Bilkent University Computer Engineering Department

MS and PhD Programs

https://w3.cs.bilkent.edu.tr/graduate-programs/

Research Areas

- Algorithms
- Artificial intelligence
- Big data
- Bioinformatics
- Cloud computing
- Computational biology
- Computational geometry
- Computer architecture
- Computer graphics
- Computer networks
- Computer vision
- Cryptography
- Data mining
- Data science
- Data security
- Database systems
- Graph visualization
- High performance computing
- Image analysis
- Information retrieval
- Machine learning
- Mobile systems
- Parallel and distributed systems
- Pattern recognition
- Robotics
- Scientific computing
- Software engineering
- Virtual reality

Applications

- Application Deadlines:

  March 18, 2024 (early-bird deadline)

  June 4, 2024 (regular deadline)

- Online Application:

  https://stars.bilkent.edu.tr/gradapp/

- Requirements for application:
  - CGPA ≥ 2.80 / 4.00
  - ALES (Turkish citizens) or GRE (Foreign applicants)
    - ALES: Quantitative ≥ 55 (for MS), 80 (for PhD w/o BS)
    - GRE: Quantitative ≥ 153 (MS), 157 (PhD)
  - English Proficiency: TOEFL (IBT) ≥ 87 or IELTS avg ≥ 6.5 (and min 5.5 in each section)
  - And YDS ≥ 55 (for Turkish citizen applying PhD).

Interview

- Date: we will inform applicants about interview dates
- If not uploaded during online application, documents need to be submitted during interview:
  - Transcript
  - ALES or GRE score report
  - Proof of English Proficiency
    (TOFLE, IELTS or YDS report)

Acceptance Requirements

- Grad committee approval
- At least one faculty member willing to work with the applicant towards thesis
- Passing the interview and department approval
- Graduate School of Engineering and Science approval

Scholarship Options

- Department scholarship
  - Tuition waiver (100%)
  - Stipend (paid by Department)
  - Eligibility for accommodation in dormitories or University housing
  - Health Insurance
  - Office (shared)
  - Meal Card support (for Ph.D. students)

Scholarship Options

- Project grants
  - Tuition waiver (100%)
  - Stipend (paid from the project budget and Department)
  - Eligibility for accommodation in dormitories or University housing
  - Health Insurance
  - Office (shared)
  - Meal Card support (for Ph.D. students)

- Graduate School scholarship
  - Tuition waiver (between 80% - 100%)

