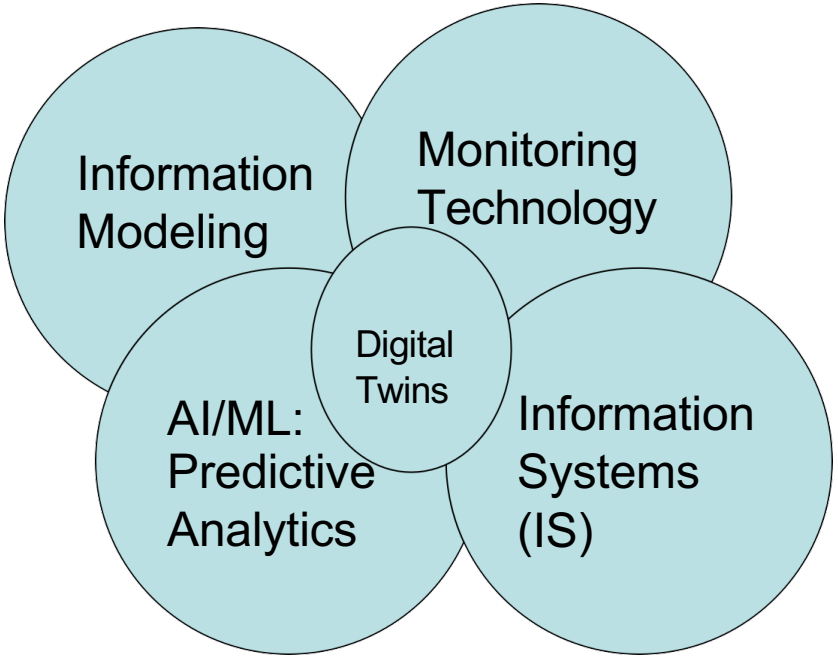
Implementing a Digital Twin for vector-borne disease outbreak monitoring in an urban environment involves several additional steps and considerations, including:

1. **Identify the target area**: The first step is to identify the target area where the Digital Twin will be implemented. This can be a specific neighborhood, district, or city.
2. **Map the physical system**: Once the target area is identified, you need to map the physical system, including the buildings, roads, water bodies, and green spaces. This information can be collected using satellite imagery, drone mapping, or street-level photography.
3. **Collect data on urban factors**: Urban factors such as land use, population density, waste management, and transportation can have a significant impact on the outbreak of vector-borne diseases. It is essential to collect data on these factors and integrate them into the Digital Twin model.
4. **Monitor the environment**: In an urban environment, it is important to monitor the environment in real-time. This can be done using IoT sensors or mobile apps that allow citizens to report mosquito breeding sites or other environmental factors that can contribute to disease outbreaks.
5. **Use predictive analytics**: Predictive analytics can be used to identify areas that are at high risk of vector-borne disease outbreaks based on environmental and demographic factors. This information can be used to allocate resources and implement targeted interventions.
6. **Collaborate with stakeholders**: Implementing a Digital Twin for vector-borne disease outbreak monitoring in an urban environment requires collaboration between public health officials, city planners, community organizations, and citizens. It is essential to involve these stakeholders in the planning and implementation of the Digital Twin to ensure that it is effective and sustainable.

Implementing a Digital Twin for vector-borne disease outbreak monitoring in an urban environment requires mapping the unban environment into a physical system, collecting data on urban factors, monitoring the environment in real-time, using predictive analytics, and collaborating with stakeholders. By implementing a Digital Twin in an urban environment, it is possible to improve the monitoring and prevention of vector-borne disease outbreaks, leading to better public health outcomes.

IM+AI/ML+IS+IoT…

Conceptually… it looks like this ©



Digital Twin References:

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- https://www.esri.com/en-us/c/corporate-programs/20/geospatial-hub
- https://www.esriuk.com/en-gb/digital-twin/overview#analyse-and-predict
- What is the Philosophy of Information? https://www.academia.edu/3491627/What_is_the_Philosophy_of_Information

Information Architecture

- https://www.youtube.com/watch?v=Ij4WquJaRTc&ab_channel=CareerFoundry

Information Model

What is an information model and why you need a one?

- An Information Model provides the framework for organizing your content.
- Once you have created an Information Model for your content repository, you will be able to label information in ways that will enhance search and retrieval.

