Seminar

Modeling and Simulation of Dynamical Systems

Presented by the
IEEE Control Systems Society
Santa Clara Valley

Sunnyvale, 5 February 2011

Session 4
Part I: Background

Visualization and Virtual Environments

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Session 4: Visualization

Content

- Introduction
- History of Scientific/Engineering Visualization
- Existing theories and methods
- Current research and emerging trends
- Annotated bibliography

Session 4: Visualization

Introduction

- Handling the ongoing information explosion
- Understanding models of complex phenomena
- Discovering/creating new theories, techniques and Methods

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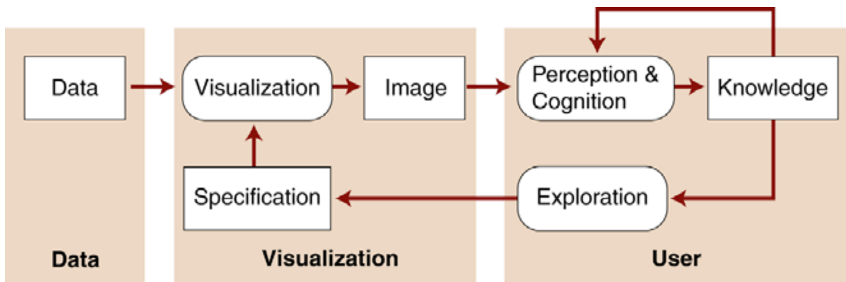

Courtesy of NIH/NSF 2006

The Discovery Process

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History of Scientific/Engineering Visualization

- October 1986, the Division of Advanced Scientific Computing (DASC) of NSF organized a Panel on Graphics, Image Processing and Workstations
- February 1987, a *Workshop on Visualization in Scientific Computing* was held in Washington D.C.
- November 1987, Special issue of Computer Graphics on Visualization in Scientific Computing
- Leading societies: IEEE Computer Society and ACM SIGGRAPH

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Existing Techniques and Methods

- Level Sets: Curves (Isolines), Surfaces (Isosurfaces), Hypersurfaces $\{(x_1,\ldots,x_n) \mid f(x_1,\ldots,x_n) = c\}$
- Volumetric rendering
- Slicing
- Contours
- Animation

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Volume Rendering – 2D projection of 3D

- Forming RGBA volume from the data (3D 4-vector data set: RGBA)
  - RGB - color components
  - A – opacity (0=totally transparent, 1=totally opaque)
- Reconstruction of a continuous function from discrete data
- Projecting the function onto the 2D viewing plane (output image) from the desired point of view

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Implementation of Volume Rendering

- Voxel – Volume element
- Marching Cubes – A surface representation is obtained by connecting patches from voxels
- Ray Casting – For every pixel in the output image a ray is shot into the data volume/voxels
- Splatting – Developed to improve the speed of calculation of Ray Casting at the price of less accurate rendering

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Current research and emerging trends

- Embedding internet into visualization process
- Collaborative visualization with augmented reality
- Integrating visualization and interaction/interfaces
  - Interactive multiviews
  - Fluid/intuitive pen and touch capabilities

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- Visualization across platforms (PC, handheld devices, wireless,...)
- Integrating visualization and modeling techniques
- Integrating virtual environments and collaborative visualization
- Distributed visualization
- Scalable and reconfigurable visualization (real-time)

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Annotated bibliography

- Visualization in Scientific Computing, ACM Siggraph, November 1987
- NIH/NSF, *Visualization Research Challenges*, January 2006
- IEEE Transaction on Visualization and Computer Graphics
- ACM Transactions on Graphics, Proceedings of the ACM SIGGRAPH Conference on Computer Graphics

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Part II: Sample of Early Work

Visualization and Virtual Environments

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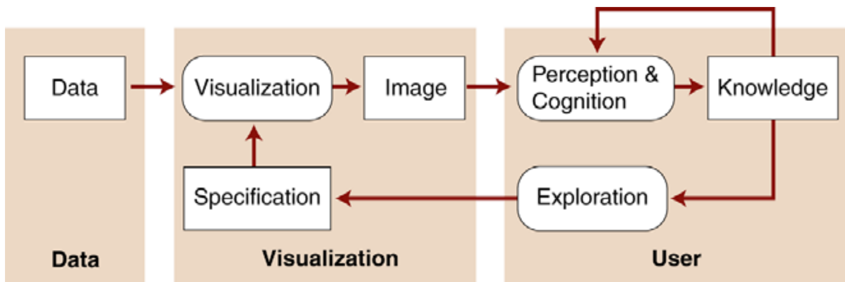
Content

- Visualization Framework
- Visualization Challenges
- Annotated Bibliography
- Appendix A