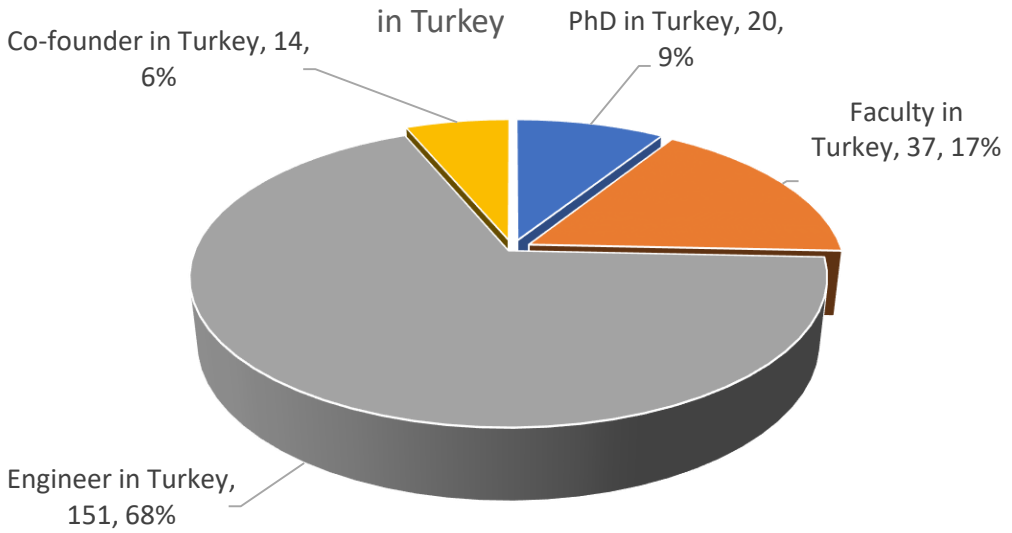
Degree Requirements

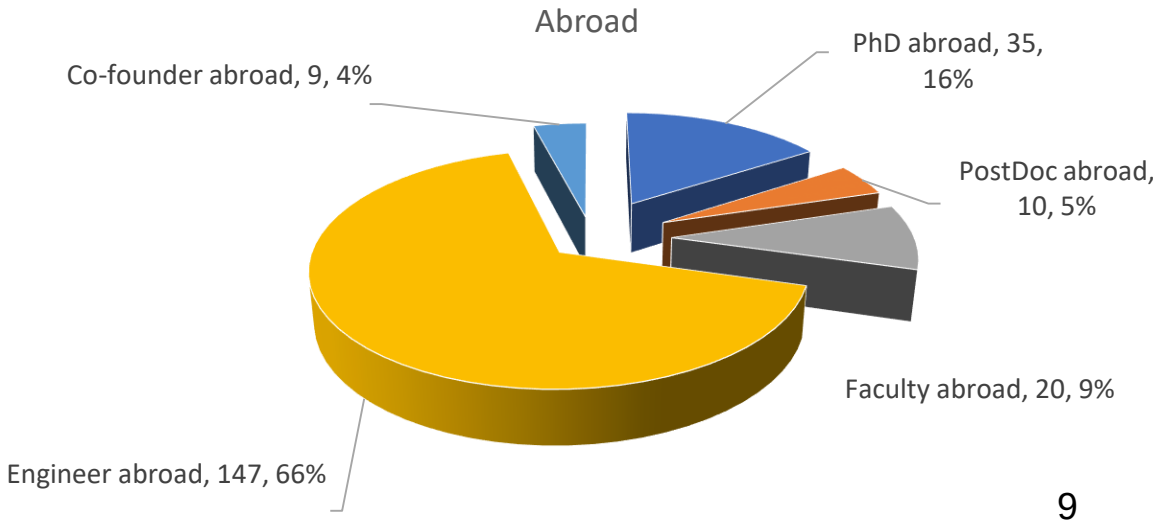
- MS
  - 7 technical elective courses + Seminar +
    MS Thesis +
    Research Methods and Academic Publication Ethics course
- PhD
  - 7 technical elective courses + Seminar +
    Qual Exam + PhD Thesis + Journal Publication +
    Research Methods and Academic Publication Ethics course

Graduates of MS Program

Position	Count	%
PhD in Turkey	20	9.0%
Faculty in Turkey	37	16.7%
Engineer in Turkey	151	68.0%
Co-founder in Turkey	14	6.3%
PhD abroad	35	15.8%
PostDoc abroad	10	4.5%
Faculty abroad	20	9.0%
Engineer abroad	147	30.6%
Co-founder abroad	9	4.1%
Unknown	37	7.7%

