Research Areas

Major areas are

* Complexity theory, algorithm design
* Automata theory, formal models, logic
* Quantum computing
* Programming languages
* Computer architecture (parallel programming, many core, GPU)
* Operating systems
* Distributed systems
* Compilers
* Networks
* Databases, data mining
* Artificial intelligence (machine learning, natural language processing, computer vision, robotics, social network analysis)
* Computational biology
* Security
* Computer graphics
* Human/computer interaction
* Scientific computing, high performance computing
* Visualization

Image Processing

1. Automatic Detection, classification, identification of single and multiple objects
2. Automatic Image Enhancement
3. Image Segmentation
4. Image Classification
5. Content based Image Retrieval
6. Image Compression
7. Image Inpainting
8. Image Restoration

Detailed subtopics

Computer [Architectures](https://www.cs.umn.edu/research/research_areas/architectures-compiler-optimization-and-embedded-systems)

Subareas: Accelerators, Clockless Logic, Energy-efficient Computing, Security

[Compiler Optimization, and Embedded Systems](https://www.cs.umn.edu/research/research_areas/architectures-compiler-optimization-and-embedded-systems)

[Bioinformatics and Computational Biology](https://www.cs.umn.edu/research/research_areas/bioinformatics-and-computational-biology)

Subareas: Biostatistics, Computational Genetics, Proteomics, Statistical Genetics

* Metabolomics and toxicology
* Trends in molecular evolution
* Automation of forensic DNA analysis
* Indexing genomic databases
* Stochastic reaction modeling
* Search optimization
* National model for bioinformatics education
* Disease analysis

[Databases, and Geographical Information Systems](https://www.cs.umn.edu/research/research_areas/data-mining-databases-and-geographical-information-systems)

### Declarative languages and runtime systems

Design and implementation of declarative programming languages with applications to distributed systems, networking, machine learning, metadata management, and interactive visualization; design of query interface for applications.

* **Parallel/distributed data mining**
* **Text/image clustering and categorization**
* **Metadata for timelining events**
* **XML database**
* **Data warehousing**
* **Biological/medical data mining**

### Scalable data analysis and query processing

Scalable data processing in new settings, including interactive exploration, metadata management, cloud and serverless environments, and machine learning; query processing on compressed, semi-structured, and streaming data; query processing with additional constraints, including fairness, resource utilization, and cost.

### Consistency, concurrency, coordination and reliability

Coordination avoidance, consistency and monotonicity analysis; transaction isolation levels and protocols; distributed analytics and data management, geo-replication; fault tolerance and fault injection.

### Data storage and physical design

Hot and cold storage; immutable data structures; indexing and data skipping; versioning; new data types; implications of hardware evolution.

### Metadata management

Data lineage and versioning; usage tracking and collective intelligence; scalability of metadata management services; metadata representations; reproducibility and debugging of data pipelines.

### Systems for machine learning and model management

Distributed machine learning and graph analytics; physical and logical optimization of machine learning pipelines; online model management and maintenance; prediction serving; real-time personalization; latency-accuracy tradeoffs and edge computing for large-scale models; machine learning lifecycle management.

### Data cleaning, data transformation, and crowdsourcing

Human-data interaction including interactive transformation, query authoring, and crowdsourcing; machine learning for data cleaning; statistical properties of data cleaning pipelines; end-to-end systems for crowdsourcing.

### Interactive data exploration and visualization

Interactive querying and direct manipulation; scalable spreadsheets and data visualization; languages and interfaces for interactive exploration; progressive query visualization; predictive interaction.

### Secure data processing

Data processing under homomorphic encryption; data compression and encryption; differential privacy; oblivious data processing; databases in secure hardware enclaves.

### Foundations of data management

Optimal trade-offs between storage, quality, latency, and cost, with applications to crowdsourcing, distributed data management, stream data processing, version management; expressiveness, complexity, and completeness of data representations, query languages, and query processing; query processing with fairness constraints.

[Graphics and Visualization](https://www.cs.umn.edu/research/research_areas/graphics-and-visualization)/Image processing

### Computer Aided Design and Modeling:

Computer aided geometric design. Splines and subdivision. Surface optimization. Texture synthesis. Sound synthesis. Rapid prototyping.

