UMBC

AN HONORS UNIVERSITY IN MARYLAND

IS 709/809: Computational Methods for IS Research Fall 2017

Course Logistics

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Department of Information Systems

University of Maryland Baltimore County

Welcome to IS 709/809

- Timings: Tuesday; 7:10pm to 9:40pm
- Location: Sherman Hall 150
- Instructor: Nirmalya Roy

  Faculty in IS,

  MS in CSE: UT-Arlington, 2004

  PhD in CSE: UT-Arlington, 2008

  Postdoc in ECE: UT-Austin, 2010

  Faculty at Washington State University, 2013

  Research Interests: Mobile, Pervasive and Ubiquitous Computing (MPSC)

- Office hours: Monday, 1:30 - 3pm or by appointment

  Email: nroy@umbc.edu

  Office: ITE 421

Welcome to IS 709/809

- Course website
  - http://mpsc.umbc.edu/cmisr/
  - Course related information will be posted on the website
  - Please check the course website frequently
- Prerequisite:
  - IS 698 (Smart Home Health Analytics) or IS 733 (Data Mining)
- Make up classes
  - Will be occasionally necessary due to travel

Welcome to IS 709/809

- Grading:
  - Participation + Presentation + Reflection: 15%
  - Homework: 20%
  - 1 Mid-term exam: 30%
  - Research Project: 35%

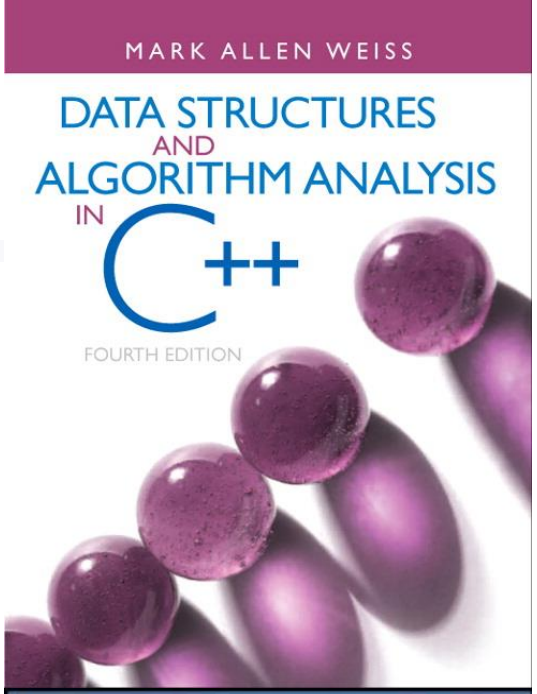
Course Expectations

- Attendance
  - You should attend class
  - Lecture notes will be made available, but they should not be considered a substitution for attending class
- Collaboration
  - Collaboration is encouraged in general but do not copy from each other

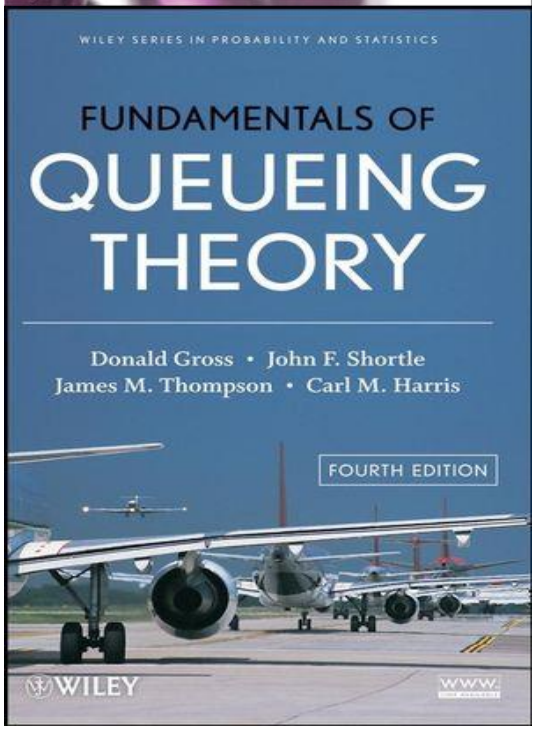
Course Information

- Course materials:
  - Textbooks (Optional):

    Data Structures and Algorithm Analysis in C++, 4th Edition by Mark Allen Weiss, 2013



Fundamentals of Queueing Theory, 4th Ed., by Donald Gross & John F. Shortle & James M. Thompson & Carl M. Harris. John Wiley & Sons, Inc, 2008



Course Information

- Class notes/slides
- Supplementary reading materials
  - Research Papers

What is this course about?