Read / Resource:
https://gilbane.com/artpdf/GR10.1.pdf/What_is_an_Information_Model___Why_do_You_Need_One.html
https://en.wikipedia.org/wiki/Information_model

Information Model

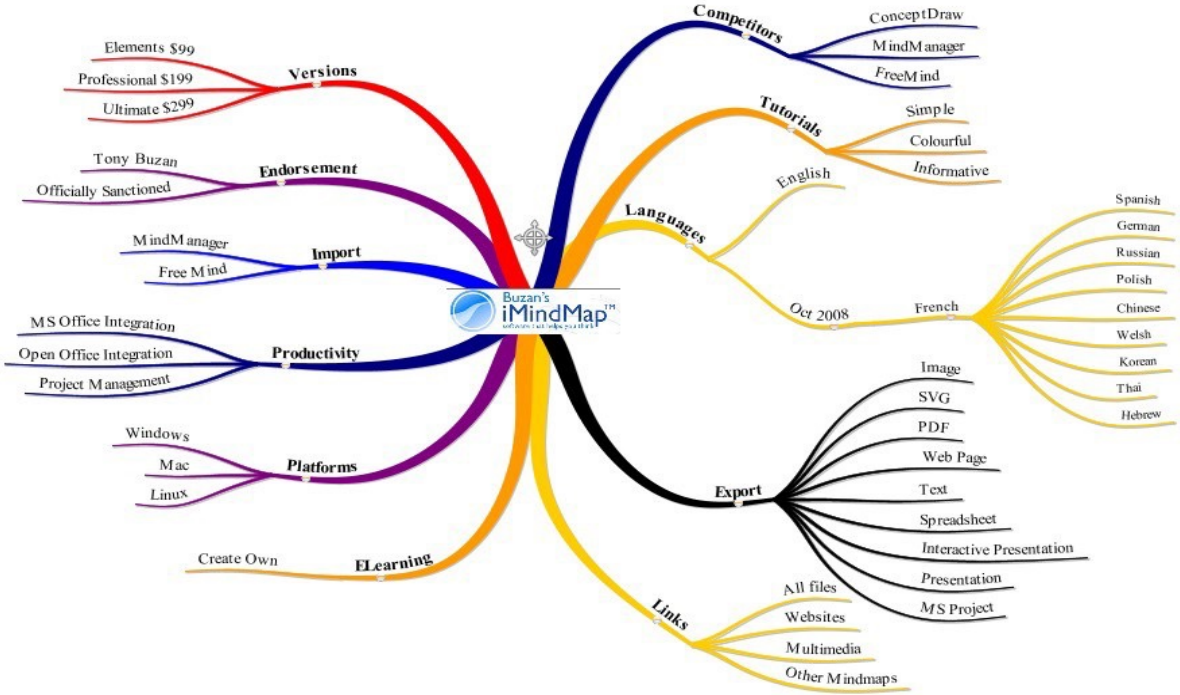
- An information model in software engineering is a **representation of concepts and the relationships, constraints, rules, and operations to specify data semantics for a chosen domain**.
- It can provide sharable, stable, and organized structure of information requirements or knowledge for the domain context.

Information Models – 3 levels

- Conceptual level
- Logical level
- Physical level

- Conceptual level models, sometimes called domain models, are typically used to explore concepts and often created as part of initial requirements envisioning efforts as they are used to explore the high-level static business or science or medical or …. structures and concepts
- *Followed* by logical and physical models

Meta-modeling -> Mindmaps



Logical models

- A *logical* entity-relationship model is provable in the mathematics of data science.
- Given the current predominance of relational databases, logical models generally conform to relational theory.

Information models - bad

- It's very easy to tell when an information system you're trying to navigate has no underlying Information Model. Tell-tale characteristics:
  - You can't tell how to get from the home page to the information you're looking for.
  - You click on a promising link and are unpleasantly surprised at what turns up.
  - You keep drilling down into the information layer after layer until you realize you're getting farther away from your goal rather than closer.
  - Every time you try to start over from the home page, you end up in the same wrong place.
  - You scroll through a long alphabetic list of all the articles ever written on a particular subject with only the title to guide you.