Visualization Framework



Courtesy of NIH/NSF 2006

Visualization Challenges in Large Scale Systems

- Dynamic Security Assessment of Power Systems:
  - Contours
  - Volume
- Power system model:

$$\begin{cases} \dot{x} = Ax + Bu + Ed \\ y = Cx + Wd \end{cases}$$

- Regulator (Exciter) Model:

$$V_R = \frac{K_A}{1 + sT_A} V_C$$

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Annotated bibliography

- M.E.El-Sharkawi, R.J.Marks II, M.E.**Aggoune**, D.C.Park, M.J.Damborg, and L.E.Atlas, "Dynamic Security Assessment of Power Systems Using Back Error Propagation Artificial Neural Networks", Proc. Second Symposium on Expert System Application to Power Systems (ESAPS), Seattle, WA, July 1989.

- M.E.**Aggoune**, M.A.El-Sharkawi, D.C.Park, M.J.Damborg, and R.J.Marks II, "Preliminary Results on Using Artificial Neural Networks for Security Assessment", IEEE Proc. Power Industry Computer Application Conference, Seattle, WA, May 1989.

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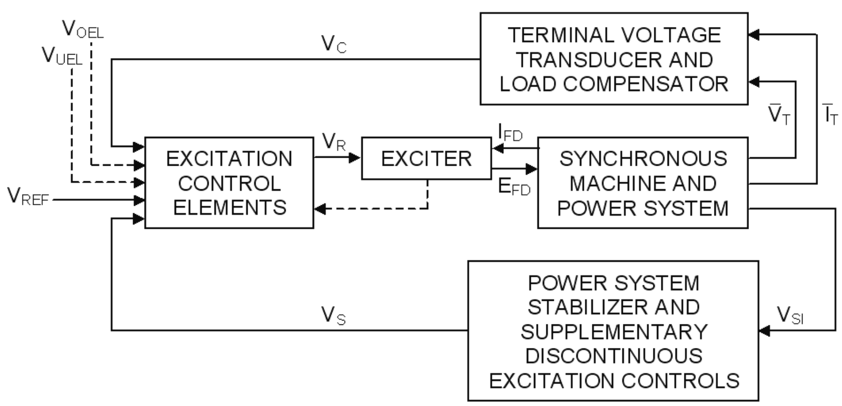
Appendix A



Generator and Control System

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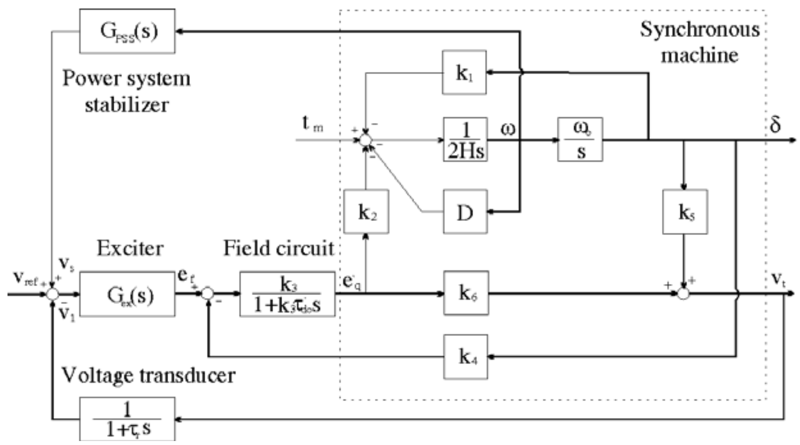

Generator and Controls Linearized Model

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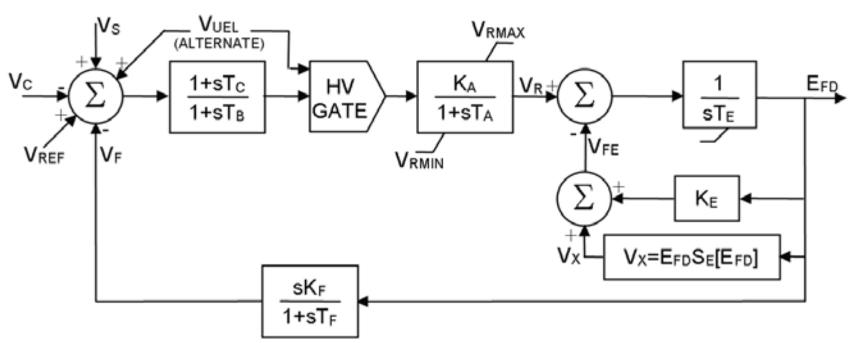

Regulator (Exciter) Model

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Part III: Recent Trends

Visualization and Virtual Environments

el-Hadi M. Aggoune, Ph.D., PE

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Content

- ESAL
- Real-Time Virtual Environment
- Command and Control
- Capabilities
- Illustrations
- Technical Consideration
- Annotated Bibliography