- Graduate level course in computational methods
  - MS and PhD students

- Learn principles of algorithm analysis
- Learn fundamentals of computational complexity
- Learn about Cyber-Physical Systems and Smart Service Systems
- Learn performance metrics of system
- Information systems performance & evaluation as case study
- Basic techniques of systems performance modeling
- Learn how to find an interesting IS research problem

Course Offerings

- At the end of the course
  - You understand variety of concepts …….
  - Designing efficient algorithms
  - Mathematical modeling and analyzing a system
  - Statistical methods and their computational implementation
  - Computational system performance evaluation
  - Exploratory and objective data analysis methods
  - Building/Simulating real systems
  - Tackling a research problem
  - …

Research Reflection

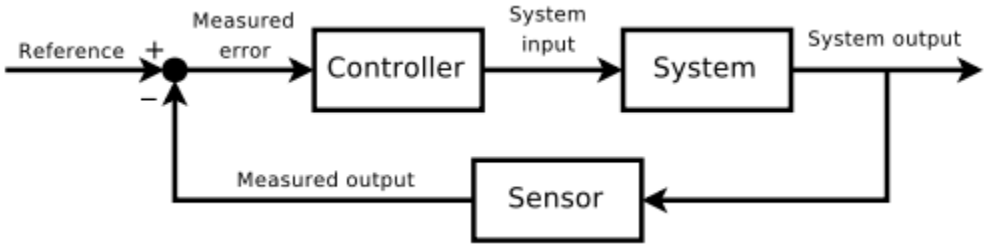
- Cyber-Physical Systems
  - engineered systems that are built from, and depend upon, the seamless integration of *computational algorithms* and physical components
  - enable capability, adaptability, scalability, resiliency, safety, security, and usability
    - exceed the simple embedded systems of today
  - transform the way people interact with engineered systems
    - Internet has transformed the way people interact with information
  - drive innovation and competition in multiple smart sectors
    - agriculture, energy, transportation, building design and automation, healthcare, and manufacturing
    - water, ecology, supply-chains, medical and assistive technology

CPS Computational Techniques

- control and/or optimization of CPS
- machine learning, data mining/analytics for CPS
- game theory applied to CPS
- model-based design and verification of CPS
- mobile and cloud computing for CPS
- signal processing for CPS
- human-in-the-loop shared or supervisory control of CPS
- …….

Example of CPS

- The Internet of Things (IoT)
  - integrates many CPS technologies that may well transform our lives
  - creates an ecosystem with tens of billions of devices
  - harnessing the power of the IoT requires
    - to identify foundational technologies that will foster an "Internet of Dependable and Controllable Things"
    - provide control algorithms that can transform IoT sensor data into action



Smart Service Systems

- Smart Service Systems
  - A **"smart" service system** is a system that amplifies or augments human capabilities to identify, learn, adapt, monitor and make decisions
  - The system utilizes data received, transmitted, or processed in a timely manner, thus improving its response to future situations
  - These capabilities are the result of the incorporation of technologies for sensing, actuation, coordination, communication, control, etc.

Research Reflection

- NSF/NIH/XXX funded research projects
  - Applications
  - Computational techniques
  - System performance
    - reliability, resilience, high-confidence, trustworthiness…….
    - dependability, security, safety, and privacy
    - timeliness, response time, delay

Research Reflection

- Federal Research Agencies
  - Department of Homeland Security, Science & Technology Directorate
  - U.S. Department of Transportation, Federal Highway Administration
  - National Aeronautics and Space Administration
  - National Institutes of Health
    - National Institute of Biomedical Imaging and Bioengineering
    - National Cancer Institute
  - National Center for Advancing Translational Sciences
  - U.S. Dept. of Agriculture
  - National Institute of Food and Agriculture

Paper Presentation

- Class presentation
  - Choose a paper related to your tentative research project
  - You present one paper (30 minutes)
    - Deadline for selecting a paper is October 3, 2017
  - Research reflection and research paper presentations are individual and separate class assignment

- Email me the title of the paper, authors list and the venue where it has been published
  - Do not worry about not knowing the topic
    - Read the paper and you will understand the main concepts eventually!

