Survey on Visualization

Visualization

Computer-based visualization systems, provide visual representations of data to help people understand the data. Not always interactive. Limited resources (CPU, human).

Human is necessary to make decisions. (i.e. Self-driving car, why did this situation happen?)
Representation generated by computer
Human visual perception is channel of communication
External representation used (i.e. maps, not needed to memorize locations)
How does the data structure look?
What do you want to do? Prove a hypothesis, explore, etc.
Operational definition of better? It's faster, simpler, etc.
Interactivity? not always wanted because not reproducible
Resource-limits: needs to be understandable(human), memory(computer)
Design space: huge, trade-offs (too complicated, needs weeks to "get into")

Search Space for Visualization Design

Know many possible types of visualizations, and consider many of them! (If you consider or know only few you might choose a poor solution)

Areas of Visualization

Scientific Visualization (i.e. medical data, data from experiments)
Information Visualization (i.e. data from social media, etc.)
Visual Analytics

Levels of Visualization Design

Characterize the problems of real-world users - what is the problem, characterize data, understand domain language
Abstract - what type of data (continuous, categorical), what type of operation
Idiom - Design Encoding and Interaction Techniques
Last: Concrete Algorithm

Analysis of Visualization Design

Domain situation - Who is the target?
Abstraction - **What** is shown? **Why** is the user looking at it?
Idiom - **How** is it shown?
Algorithm - Efficient computation?

What?

Data Types (Items, Attributes, Links)
Attributes (Categorical, Ordinal) - Ordering Direction (sequential, cyclic)
Data and Dataset Types (Tables (items, attributes), Trees(items, links), Networks)

Why?

Discover distribution, compare trends, locate outliers (find action-target pairs)
Actions
Analyze (Consume - discover, present OR produce (annotate, record))
Search (Lookup, brows, locate)
Query (Identify, Compare, Summarize)
Targets
All Data - Trends, Outliers, Features
Attributes - One (distribution), Many (dependency, correlation)
Network Data - Topology
Spatial Data - Shape
How?
Encode (Arrange - Express, Separate, Order; Map - Color, Size, Shape)
Manipulate - Change, Select, Navigate
Facet - Juxtapose, Partition, Superimpose (overlay visualizations in same graph)
Reduce - Filter, Aggregate, Embed

Guidelines
No unjustified 3D (occlusion problems, etc.)
Eyes over Memory (use a map of cities instead of just tables, etc.)
Resolution over Immersion (large screen-projection better than VR/AR)
Function First - Form Next (what do you want to achieve - then aesthetics)
Get it Right in Black and White (use color carefully - redundant encoding)

Data Centric Techniques (Scientific)
Scalar Field Visualization (Isosurfaces, Volume Rendering)
Vector Field Visualization (Flow, show only a few lines)
Tensor Field Visualization (i.e. visualize Matrix)

Visualization Topics
Geometric Modeling for Visualization (3D Mesh compression, model simplification - be careful it can introduce errors)
Virtual environments (info on mobile device)
Large-Scale Data Visualization (many datasources - streaming approaches)
Visualization of Time-Varying Data (how to keep/analyze? i.e. aggregate uninteresting part)
Perceptual Issues in Visualization
Visual Data Science (much data → reason, look up old data to predict i.e. weather)
Physicalization (i.0e. 3D printing digital models)
Visual Modelitics (automated analysis, model buildings - semantic supports (i.e. designing a house with suggested constraints: i.e. room size, etc.))
Medical Visualization (P4 - personalized, predictive, preventive, participatory, i.e. virtual avatar)
Biomedical Visualization (simulations to narrow down to limit number of experiments)
Cohort/Comparative (100 datasets need to compared i.e. 100 patient datasets)
Visual Data Assimilation (compare measurements with phenomena)
Machine Learning (explainable AI, why this outcome?)
Immersive Analytics VR/AR (goggles display data on real-world objects)