Resource: https://gilbane.com/artpdf/GR10.1.pdf/What_is_an_Information_Model_Why_do_You_Need_One.html

Information models – good

- Oddly enough, you generally don't notice a well-conceived Information Model because it simply doesn't get in your way….
  - On the main page, you notice promising links right away.
  - Two or three clicks get you to exactly what you wanted.
  - The information seems designed just for you because someone has anticipated your needs.
  - You can read a little or ask for more - the cross-references are in the right places.
  - Right away you feel that you're on familiar ground - similar types of information start looking the same.

Resource: https://gilbane.com/artpdf/GR10.1.pdf/What_is_an_Information_Model_Why_do_You_Need_One.html

Logical models

- For a logical data model to be normalized, it must include the **full population of attributes** to be implemented and those attributes must be defined in terms of their domains or **logical data types** (e.g., character, number, date, picture, etc.).
- A logical data model requires a complete scheme of **identifiers** or candidate keys for unique identification of each occurrence in every entity. Since there are choices of identifiers for many entities, the logical model indicates the current selection of identity. Propagation of identifiers as foreign keys may be explicit or implied.
- Since relational storage cannot support many-to-many concepts, a logical data model resolves all many-to-many relationships into **associative entities** which may acquire independent identifiers and possibly other attributes as well.

Coneptual -> Logical

- Identify objects (entity) and their types
- Identify attributes
- Apply naming conventions
- Identify at least one relationship
- Assign relationships

Some tools

- For use case development – simple graphics tools, e.g. graffle
- Mindmaps, e.g. Freemind
- For modeling (esp. UML if you like it):
  - http://en.wikipedia.org/wiki/List_of_Unified_Modeling_Language_tools
- Concept, topic, subject maps (try searching)
  - http://cmap.ihmc.us

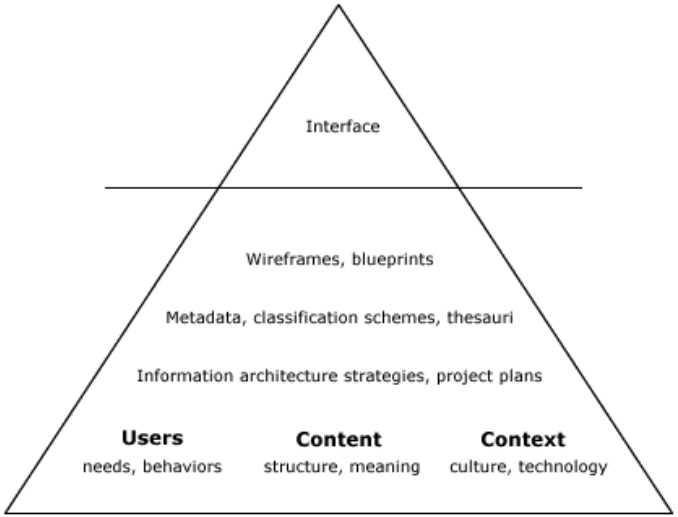
Information architectures: theory and practice

(Information) Architecture

- Definition:
  - “is the art of expressing a model or concept of information used in activities that require explicit details of complex systems” (wikipedia)
  - “… I mean architect as in the creating of systemic, structural, and orderly principles to make something work - the thoughtful making of either artifact, or idea, or policy that informs because it is clear.” ~ Wuman

Architectures – what is seen?

- **Some illustrate information architecture as an iceberg**.
- Just like an iceberg, the majority of information architecture work is out of sight, "below the water."
- The work includes the creation of plans, controlled-vocabularies, and blueprints all before any user interfaces are created.



More detail to connect us

- “The term information architecture describes a specialized skill set which relates to the interpretation of information and expression of distinctions between *signs and systems of signs*.” (wikipedia, emphasis added)

Image Credit: http://www.chi-athenaeum.org/archawards/2007/2007photos/AA07-72.jpg

Meaning not *deep* thought

- “**Information architecture is the categorization of information into a coherent structure**, preferably one that most people can understand quickly, if not inherently.
- It's usually hierarchical, but can have other structures, such as concentric.