Selecting the Papers

- Select a paper from a top Computing or Cyber-Physical Systems conference (pervasive, ubiquitous, mobile computing)
- Name of the good conferences and workshops in broad area of computing and CPS:
  - IEEE CPS week
  - IEEE ICDM, ICDE, ICML
  - ACM Ubicomp, MobiSys, CHI, PerCom
  - ACM SenSys, IPSN, BuildSys
  - International Symposium on Wearable Computers (ISWC)

CPS Week 2017

- **HSCC 2017** – the 20th ACM International Conference on Hybrid Systems: Computation and Control
- **ICCPS 2017** – the 8th ACM/IEEE International Conference on Cyber-Physical Systems
- **IoTDI 2017** – the 2nd IEEE International Conference on Internet-of-Thing Design and Implementation
- **IPSN 2017** – the 16th ACM/IEEE International Conference on Information Processing in Sensor Networks
- **RTAS 2017** – the 23rd IEEE Real-Time and Embedded Technology and Applications Symposium

CPS Week 2017 workshops

- **ARCH 2017 –** 4th Applied Verification for Continuous and Hybrid Systems
- **CMAAS 2017 –** 2nd Workshop on Certifiable Multicore Avionics and Automotive Systems
- **CPSR-SG 2017 –** 2nd Workshop on Cyber-Physical Security and Resilience in Smart Grids
- **CySWATER 2017** – 3rd International Workshop on Cyber-Physical Systems for Smart Water Networks
- **MSCPES 2017 –** Workshop on Modeling and Simulation of Cyber-Physical Energy Systems

CPS Week 2017 workshops

- **MT-CPS 2017 –** 2nd Workshop on Monitoring and Testing of Cyber-Physical Systems
- **SCAV 2017 –** 1st International Workshop on Safe Control of Connected and Autonomous Vehicles
- **SCOPE 2017 –** 2nd Workshop on Science of Smart City Operations and Platforms Engineering
- **SelPhyS 2017 –** Self-Awareness in Cyber-Physical Systems
- **SocialSens 2017** – 2nd International Workshop on Social Sensing

Course Research Projects

- Projects consist of 3 parts:
  - Choosing an interesting topic
    - Identifying what new you can do
  - Proposing your novel ideas
    - Designing or modeling the solution
  - Performance evaluation
    - Testbed development and data collection/selection
    - Prototype Implementation

Possible Research Project Ideas

- Smart Hair Cutting Services
- Smart In-House Cooking Services
- Smart Plumbing Services
- Smart Tutoring/Coaching Services
- Stress Measurements at Workplace
- Smart Appliances/Engines/Structural Health Monitoring
- Smart Workplace Performance Measurements
- …….

NIST working groups

- International Technical Working Group on IoT-Enabled Smart City Framework
  - https://pages.nist.gov/smartcitiesarchitecture/

- Draft Framework to Help 'Cyber Physical Systems' developers
  - https://pages.nist.gov/cpspwg/

Possible Research Project Ideas

- Research on Human Science
  - Human behavior variability
    - perceptual, cognitive, affective, physical, and social behaviors
      - Perceptual control theory (PCT)
  - Human behavior performance
    - Multiscale
    - Group/team behaviors
    - Interactions
  - Human behavior assessment
    - intended behaviors, unintended behaviors, physiology, subjective experiences, social interactions, environmental factors, and tasking

https://www.arl.army.mil/opencampus/?q=activeresearch/HumanBehavior

Research Projects

- Examples of projects
  - Internet of Things
    - RESTful API, IoTivity project
    - Service-Oriented Architecture (web service, OSGi, DPWS etc.)
  - Collaborative Opportunistic Sensing
    - Opportunity Project - Activity and Context Recognition with Opportunistic Sensor Configurations
  - Mobile phone based heath (mHealth)
  - Data to knowledge to decision
  - Wireless sensor networks
    - Human activity recognition (PerCom, MobiSys, Ubicomp etc.)
    - Building energy analytics (ACM BuildSys, SenSys etc.)
    - Wireless health (http://www.wirelesshealth2015.org/, ISWC etc.)
    - Smart health and big data (IEEE CHASE, ICDM, ICDE etc.)