* **Modeling**
* **Tracking**

### Rendering:

Image based rendering. Vision realistic rendering. Computational photography and video.

### Visualization:

Scientific and information visualization. Virtual environments, tele-immersive environments

### Animation and simulation:

Motion capture analysis and synthesis. Physically based simulation. Video games.

* **Graphic hardware**
* **Object recognition in digital images and video**
* **Multimedia content classification and indexing**
* **Integrated search and retrieval in multimedia repositories**
* **Background elimination in live video**

[High Performance Computing](https://www.cs.umn.edu/research/research_areas/high-performance-computing)

[Human Computer Interaction (HCI)](https://www.cs.umn.edu/research/research_areas/human-computer-interaction-hci)

* **Assistive Technology**
* **Human Factors Analysis**
* **Sound & Audio Display**
* **User-Interface Toolkits**

### Context-aware computing:

Activity analysis, Embodied and Wearable Computing, Smart Spaces, Location-aware systems, Privacy technologies, Affective Computing.

### Perceptual Interfaces:

Virtual reality (VR) and Augmented reality (AR), Vision-based interfaces, Conversational interfaces

### Collaboration and Learning:

Tutorial and instruction systems, Crowdsourcing, Pattern-based authoring tools, Learning at scale, Remote group collaboration technologies, Citizen science

### Digital Design and Fabrication:

Prototyping tools, DIY and Maker Culture, Computational Design, Creativity-support tools, Sensing technologies

### Human-Centered Artificial Intelligence:

Human-robot interaction, Explainable AI, Interactive Machine Learning, Responsible AI, Multimedia retrieval and understanding, Recommender Systems

### Interactive Data Exploration and Presentation:

Visualization and visual analytics, Sketch-based and direct manipulation interfaces, Computational notebooks

### Optometry and Human Vision Simulation:

Computer aided cornea modeling and visualization, Medical imaging, Virtual environments for surgical simulation, Vision realistic rendering

### Usable Programming:

Usable programming languages, Programming environments, Program synthesizers, Programming by demonstration, Tools for non-programmers, novices and end-user programmers

[Artificial Intelligence](https://www.cs.umn.edu/research/research_areas/robotics-and-artificial-intelligence)

### Learning and Probabilistic Inference:

Graphical models. Kernel methods. Nonparametric Bayesian methods. Reinforcement learning. Problem solving, decisions, and games.

### Knowledge Representation and Reasoning:

First order probabilistic logics. Symbolic algebra.

### Search and Information Retrieval:

Collaborative filtering. Information extraction. Image and video search. Intelligent information systems.

### Speech and Language:

Parsing. Machine translation. Speech Recognition. Context Modeling. Dialog Systems.

### Vision:

Object Recognition. Scene Understanding. Human Activity Recognition. Active Vision. Grouping and Figure-Ground. Visual Data Mining.

### Robotics:

Motion Planning, Computational Geometry. Computer assisted surgical and medical analysis, planning, and monitoring. Unmanned Air Vehicles

[Software Engineering and Programming Languages](https://www.cs.umn.edu/research/research_areas/software-engineering-and-programming-languages)

[Theoretical Foundations](https://www.cs.umn.edu/research/research_areas/theoretical-foundations)

### Autonomous and Cyber-Physical Systems

###### **Subareas: Real-time and Embedded Systems, Sensor Systems, Mobile Computing, Control Theory and Systems, Formal Methods, Automated Verification and Certification**

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### Geometric Computing

###### **Subareas: Geometric Modeling & Computation, Solid Modeling**

### High-Performance Computing

###### **Subareas: Parallel Algorithms, Cyberinfrastructure, GPUs & Other Computational Accelerators, Performance Analysis, Programming & Memory Models for Parallel Computing, Scientific Computing**

### Machine Learning and Data Mining

###### **Subareas: Data Integration, Internet of Things, Knowledge Discovery, Machine Learning, Scientific Data Management, Visual Analytics**

### Medical Image Analysis

###### **Subareas: Biomechanical Modeling, Diffusion Imaging, Image-guided Interventions, Segmentation, Shape Analysis, Registration**

### Neural systems

Sensory motor control. Vision. Audition. Biomimetics. Brain-machine interfaces. Computational neuroscience.

### Biomedical systems

Sensors. Healthcare systems. Physiological modeling. Medical imaging and bioimage analysis.