In Turkey	222	46.3%
Abroad	221	46.0%
Unknown	37	7.7%
Total:	480	100.0%





Graduates of MS Program

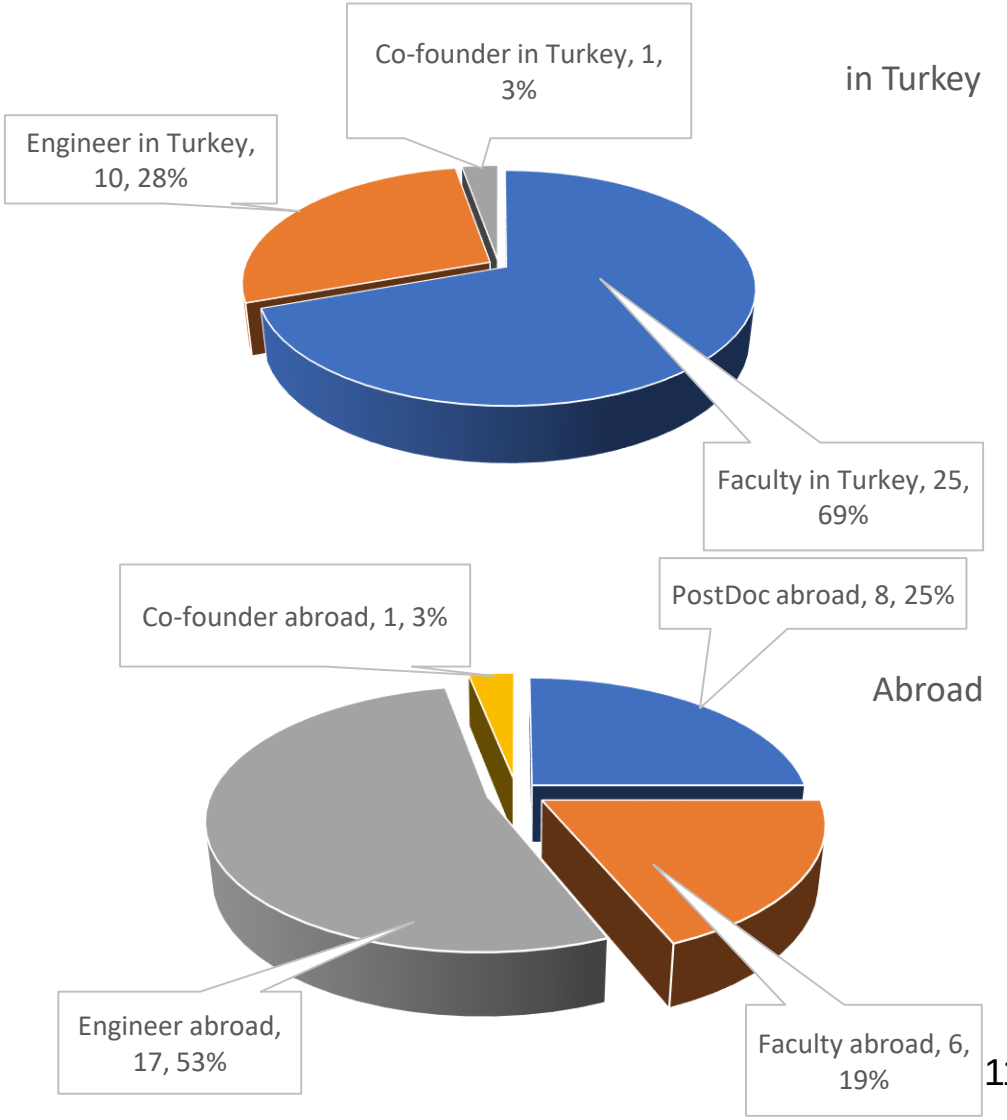
in Turkey	
Bilkent Univ.	25
ASELSAN	20
HAVELSAN	16
TÜBİTAK	13
Hacettepe Univ.	6
METU	6
TSK	5
STM	4
TCMB	4
Vestel	4
Cybersoft	3
Garanti Teknoloji	3
MilSOFT	3
OpsGenie	3
Sabancı Univ.	3
Akdeniz Univ.	2
Oracle	2

Abroad	
Microsoft	23
Google	16
Amazon	6
Booking.com	4
Case Western Reserve Univ.	4
Facebook	4
Univ. California	4
SAP	3
U. of Massachusetts Amherst	3
UBER	3
EPFL	2
ETH	2
Imperial College	2
Sandia National Labs.	2
U. of Texas at San Antonio	2
University of Florida	2
University of Waterloo	2
U. of Illinois at Urbana-Champaign	1
Washington U. in St. Louis	1

Graduates of PhD Program

Position	Count	%
Faculty in Turkey	25	69.4%
Engineer in Turkey	10	27.8%
Co-founder in Turkey	1	2.8%
PostDoc abroad	8	25.0%
Faculty abroad	6	18.8%
Engineer abroad	17	53.1%
Co-founder abroad	1	3.1%

In Turkey	36	52.9%
Abroad	32	47.1%
Total:	68	100.0%



Graduates of PhD Program

in Turkey	
METU	4
Bilkent University	3
Hacettepe Univ.	3
Akdeniz University	2
Sabancı Univ.	3
TED University	2
Ankara University	1
Aselsan	1
Atılım University	1
Beykent University	1
Çukurova Üniversitesi	1
SAP	1
TAI	1
TCMB	1
Turkcell	1

Abroad	
Amazon	3
Oregon Health and Sci. U.	3
Case Western R. U.	2
Lawrence Berkeley Lab	1
LIP ENS-LYON CNRS	1
ETH	1
Facebook	1
Fraunhofer	1
Georgia Tech	1
Google	1
Microsoft	1
Oracle	1
Salesforce	1
Sandia National Labs.	1
Stony Brook University	1
U. of Central Florida	1
Uber	1

Faculty Members
Georgia Institute of Technology
Oregon Health and Science University
Stony Brook University
University of Calgary
Bilkent University
Akdeniz University
Ankara University
Ankara Yıldırım Beyazıt University
Atatürk University
Atılım University
Beykent University
Celal Bayar University
Çukurova University
Hacettepe University
Konya Food & Agriculture University
METU
Sabancı University
Selçuk University
TED

Faculty Members

- In alphabetical order
- Please contact them in person for details.
- Most up-to-date information can be obtained from their websites.