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ESAL

Products

- Real Time Virtual Environment
- Concept of Operation Scenarios (CONOPS)

Engineering Simulation and Animation Laboratory

ESAL

Cogswell Polytechnical College

Real-time Virtual Environment

Engineering, Operations & Technology | **Boeing Research & Technology**

Used for:
•Virtual Environment for concept-of-operation demonstrations
•3D command and control interface and situational display

Features:
•Real-time interface for both simulation and real vehicles
•6DOF high fidelity animation
•Supports large number of heterogeneous vehicles (>100)
•Customizable (e.g. urban, forest, etc…)
•Vehicle condition and capability visualization
•Task and Mission commanding the vehicle
•Flight views including first person, third person,
•Fog of War display for search missions
•Flight traces
•Vehicle editing

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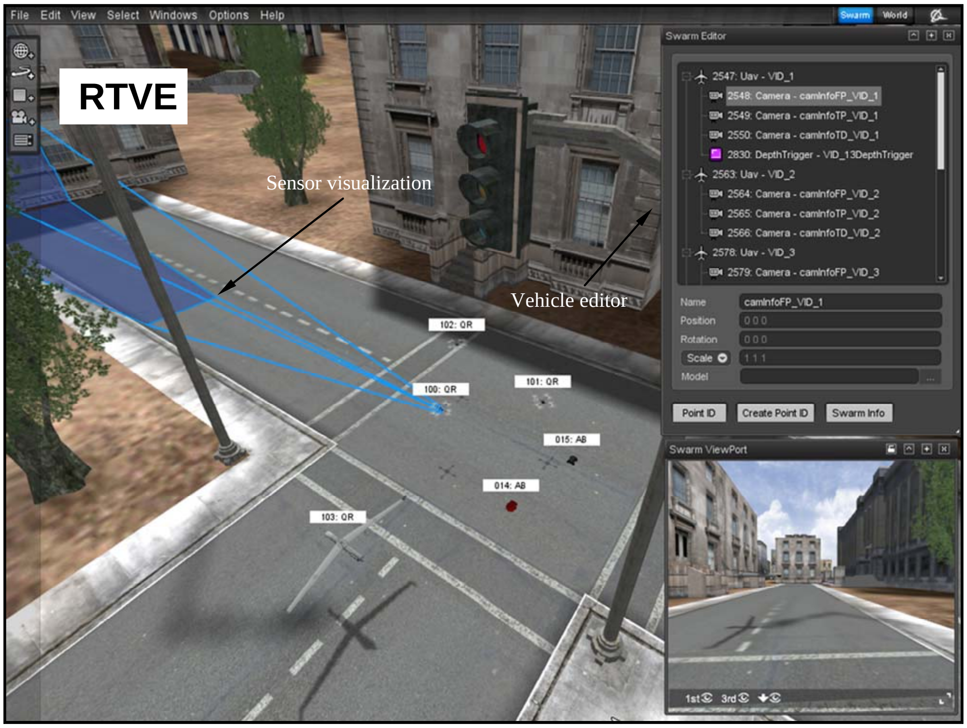

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Illustrations

CONOPS

- Autonomous Surveillance
- Automated Pre-Flight Inspection
- The Future With Sentient Adaptive Systems

Command and Control Environment

- Boeing Vehicle Swarm Technology Lab
- 3D Situational Vehicle Capability Display

ESAL
Cogswell Polytechnical College

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Technical Considerations

- **Quadrotor model**. Six-degree-of- freedom (6DOF) equations based on the kinematic and moment equations are used to derive the nonlinear quadrotor model.

- **Vehicle health monitoring**. Vehicles are equipped with onboard sensing, computational, and communication capabilities which allow them to monitor and adapt to system degradations in real-time.

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- **Adaptive control and supervision**. When communication is lost, the vehicle no longer receives information about its position and will become unstable. By monitoring real-time command communications latency, the vehicle can initiate a gyro-augmented (on-board) controlled landing as a result of loss of communication.

- **Health-adaptive collision avoidance and real-time deconfliction**. This involves looking along the planned path for possible conflicts and altering the path appropriately. This is then balanced by the desire to return to the originally planned path or waypoint.

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Annotated bibliography

- Emad Saad, John Vian, Greg J. Clark, and Stefan Bieniawski, **Vehicle Swarm Rapid Prototyping Testbed**, American Institute of Aeronautics and Astronautics (AIAA), Infotech Conference, Seattle WA, April 2009.

- Jonathan P. How, Brett Bethke, Adrian Frank, Daniel Dale, and John Vian, **Real-Time Indoor Autonomous Vehicle Test Environment** IEEE Control Systems Magazine, April 2008.