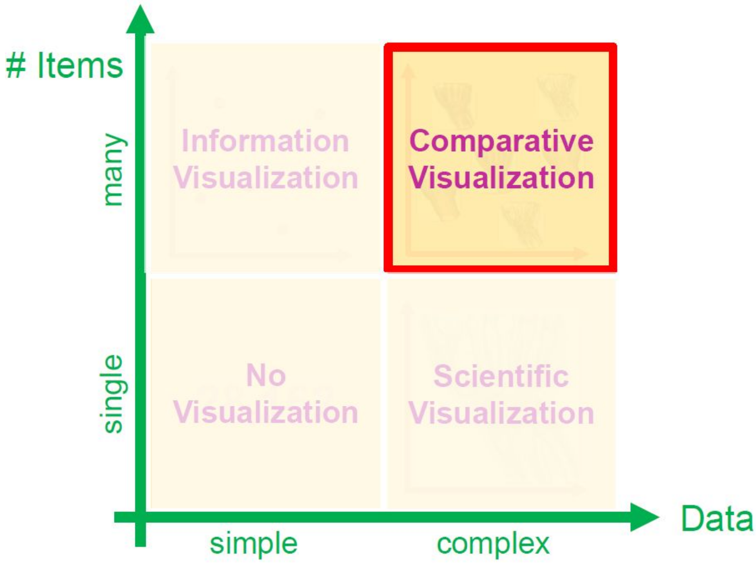
Scalability (what happens if data grows too large? 100 nodes vs. 1000000 nodes - new model necessary)
Data driven → task driven visual analysis (defined task - don't care about data; automatic)
Visualization Systems VTK, SCIRun, IRIS, AVS, ParaView, Amira, Xmdv Tool, Tableau, d3
Visualization STAR …

Visualization Multivariate Networks
Layouting (topology-driven, attribute-driven), View Operations (juxtaposed, integrated, overloaded)

Visual Analysis for Ocean Atmospheric Datasets
(Parallel Coordinates Plot), etc.

Comparative Visualization

Visualize several data sets and compare them (i.e. data of 100 patients over period of time)
(Data) Visualization data is changing, increasingly complex, different quality, heterogeneity → data streaming if data gets too large
Comparative Visualization complex data and many items (i.e. medical data)



Examples Shape indicates relation (skull embedded in Grid), Motion (linear, keyframes, overlayed)
Approaches Juxtaposition (side-by-side) needs focus shift when comparing, Superposition (overlay - semi-transparent) leads to clutter, Explicit Encoding (calculate derived value from data, differences etc.) how info on single dataset?
Dataset Series
Varying Parameters; Compare several measurements;
Comparative Slice View, checkerboard pattern (on black fields one datasets, on white fields others) → multiple datasets on one screen; Hexagon divided into several regions (datasets) - center (i.e. fused dataset)

Visual Steering to Support Decision Making in Visdom
Branching tree (from many simulations) shows alternative scenarios (i.e. flooding simulation); Human controls simulation worldlines; gets knowledge from the data in different views;

Visual Comparison
Analysis of Image Set differences; Juxtaposition not enough gets too complicated with too many pictures;
Only Differences are shown (get detailed view by clicking on it) other parts background image;

General Comments
What and how to compare? Find outliers, find averages, etc. depending on that find feature vectors etc.
Scatterplot to illustrate nD point sets (use points as primitives, eliminate most dimensions, visualize distances)
(Mean Object) MObjects to illustrate pores in XCT of CFRP (use pores as primitives, eliminate spatial location, visualize pore orientations) (material breaking because of too many pores, where are they, etc.) → normalize objects to make them comparable i.e. take out spatial info;

Task dependency to visualize (similarities, outliers, trends) → defines how objects are shown
Complex data leads to complex metrics (How to compare curves, surfaces, etc.)