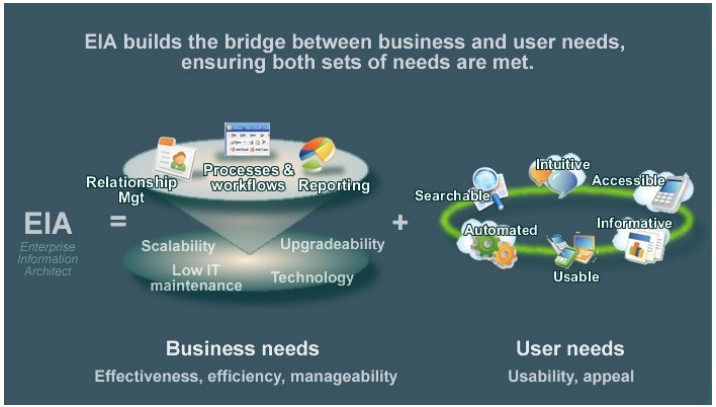


Image Credit: http://community.intellicore-design.com/storage/images/intellicoredesign/EIAServices_DefinitionDiagram_v2_web.jpg

Art or skill?

- Form follows function (Louis Sullivan) – who put this into effect in building structures, homes.
- Based on two previous foundations classes, information theory and signs (semiotics), it should be clear you that the answer is ‘yes’ (both).

- (Background Reading on Louis Sullivan and Form follows function : https://en.wikipedia.org/wiki/Form_follows_function)

Image Credit: http://www.busyboo.com/wp-content/uploads/2007/12/dynamic-architecture-design.jpg

Remember this one?

Examples

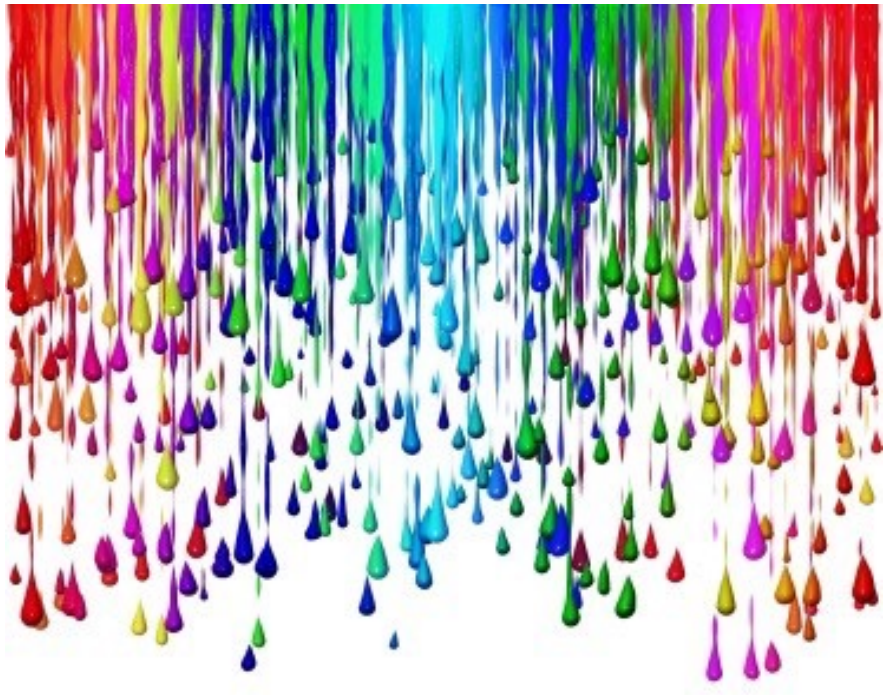
Assignment 4

- Construction of an information model and preliminary information architecture/ discussion of design issues of <your> use case from Assignment 1 & 2.

So, now some “design”

Design theory; elements, principles, color…

- Elements
  - Form
  - Value
  - Texture
  - Lines
  - Shapes
  - Direction
  - Size
  - Color



- Relate these to previous class, signs and relations between them

Principles of design

- Balance
  - Balance in design is similar to balance in physics
- Gradation
  - of size and direction produce linear perspective.
  - of color from warm to cool and tone from dark to light produce aerial perspective.
  - can add interest and movement to a shape.
  - from dark to light will cause the eye to move along a shape.
- Repetition
  - with variation is interesting, without variation repetition can become monotonous.