Possible Research Project Ideas

- Mobile Phone and Wearable Sensor based Collaborative Smart Service Framework
- SmartQueue: Collaborative Opportunistic Sensing
- SenseTalk: Mobile Phone and Ambient Sensor based Conversation Detection for People Centric Applications
- StayFit: Group based Exercising using Sensor and Mobile Phones
- Control Diet: Keeping an eye on your diet
- StressSense: Measuring stress level using smart wristband at work

Possible Research Project Ideas

- Am I old? Mobile phone based Virtual Age Recognition
- Driving behavior and Potholes detection using smartphone and wristband
- Gesture Sense: Controlling Smart Phone from the air using depth sensor map: Is this natural interaction better than touch?
- Are you a Chain Smoker? Smart wristband based detection and intervention
- ……

Testbed Development Projects & Platforms

- Smart Home in a Box (SHiB)
  - ADL monitoring toolkit in smart homes at large scale
- Tweet-a-Watt
  - Build a wireless home-power monitoring system
- Microsoft HomeOS and openHAB
  - Enabling Smarter Homes for Community
- Shimmer GSR/Optical Pulse Development Kit
  - Stress Detection and Analysis
  - Affective Computing and Cognitive Factors Research
  - Emotional Engagement; Agitation Detection
  - Psychological Arousal like Mental Effort, Excitement, Shock etc.

Testbed Development Projects & Platforms

- ActiGraph
  - Sleep and Wellness Assessment
- Shimmer Sensing Platform
  - Wearable Sensing: Kinematics, motion, biophysical like cardio, EMG, GSR, Strain Gauge
- Fitbit
  - Fitness, ADL monitoring
- Microsoft Lab of Things
  - Connect devices home & beyond
  - Support HomeOS

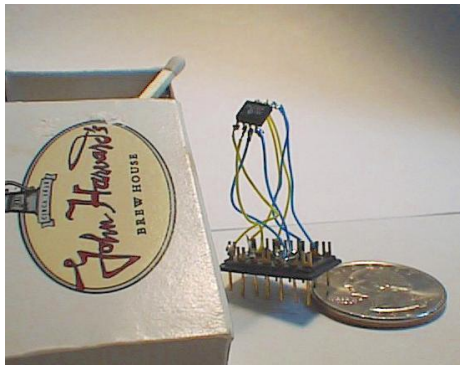
Testbed Development Projects & Platforms

- Waspmote from Libelium
  - Smart Cities (Smart parking, Smart lighting, Traffic congestion, Waste management etc.)
  - Smart Environments (Air pollution, Forest fire detection, Snow level monitoring etc.)
  - Smart Utility (Water or Gas leakages, Water quality, Energy consumption monitoring etc.)
  - eHealth (Fall detection, ADL monitoring etc.)
  - Internet of Things