Profile Flags: Choose a point, show curves on banner, range selector (how many curves are compared)

Maximum similarity isosurfaces: Compare isosurfaces in a matrix (low energy with high energy → black = similar); Isosurfaces are embedded into a 3D distance field → compare those; take most similar isovalue to compare;

Visualization of sets ←→ Statistical Visualization (too distributed vs. too aggregated) → Localize analysis in space and/or time; Allow interactive exploration;

Explicit encoding: How to show subtle differences? Color, Cut-outs, Ghosting, exploded views, focus + context, distortion

Caricaturistic Visualization (extrapolate differences between items or average)

Parameter space analysis, Uncertainty (showing/hiding), Variability/Robustness, Mapping complex objects onto each other; Scalability (items and complexity)

Text and Document Visualization

Textual information is everywhere / unstructured;
Sources: articles, emails, papers, etc.
Domains: legal matters, feedback, etc.

Analysis Task
Topics: What are main Topics? Difference between documents? How do topics change?
Events: What events can be tracked in a text stream?
Sentiments: What do people think about a topic? Customers opinion on different Products?

Visual Text Analysis
Analytics: Structure text input, derive patterns/categories, interpretation;
Visualisation: transform text into spatial representation

Text and Document Data
Text itself (document), collection of text docs (corpus), Stream
Paragraphs → Sentences → Words → Characters
Text, Citations, Authors, Metadata

Text Representation Levels

Phonetic Level acoustic and articulatory properties

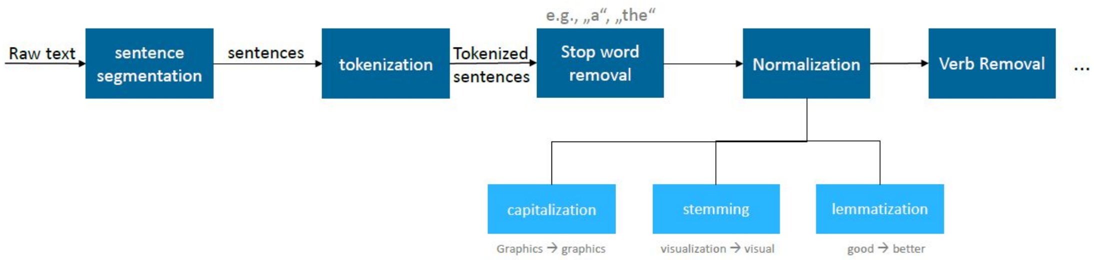
Lexical Level character strings, atomic entities → Tokenization:
Character Sequence → Characters, Words, Phrases, Sentences
Application: Arc Diagrams (repetition in text), Word Tree (tree: root node = search term)

Syntactic Level identify and tag the function of each token
Chunking and labeling of multi-token sequences - lexical category, singular, tense
Use supervised learning;

Semantic Level extraction of meaning and relationship
Identify and tag functions of objects: predefined categories (dates, persons, etc.)
Extraction process: Named-Entity-Recognition (recognise with supervised learning)
Named (Person, location), Numerical (Money, number), Temporal (Date, time)
i.e. investigative journalism: panama papers

Dependencies
Deriving dependencies between parts of speech or entities; Lexical dependencies;
Document occurrences;

Vector Space Model
Bag-of-words representation (feature vector, weight for each token: i.e. occurrence count)
Preprocessing



lemmatization - “better” is a form of “good”, “am” is a form of “be”

Encoding
Items: tokens, entities,
Links: entity dependencies,
Attributes: weight, category (place, date)

Highlighting Text bold, yellow background, etc.

Word Clouds log (term frequency) = font-size, same font-size → long works look bigger

Wordle brute force layouting of Word Clouds

Phrase Nets variation of word clouds, Input: regex; Nodes: words; Edges: user-specified relations, weighted by number of matches;
compress edges and show only N most frequent terms;

Document-Comparison Visualization
Euler-Diagrams, Term-Document Matrix (weighted → color shade: term frequency * inverse document frequency; word important if appears in fewer documents and more often in a target document)
Euler(Venn)-Diagrams scale bad!