Balance, gradation, repetition

Principles of design

- Contrast
  - is the juxtaposition of opposing elements e.g. opposite colors on the color wheel - red / green, blue / orange etc.
  - in tone or value - light / dark.
  - in direction - horizontal / vertical.
  - The major contrast in a painting should be located at the center of interest.
  - Too much contrast scattered throughout a painting can destroy unity and make a work difficult to look at.
  - Unless a feeling of chaos and confusion are what you are seeking, it is a good idea to carefully consider where to place your areas of maximum contrast.

Contrast


He'd been burned once before by a glamorous girl.
Look out, Amy! You'll scorch your husband!
SOMETHING
WITH
BY ROBERT FONTAINE
LILACS

Principles of design

- Harmony
  - in painting is the visually satisfying effect of combining similar, related elements. e.g. adjacent colors on the color wheel, similar shapes etc.

- Dominance
  - gives a scene interest, counteracting confusion and monotony
  - can be applied to one or more of the elements to give emphasis

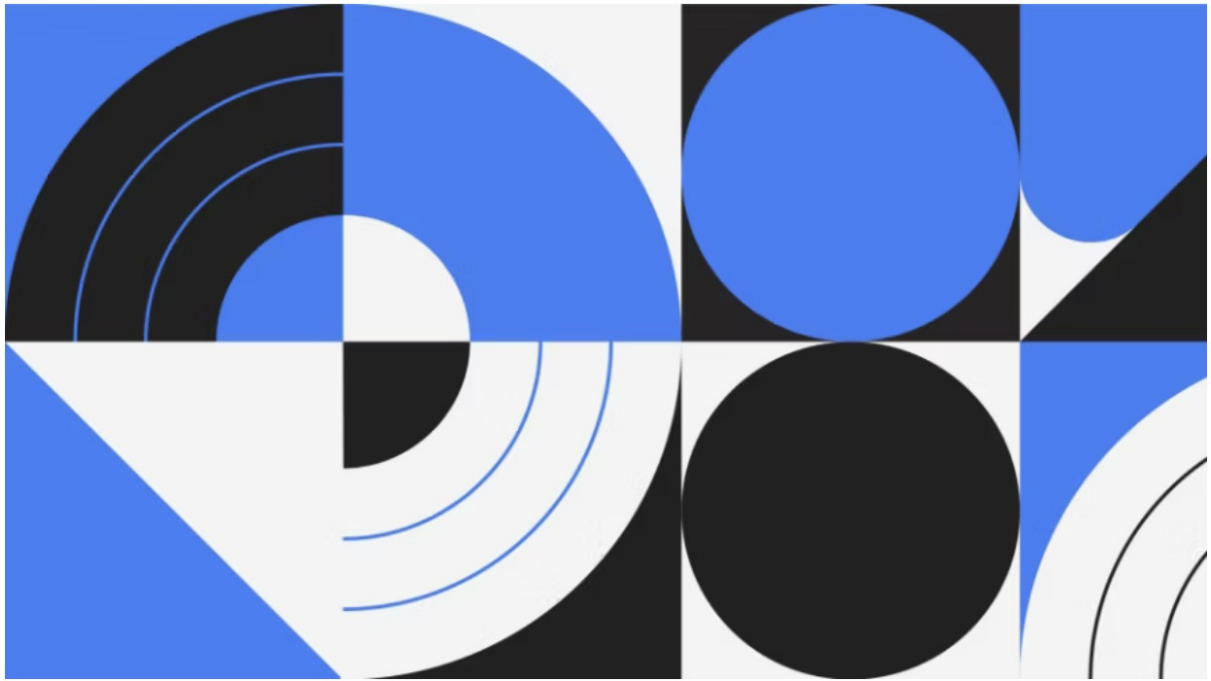
Harmony, Dominance

Principles of design

- Unity
  - Relating the design elements to the idea being expressed in a rendering reinforces the principal of unity.
  - E.g. a scene with an active aggressive subject would work better with a dominant oblique direction, course, rough texture, angular lines etc. whereas a quiet passive subject would benefit from horizontal lines, soft texture and less tonal contrast.
  - in a painting also refers to the visual linking of various elements of the work.