“Cool” Internet Appliances

IP picture frame
http://www.ceiva.com/

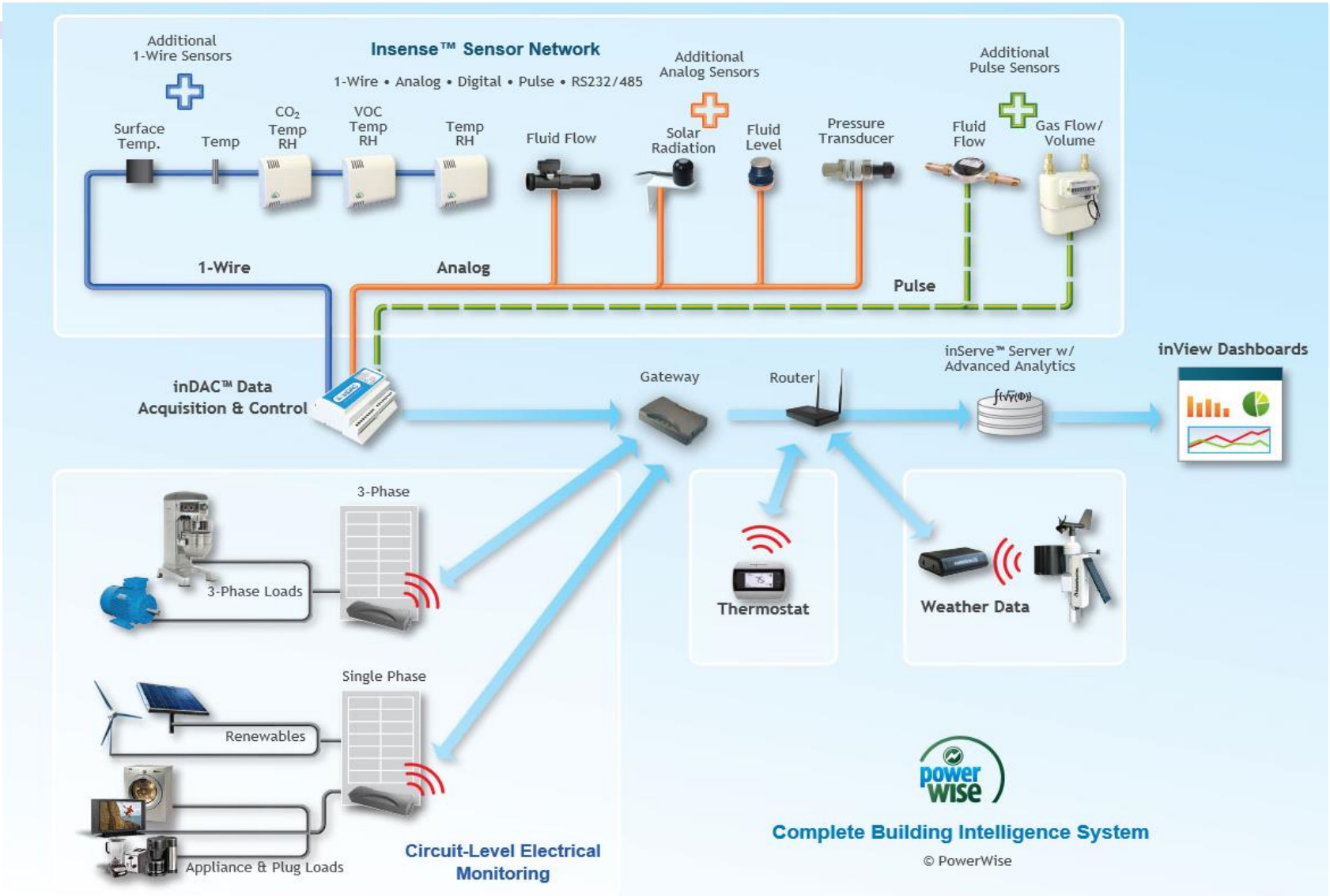
Internet phones



World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Web-enabled toaster +
weather forecaster

Energy Data Analytics: eMonitor



http://mpsc.umbc.edu/softwaredata/

Energy Analytics

- Appliance Energy Profiling Database Creation
  - building a dynamic catalog of the types and number of devices connected by a consumer
- Development of a Web-based Energy Management Dashboard
  - energy consumer can create goals
  - select and commit to energy savings tasks and habit changes
  - link to utility efficiency and rebate programs
  - share experiences with others and track their success and reward potential

Smart Plugs

PowerLinc Modem - INSTEON
USB Interface (Dual-Band)

iMeter Solo - INSTEON
Power Meter (Plug-In)

Your Take on Testbed Development Project

- Come talk to me during my office hours
- Finalize the research idea and then look for the equipment you need to do a great development project!
- Testbed development project pitch
  - Identify the platform and devices
  - List those devices with their price
  - Let the class know what you are proposing, why you need those devices, how you will integrate all and deploy to get data, and what's the final results you are expecting
- Feel proud of your testbed development idea
- Use this testbed for your research project