Compact Rectangular Euler Diagram
Split intersecting sets → containment hierarchy
Constraint-based layout; Link bundles;

Other Visualisations
Parallel Tag Cloud, Radial layout (merged word clouds with spring-based layout)

Vector Space Model - Document Similarity
All documents represented by feature vectors (high-dimensional; if small angle → documents are similar)
Jaccard coefficient: proportion of terms two documents have in common vs. what they do not have in common

Dimensionality Reduction
transform into lower dimensional space; linear (PCA), non-linear (isomap); Visualization as scatterplot

Document Landscapes
MDS for 2D embedding, encoding (height & color: density documents, labels for frequently used words within clusters)

Term Landscapes term extraction → term ranking (similarity) → euclidean distances → MDS → clustering → term intersections
Term Expressiveness
tf*idf poor summary; first occurrence in document, keyphrase grouping, keyphrase selection (remove similar ones)

Word Embeddings Shallow neural network; Input = text window; Output = Vector Space Model of words; wants to predict nearby words

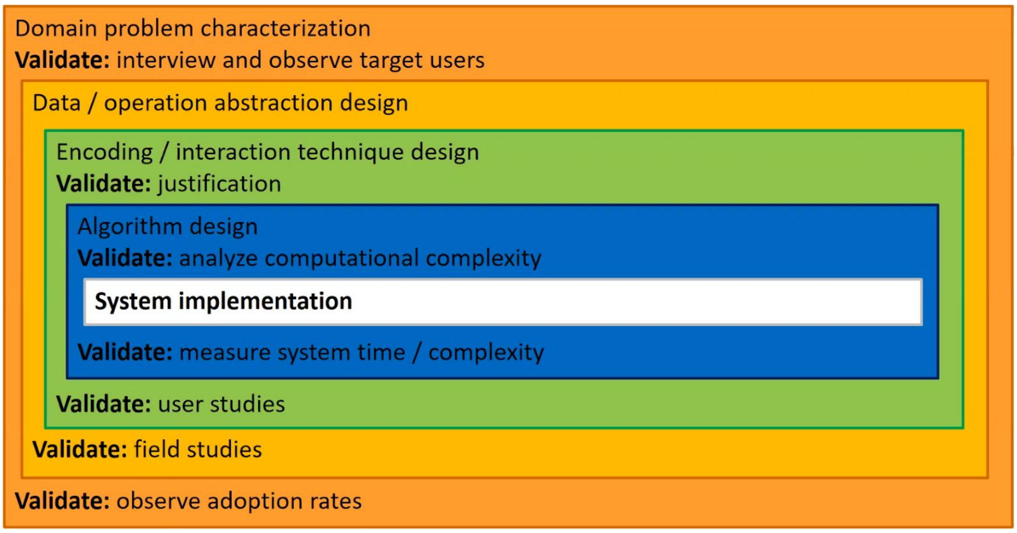
Evaluating Visualization

What is a good visualization?
Should Amplify Cognition! How to measure "Insight" (discovery, decision making and explanation)?

Examples of Questions that can arise
Which data analysis and visualization tools could help them?

Horizon Graph: line chart (with +/- values) → color negatives red and take abs; cut in middle → overlay peaks;
Space-efficient time-series visualization technique; increase density for time charts;
How does compression effect insight?
Radial vs Linear charts, can daily patterns be better perceived in clock-like radial charts?
Diploma Thesis: how will you validate your proposed solution?

Nested Model for Visualisation Design



Interview and observe target users
Semi-structured interview; key questions → general area to explored; freedom to diverge;
Recorded and transcribed (notes are only selective “only what we want to hear”)

Coding
Iterative characterization of qualitative data (transcript, etc.)
Open Coding: label observed phenomenon = concept → group concept into categories
Quality Assurance: Code Book (what codes, description, examples) - multiple independent coders (inter-rater reliability; iteratively trying to reach a certain reliability)

Justification
Why are the specific interactions chosen.

Design Principles
Expressiveness: Tell the truth. (i.e. misleading axis)
Effectiveness: Use encoding that people decode better.