Unity

Unity

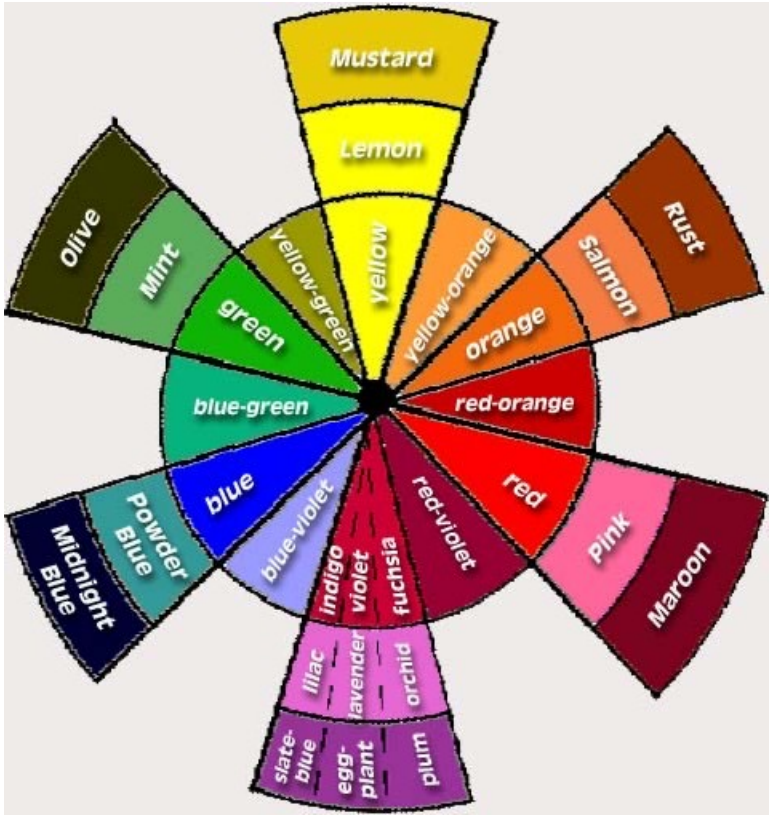


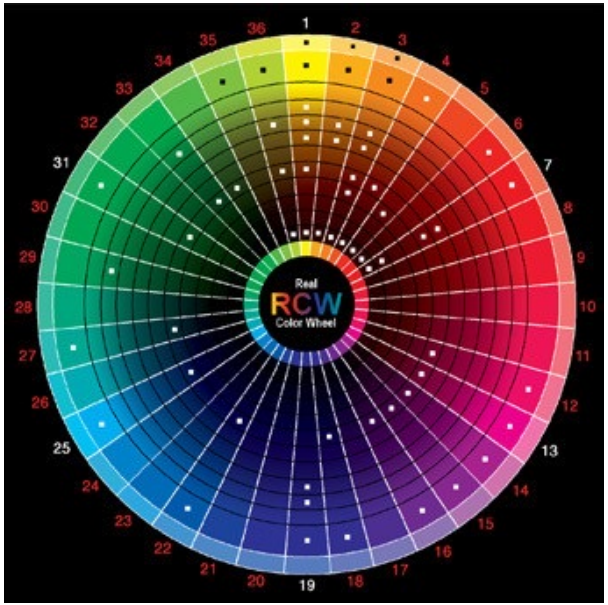
https://helpx.adobe.com/lv/express/how-to/graphic-design-basics.html

Color

- **Primary** Colors - Red, Yellow, Blue - these colors should not be intermingled, they must be brought together in some other form
- **Secondary** Color - Orange, Violet, Green, these colors are created by mixing two primaries.
- **Intermediate** Colors - Red Orange, Yellow Green, Blue Violet, etc.; mixing a primary with a secondary creates these colors.
- **Complementary** Colors - are colors that are opposite each other on the color wheel. When placed next to each other they look bright and when mixed together they neutralize each other.

Wheels


Mustard
Lemon
Olive
Mint
yellow-green
yellow
green
yellow-orange
orange
Salmon
Rust
blue-green
red-orange
blue
Powder Blue
Midnight Blue
blue-violet
indigo
violet
fuchsia
red-violet
red
Pink
Maroon
lilac
lavender
orchid
state-blue
egg-plant
plum


Real
RCW
Color Wheel

Color applied

- Warm colors are on one side of the color wheel and they give the felling of warmth for example red, orange and yellow are the color of fire and feel warm.

- Cool colors are on the other side of the color wheel and they give the feeling of coolness for example blue, violet, are the color of water, and green are the color of cool grass.

Term Project!

Thanks!

Have a great spring break!!!