Your Take on Public Datasets/Simulation-based Project

- Finalize the public datasets you will use for your project
- Examples:
  - KDD Cup 2010: Educational Data Mining Challenges
    - http://pslcdatashop.org/KDDCup/
  - Image database
    - http://image-net.org/
    - http://cocodataset.org/
  - YFCC100M: The New Data in Multimedia Research
    - https://webscope.sandbox.yahoo.com/catalog.php?datatype=i&did=67
- Finalize the steps for simulation based approach
  - Synthetic data

Human Activity/Behavior datasets

- Activities of Daily Living Datasets
  - http://ailab.wsu.edu/casas/datasets/
- DEAPdataset: a dataset for emotion analysis using EEG, physiological and video signals
  - http://www.eecs.qmul.ac.uk/mmv/datasets/deap/
- Eight-Emotion Sentics Data
- Driver Stress Data
  - http://affect.media.mit.edu/share-data.php
- Physiologic signals (i.e., dehydration datasets etc.)
  - https://physionet.org/

Audio/Image Data

- NSF HEARABLES CHALLENGE
  - pre-recorded audio file of a spoken conversation in a noisy restaurant setting, to develop the proposed solution and report the words heard in the recording
  - https://ninesights.ninesigma.com/web/hearables/innovation contest

- NIH Pill Image Recognition Challenge
  - https://pir.nlm.nih.gov/challenge/index.html

Some Other Datasets we can provide

- EMS datasets
  - A county in Maryland
- State Highway Administration
  - Maryland

Wearable Sensor

- Samsung Gear: Smart Wristwatch

http://www.samsung.com/global/microsite/gear/

- Features:
  - Accelerometer, Gyroscope, Compass, Heart Rate monitor, Ambient Light sensor, UV sensor and Barometer
  - Watch is able to connect directly to the internet, make phone calls and send SMS's without needing a phone
  - first wearable device to include Wi-Fi, Bluetooth and 3G connectivity

Ambient Sensors

- iBeacon http://estimote.com/
  - tiny wireless sensors
  - attach to any location or object
  - broadcast tiny radio signals
  - smartphone can receive and interpret
  - location and context awareness applications

- Texas Instrument Sensor Tags
  - supports Bluetooth Smart, 6LoWPAN and ZigBee
  - low-power sensors such as light, microphone and magnetic sensors
  - http://www.ti.com/ww/en/wireless_connectivity/sensortag2015/?INTC=SensorTag&HQS=sensortag

Energy Devices

- *Z-wave Smart Metering and Communication:*
  - *Z-Wave Smart Energy Power Strip*
- *Insteon Energy Metering and Communication:*
  - *iMeter Solo - INSTEON Power Meter (Plug-In)*
  - *PowerLinc Modem - INSTEON USB Interface (Dual-Band)*
- *Enmetric System for Intelligent Plug load Management and Power Telemetry Communication*
  - *Enmetric PowerPort*
  - *Enmetric Wireless Bridge*

Energy/Green Devices

- *SiteSage (previously was known as eMonitor)*
  - *Powerhouse Dynamics: Energy Management System*
  - *SiteSage for Homes M-24h Energy Monitor (formerly eMonitor 4-24)*

- *The Energy Detective Electricity Monitor http://www.theenergydetective.com/*

- *Energy Hub http://www.energyhub.com/*

- *PeoplePower http://www.peoplepowerco.com/*

- *Nest Lab https://nest.com/*
  - *Nest Thermostat*
  - *Nest CO2 monitoring device*

More Devices

- DrinkMate: http://www.getdrinkmate.com/
- Amazon Echo: www.amazon.com/echo
- Nike Sensor
- Jawbone UP 3
- Microsoft Band: https://www.microsoft.com/microsoft-band/en-us

More Devices

- Actron CP9599 U-Scan
  - Be Safe: Monitoring the Driving Behavior and Road Condition
- Myo Armband
  - Voice through Motion
- Google Home
  - https://madeby.google.com/home/
- Samsung SmartThings Home Monitoring Kit
  - http://www.samsung.com/us/smart-home/smartthings/

Disclaimer: All the devices will be provided by the Mobile, Pervasive and Sensor Computing (MPSC) Lab in the Information Systems department at UMBC.