Psychophysical Experiments measure human sensation triggered by physical stimuli
Flicker frequency so that the signal is perceived as steady; finding noticeable difference between two colors; etc.
In experiments: Precise physical definition of stimulus patterns; assuming no/low instructional bias (low number of participants);

Method of Adjustment
observer can adjust stimulus intensity; until it becomes just noticeably different from standard; (adjust color until its the same, or same length of lines)

Staircase Procedure
Dynamic adaptation of stimulus based on observers response;
Threshold: average stimulus intensities when observer response changed;
(go down, then up, then down, depending on the response)

Just noticeable difference (JND)
size of difference must be proportional to the background; k = delta I / I

$p = k \ln (I/I_0)$ perceived sensory intensity p from stimulus intensity; (the more points there are the more points need to be added to spot an easy difference)

Stevens Power Law $p = kI^a$ Length (a = 1), Brightness (0.5) → brightness underestimated; Electric Shock (3.5) → overestimate;

Encode Changes with perfect correspondence; i.e for area needs to be inflated much larger to be perceived correctly;

Perception of correlation in scatterplots is proportional to actual correlation coefficient;
Slant: Orienting a probe towards the estimate surface normal;

Psychophysics and Visualization Decoding
Elementary psychophysical findings cannot be directly translated to Vis (increased task complexity, more stimuli)

Proportional Judgement → stacked barchart with gap = bad, pie charts, bubble, treemap also bad

Color
Luminance / Saturation = Ordered; Hue unordered

User Studies
Controlled user study (lab, crowdsourcing, eye tracking)
Inspections performed by experts (heuristic evaluation (informal), cognitive walkthroughs (specific tasks))
Qualitative result inspection

Controlled User Studies
best; Hypothesis: logical, precise, testable (Visualization A will make people solve task B fast.)
Independent variables (chosen variables) / factors : visualization method, task, datasize;
Levels: number of variations for each factor = test conditions;
Dependent variables (cannot be chosen): measured user performance (task completion time)
Experimental Design: within-subject - all users do everything = repeated measures (care for learning effect)
Between-subject design: users divided into groups, perform different variations of one independent variable; - users does study with one visualization
Mixed design: users are divided in groups perform different variations of one independent variable and all variations of others;

Analysis: how large is the difference - use statistically significance i.e. ANOVA, t-test;
Answer: is the difference of practical significance;

Nested qualitative inquiry: put quantitative data into social context; experimenter observations → detect unexpected events, explanation for outliers;
User opinions - semi structured interviews, questionnaires;

Typical low-level tasks for evaluating infovis (retrieve value, filter, compute derived value, etc.)

Recap: High Level Tasks
Exploration (search and analyze data without hypothesis) - Confirmation (examine hypothesis) - Presentation (communicate facts)

Crowdsourcing Visualization Evaluation

Web workers perform small tasks (Mechanical Turk)
Advantages: more diverse population → ecological validity (not only CS students); large population → large design space evaluation
Disadvantages: no control over experimental conditions, subject motivation?

Untargeted Analysis show visualization for a certain time; then let them "report". Code answers;

Eye Tracking where people look depending on tasks; Fixations (areas of interest), Saccades (transition between fixations), Scanpath (series of fixations)

Qualitative Result Inspection
no experiment, reader inspects result image or walkthrough (comparative, isolated) - no previous solution; hard to decide when user study is not necessary (know SofTA); Show it on multiple examples;

Field Studies
Qualitative data acquisition: users work on their own problems in normal environment;
Unobtrusive on-site → realistic, not generalizable; Observations (field notes, video, audio, field logs), Interviews;
Coding to analyze data;

Other methods with domain experts
Usability study (lab study, pre-defined task, observations/interview); Field Experiment (on-site controlled study); Informal evaluation (demo to domain experts in lab, no predefined task) → not so useful as they won't say its bad probably

Summary
Designing and validation visualizations (Understanding data analysis process - field and interview), design choices & justifications (expressiveness & effectiveness), validation (visual encoding and interaction techniques - controlled user studies, inspection methods), abstraction design (field logs, useability studies)

Validation method should be chosen according to contribution claim!

Upstream errors cascade to downstream levels! If you show the data in a great way, for a "non-problem" its useless.