### Medical imaging and instrumentation

* Image registration in surgical navigation
* Segmentation of MR and CT images for spinal surgery
* Design of a surgical robot assistance for biopsy
* Detection and visualization of brain shift during brain surgery
* Automated endoscopic imaging
* Bio-signatures of in-vivo cells

### Natural Language Processing

###### **Subareas: Language Generation, Multimodal and Grounded NLP (with Vision and Robotics), Question Answering and Dialogue, Documment summarization,** Parsing. Machine translation. Speech Recognition. Context Modeling. Dialog Systems, Sentiment analysis

### Networking

* Wireless Sensor **Networks**.
* Wireless ad hoc **Networks**.
* Wireless Local Area **Network**.
* **Network** Security.
* VANET.
* Software-defined **Networks**(SDN)
* **Ultra-high speed optical network**
* **Music telepresence**
* **Cognitive radio and dynamic spectrum access**
* **Secure protocol and secure processors authentication**
* **Cyber-physical systems**
* **Network coding**
* **Multimedia Systems and Multimedia Transport**
* **Network Protocols**

### Internet architecture:

Overlay architectures. Distributed hashing. Naming. Next generation network design. Peer to peer networking. Mobile and ad-hoc networking. Troubleshooting. Implications for energy efficiency.

### Security:

Malware detection. Secure routing. Testbeds for security applications. Operating systems security. Intrusion detection/prevention. Availability. Authentication. Botnets and worms.

### Distributed Systems:

Experimental testbeds. Distributed logging. Declarative networking.

### Operating systems:

OS for sensor networks. Monitoring OS behavior for malware detection. Performance analysis. Programming languages for systems. Power aware computing.

### Operating Systems

###### **Subareas: File Systems, Virtualization, Concurrency, Software Support for Secure Hardware**

### Robotics

###### **Subareas: Assistive Robotics, Manipulation, Medical Robotics, Motion Planning & Control, Robot Learning, Robot Perception,** Computational Geometry. Computer assisted surgical and medical analysis, planning, and monitoring. Unmanned Air Vehicles

### Security

###### **Cloud Computing Security**

* Cloud infrastructure for data management
* Privacy and security in cloud data management
* Cloud-based mining and learning algorithms
* Cloud support for text mining and web search
* Large-scale natural language modeling and translation
* Parallel and distributed algorithms for bioinformatics
* Performance evaluation and benchmarking

###### **Hardware Security**

###### **Mobile Device Security**

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### Cryptography

complexity-theoretic approaches to cryptography, development of new cryptographic systems, cryptanalysis, protocol development, applied cryptography, quantum computation, and applications that include electronic commerce, electronic voting, wireless communications, and protocols for sensor webs. See [here](http://crypto.eecs.berkeley.edu/) for more information.

### Privacy

### Social implications of security

### Sensor web security

### Testbeds for security

### Security, programming languages, and software engineering

### Human interfaces and security

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### Identity and integrity

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### Network security

### Electronic voting

### Software

###### **Subareas: Agile Methods, Aspect-oriented Programming, Collaborative Development, Design Patterns & Analysis, Model Federations for Systems Science**

### Search and Information Retrieval:

Collaborative filtering. Information extraction. Image and video search. Intelligent information systems.

Programming systems

### Programming Language Design and Implementation:

Compiler optimization. Semantics. JIT compilers. Domain-specific languages.

### Programming Environments and Tools:

Monitoring. Programmer search engines. Model-based design.

### Program Analysis and Verification:

Model checking. Static and dynamic analysis. Theorem proving. Schedulability analysis for real-time systems.

### Software design, synthesis, and testing:

Software design for parallel computing; for embedded systems; for numerical computing; for symbolic computing; for distributed computing. Software Testing. Sketching-based synthesis.

## Semantic, Social and Sensor Webs

* Computer assisted document interpretation tools
* Information extraction from semi-structured documents
* Metadata for timelining events
* Semantic Web knowledge representation
* Semantic sensor web
* Linked and Big Data

## Soft Computing and Machine Learning

* Knowledge Representation and Reasoning
* Intelligent agents
* Natural language understanding
* Evolutionary algorithms and evolvable hardware
* Autonomous robotic systems
* Machine learning
* Fuzzy and neural systems
* Intelligent control systems