Let’s get back to our business!!

Computational Methods

Computational Methods

Introduction to Algorithm Analysis

AND

Introduction to System Modeling

Algorithms

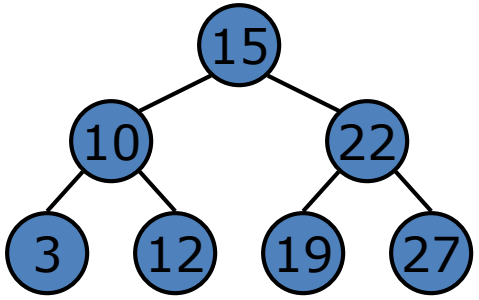
- Computational Complexity
- Runtime computation of several sorting algorithms
- Graph Algorithms
  - Shortest paths; Network flow; Minimum spanning tree etc.

Why do we need Algorithms and Data Structures?

- "Why not just use a big array?"
- Example problem
  - Search for a number k in a set of N numbers
- Solution # 1: Linear Search
  - Store numbers in an array of size N
  - Iterate through array until find k
  - Number of checks
    - Best case: 1 (k=15)
    - Worst case: N (k=27)
    - Average case: N/2

Data Structures

- Solution # 2: Binary Search Tree (BST)
  - Store numbers in a binary search tree
    - Requires: Elements to be sorted
  - Properties:
    - The left subtree of a node contains only nodes with keys less than the node's key
    - The right subtree of a node contains only nodes with keys greater than the node's key
    - Both the left and right subtrees must also be binary search trees
  - Search tree until find k
  - Number of checks
    - Best case: 1 (k=15)
    - Worst case: $\log_2 N$ (k=27)
    - Average case: $(\log_2 N) / 2$