Spatio-Temporal Visualization

Spatial Data
Spatio = space, visualisation for data with a spatial reference (i.e. map reference)
Spatial statistical attributes, point data, connections, simulations
Challanges
Spatial reference, large datasets (cluttering)
Statistical Attributes

statistical values related to spatial reference (BIP, etc.); use relative values!
→ Choropleth Maps
Geographic entity coloured (color ramp) according to some statistical value;
Choose right visual mapping; (number of classes changes how the map looks)
Bigger entities always stick out, can hide smaller entities;
Diverging (2 emphasized ends → transition phase) vs. Sequential (light to dark) color map;
Or use colors with semantic meaning (i.e. political affiliation)
Spatial Resolution: fine-grained may show a better picture
→ Circle Maps
reflects attributes better than just the geographic size
→ Tile Grid
entities get all the same size, placement assigned according to geographic location
→ Cartograms
Contiguous, morph geographic entities according to the attribute

Point-based Data
points represent geographic position, for each position we have a value (i.e. pictures taken per location in germany)
draw points on a map; growing circle map;

Connections
OD-relations (origin and destination)
Cluttered Relations improved by Edge Bundling; (bundle edges together based on forces between them) - spring forces (hold points in position) vs. electrostatic forces (pull points closer), additional parameters (compatibility measures - angle, length, distance) to check which edges can be bundled together
OD-Maps red squares for origins, blue for destinations within an entity;

Simulations
Visualisation of spatial simulation is important (only numbers don't tell you much)

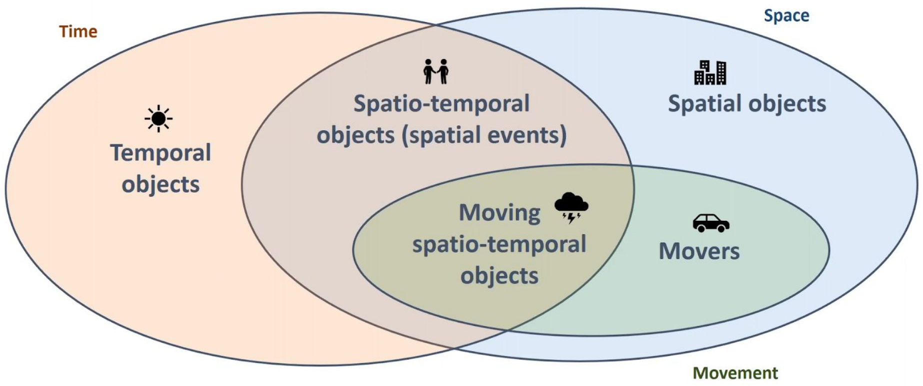
Trajectory Data
Temporal → time; Visualisation for data with a spatial and a temporal reference;
Data Types (Space, Time, Objects)
Systematic description of information; possible describe structure of datasets, compare datasets and visualisation, define views onto the data;

Space
sets consisting location defined by coordinates; continuous; distances between locations; no natural origin or ordering; from 1 to 3D;

Time
timestamps, continuous, linear, natural ordering, needs reference system (timezone)

Objects
physical/abstract entities; they move in time/space → should be analyzed;

Fixed position (spatial objects, i.e. building), events with limited time of existence (temporal objects i.e. sunrise), events with fixed position in space and limited time of existence (spatio temporal objects = spatial events i.e. concerts), changing spatial position over time (moving spatial objects = movers), moving events with changing spatial position and limited time of existence (moving spatio-temporal objects, i.e. clouds)



Visualisation Foci
Define from which view data is visualised (focused on movers/spatial temporal-objects/time/space) depending on focus different aspects of the data can be studied

Focus on Movers
movers = objects that change spatial position over time; Movement = change of spatial position of an object;

Movers are characterised by their trajectories (points sampled in space i.e. GPS), interpolated curve, optional attributes (i.e. speed); movement is a sample problem → enough samples necessary;
Challenges: Noise (from sensors) - solved by filtering (Kalman (predicts next point from previous points), Particle, Mean);
Map-Matching (align trajectory to road - solved geometrically/topologically or probabilistic)

Space-Time Cube
well known, X/Z = map, Y = time; shows spatial extent as well as temporal patterns;
Problems: cluttering;
Solve by: Trajectory aggregation, i.e. Clustering, Edge bundling

Summary User can concentrate on individual movements, understand mobility behaviour and detect temporal/spatial patterns;

Focus on Spatial Events
spatial event = entities defined by space and an interval in time (limited existence)
Individual (along a single trajectory) i.e. stops, turns; Collective (involving multiple movers) i.e. traffic jam

How to extract stops? stop is point in space where people stayed a while;

Simple: check if distance and successor is less than a threshold (i.e. 100m) → find last successor that fulfills this criteria, check if timespan is above threshold → all points there summarised as a stay point;

for Vehicles: a point is considered a stop if velocity meets certain criteria;
for pedestrians: unclear meaning (if in shopping center?)

no fits all solution, depends on sensor setting / movers, etc.

Focus on Space
basic concept for the visualisation; involves aggregation of data to create an overview;
i.e. height maps (color represents number of movers), flow maps (represented as arrows)
Space needs to be divided into grid; space tessellation (create regular/irregular grid, voronoi tessellation); grid defines granularity of visualisation; fine grained visualisation needs fine-grained grid;

Accessibility: visualize all points that can be reached within a certain time;

Summary
allows users to get an overview, detect spatial patterns

Focus on Time
time as basis for visualisation, produces abstract visualisations (decoupled from map)

Summary
overview of temporal distribution, cycles and temporal patterns

Sports Data Visualisation

Different types of data: abstract, statistical, spatial; Many different user groups
Data Visualisation after event has taken place;
More data available, no collection standard; clubs interested to improve performance

Sports Data
different parameters; multiple levels (team structures, athlete performance, etc.)
Development over time, spatial positions, abstract data (goals); Big Data
Collected via. video analysis, multi-camera setups, manual data collection, sensors in sport equipment; → expensive!

User Groups and Tasks
Athletes, Trainers (analytic: overview, performance, comparison, spatial info, decision making - swap players etc.), Fans, Media, (narrative: overview/detail comparison, “visualisation for masses”) … with different interest

Types of Data
Box-score data - statistical i.e. goals / game
Tracking data - spatio temporal data i.e. player position in the field
Meta data - combination of box-score and tracking data; adding info i.e. weather

Box-Score Data
statistical, summarises an event;
Show Time-evolving championship tables and rankings:
Example: Ribbon per team, ribbon y-position shows rank;
Show Scores, goals and points;
Bars show goals and received goals OR line chart etc.

Glyphs
markers representing data; marker corresponds to attributes of the represented data; encode several attributes in a glyph;

Tracking Data
Events and Trajectories
positions interpreted as trajectory (movement);
use lines/splines to display data (intuitive, color for additional attributes)
i.e. Overview of team movement;
→ large data = cluttered
Solution: Aggregation of Data
Positions aggregated with Heat Maps (gives good overview of spatial position of players)
Network or Graph visualisation (i.e. connections between players i.e. passes)

Players point of view
data collected on individual basis (i.e. running apps)

Visual Analytics (still tracking data)
just showing trajectories will be one big clutter; improve by using i.e. mean position + variance (circle);
Use role assignment (every player has a role per frame, can only be present once) → only use data for one role per player → no more overlaps

Meta data
Sports, Players and Game Characteristics
i.e. Arc Diagrams (vertices placed along lines, arcs connect vertices);

Players and Team Performance
compare performance;

Competition structure
i.e. events with twitter messages (sehr fesch)

Visual Analytics (this time for metadata)

based on roles find different formations (i.e. attacking formation, defensive, neutral…)
compare formations over games home/away (overlap of marks)

Glyph based Visualisation for Real-Time Analysis
summarise data of sports event after it took place; decision making on demand; real-time visualisation; overview over entire match; record events (i.e. goals, etc.) → represented by pictograms = easy to understand; pictograms have additional info on them (i.e. duration bar, etc.) → timeline to arrange glyphs;

Visualization for Non-Destructive Testing

Material science (understanding, discovery and use of new materials (structure, performance, properties, processing)

Materials Testing
Destructive (no additional tests) vs. Nondestructive testing (digitalize and then test, no damage caused to original object)
Techniques for NDT: ultrasonic, CT, magnetic-particle, etc.