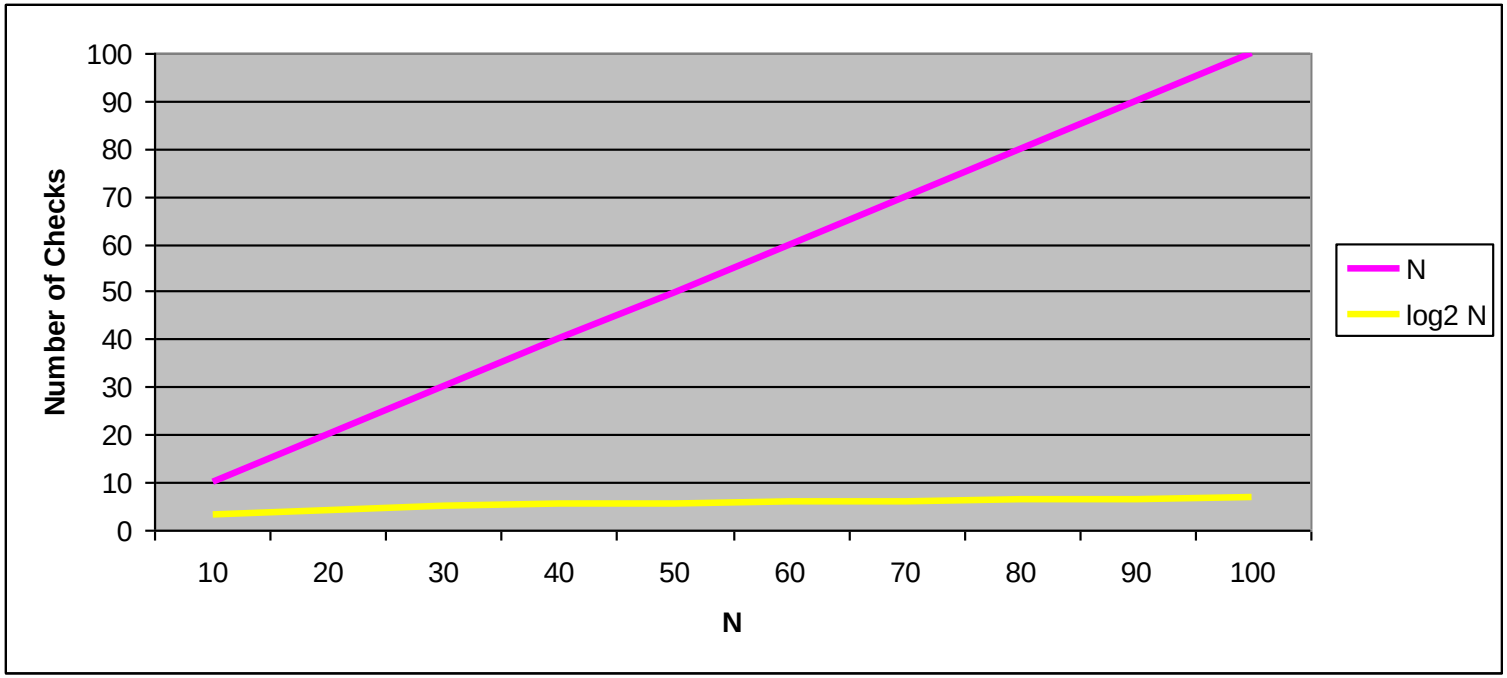


Example

- Does it matter?
- Problem Artifacts
  - N = 1,000,000,000
    - 1 billion (Walmart transactions in 100 days)
  - 1 Ghz processor = 10^9 cycles per second
- Solution #1 (assume 10 cycles per check)
  - Worst case: 1 billion checks = 10 seconds
- Solution #2 (assume 10 cycles per check)
  - Worst case: 30 checks = 0.0000003 seconds

Computational Complexity & Analysis

- Does it matter?
  - N vs. ($\log_2$ N)



Insights

- Moral
  - Appropriate data structures and algorithms ease design and improve performance
- Challenge
  - Design appropriate data structure and associated algorithms for a problem
  - Analyze to show improved performance

Why do we need Math for algorithm analysis?

- Analyzing data structures and algorithms
  - Deriving formulae for time and memory requirements
  - Will the solution scale?
- Proving algorithm correctness

Computational Methods (contd.)

Cyber-physical systems

And

Smart service systems

And

Big Data Management

Performance Measurements

Systems

- Performance evaluation and modeling
- Concepts and techniques needed to plan the capacity of computer/information systems
  - predict their future performance under different configurations
  - design new applications that meet performance requirements
  - analytic queuing network models of computer systems
  - study the performance of centralized, distributed, parallel, client/server systems, web server, and e-commerce site performance
- Database systems, mobile systems, networked systems, CPS, Smart service systems
  - Telecommunication network design …….

Queueing Theory

- Waiting in lines
  - In the grocery store, on the telephone, at the airport, on the road
- Queueing theory is the mathematical study of lines
  - What are the stochastic characteristics of delay?
  - For example, what is the average delay?
  - What is the probability that delay exceeds some threshold?
  - What fraction of customers are turned away?
  - What system capacity (e.g., what number of servers) is needed to achieve a specified quality of service?
- Provide decision makers a way to efficiently allocate resources to reduce delay

Applications of Queueing Theory

- Applications to operations research, cyber-physical systems, smart service systems, big data management, management science and industrial engineering
- Examples are
  - Traffic flow (vehicle, aircraft, people communication)
  - Scheduling (patients in hospital, jobs on machines, programs on a computer)
- Facility design
  - Banks, post offices, amusement parks, fast-food restaurants

Applications of Queueing Theory

- Applications to Networks
- Study of the performance of systems composed of
  - Waiting lines
  - Processing units
- Allows to estimate
  - Time spent in waiting
  - Expected number of waiting requests
  - Probability of being in certain states
- Useful for the design of systems such as telecommunication networks
  - Delay, blocking probability, links, bandwidth, number of processors, buffers size

In this course

- Survey the quantitative models used to analyze queueing systems

- Focus will be both on mathematical analyses of such models as well as practical issues in using such models to represent real CPS and SSS problems

Questions

?