XCT Analysis Workflow
Take part from component → CT scan → CT Dataset
Reinforcement Components (fibers absorb forces), determine material characteristics
3DXCT data → label data characteristics;

NDT & Big Data
lare data, multiscale, multimodal, multivariate, derived data → complex data
missing intuition: no simple intuition, data represents diverse quantities
Limited human perception

Data always growing, uncertainty needs to be known, data gets more heterogeneous (CT + ultrasound + ..), real-time wanted (CT within seconds)

Material Systems
Composite (bikes), Polymer (foams, etc.), Non-Metal Inorganic (windshield), Metal and Alloys, construction materials (Mörtl), Biological and Biomedical Materials (Stent)

Exploration/Visualization of Finite Element Simulations
extract representative volume elements; understanding materials science processes modelled in FE simulations;

Analytics of Computational Fluid Dynamics
analysis and quantification of porous media (permeability, diffusion properties etc.);
Use topological descriptors to show flow of fluids;
Applications: Filtering, etc.

Analysis and Visualization of Molecular Dynamics Simulations
Characterise structural changes under external force;

Feature Extraction and Quantification
quantify properties, statistical evaluation;

Stress and Deformation Analysis
Evaluation of critical areas; combination with FE-Simulation

Fatigue Testing and Damage Analysis
escalation step of stress/deformation analysis; material fails while aging

Dimensional Measurements
get measurements (straightness, circularity, flatness)) and tolerances; coupled with uncertainty quantification and visualization

Uncertainty Quantification and Visualization
determine uncertainty budgets, quantify and visualize uncertainty, avoid wrong assumptions

Optimization
specify aspects of simulation, data acquisition or data evaluation; helps with parameter sampling (histograms, etc.)

Risk Analysis
encode risk (i.e. mark mural parts for i.e. cracks, etc.)

Data Types
1-dimensional (overall porosity value etc.)
2-dimensional (intuitive, spatial context of input/output/derived data)
3-dimensional (3D nature of specimens/features, reconstructed from 2D inputs)
Temporal (insight into ongoing process, data over time in discrete and continuous manner)
Multi-dimensional data (different testing methods, deriving additional data)

Trees (guidance) and Networks (abstraction of complex linked features) i.e. pore network

Spatial Data (Simulation)
3D renderings + labeling, glyphs, isosurfaces, etc.
Spatio-temporal Data (Analysis)
3D animations, juxtapositions, pathlines, points, subsets
Material Analysis Spatiotemporal Data (Simulation)
tracking graphs, maps, volume blending (to visualize ongoing process over time/under load)
Quantitative / Derived Data (Simulation)
Stress/strain tensors, glyphs, color coding
Quantitative / Derived Data (Analysis)
scatter plot, parallel coordinates, tailored aggregations
Interaction Techniques

growing demand with increasing complexity of data, passive visualization is limited;

Explore and Reconfigure

for spatial, spatiotemporal, quantitative + derived data

explore: zoom, rotate

re-configure: different perspectives - change arrangement

Brushing and Linking

multiple views → linking (update all views if one is changed), brushing (selecting)

Focus Plus Context

select a subset (focus) and context for complete dataset

Filter

search via free text, drop downs, sliders, etc.

Interactive Steering

adjust parameters of data acquisition process during process, review intermediate results to steer data acquisition

Challenges

Integrated visual analysis (complex data → complex metrics, how to analyze, guide exploration)

Quantitative Data Visualization (how to encode subtle differences, visualize similarities)

Visual Debugger (how to explore parameter space, how to identify errors)

Interactive Steering (ensure reliable predictions in cycle time)