Selim Aksoy

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http://www.cs.bilkent.edu.tr/~saksoy
Office: EA 422 (4th floor)

Research interests:

- Computer vision
- Pattern recognition
- Machine learning

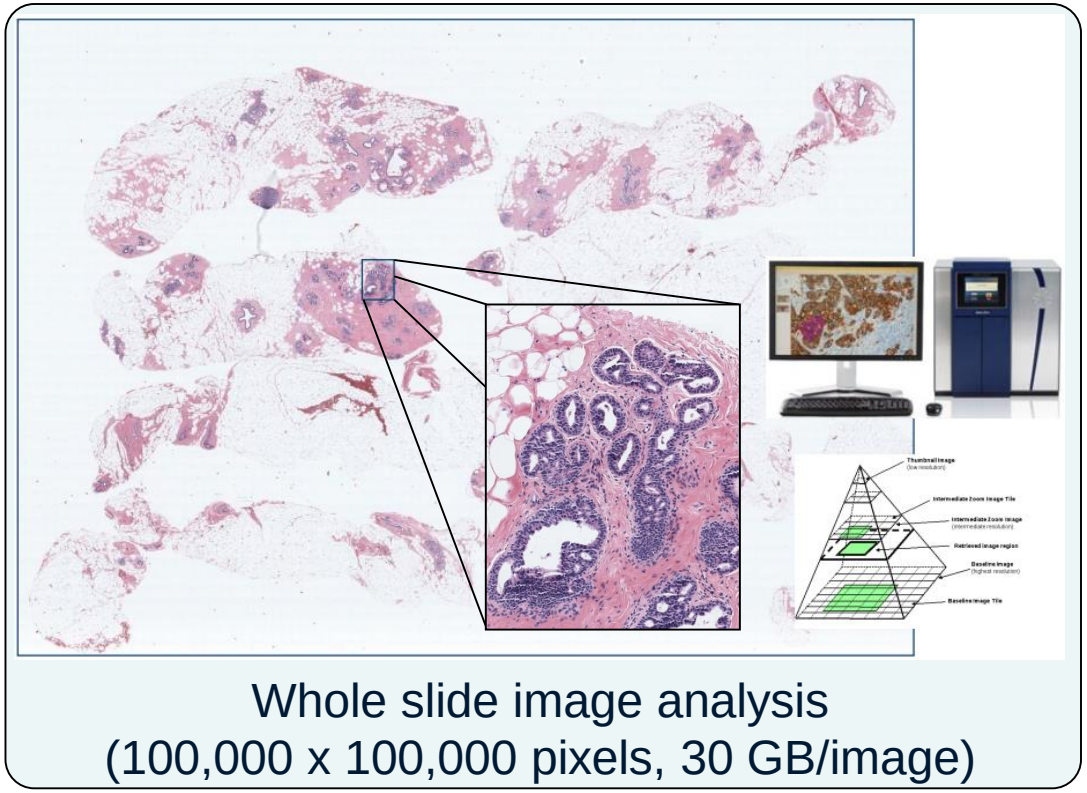
Current topics:

- Medical image analysis
- Remote sensing image analysis
- Image classification
- Object recognition
- Content-based image retrieval

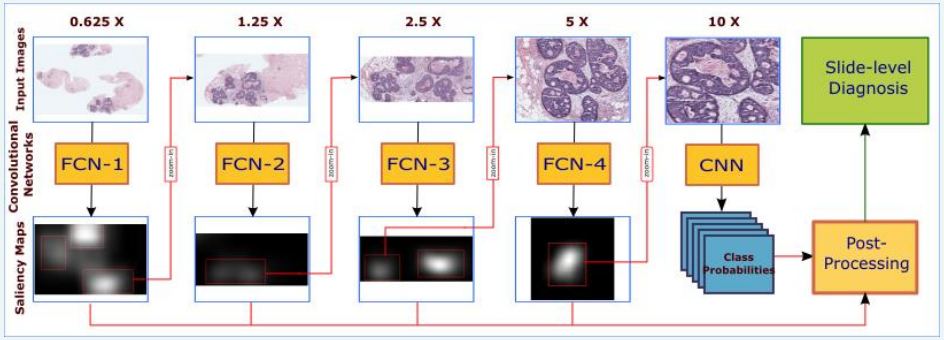
Sponsored Research Projects

- Medical image analysis
  - TÜBİTAK 1001, 2018-2021
  - TÜBİTAK 1001, 2014-2017
  - TÜBİTAK CAREER Grant, 2005-2010
- Remote sensing image analysis
  - TÜBİTAK 1001, 2010-2012
  - European Commission, Joint Research Centre, 2008-2009
  - TÜBİTAK CAREER Grant, 2005-2010
  - FP6 Marie Curie Grant, 2005-2007
- Image and video mining
  - TÜBİTAK and COST 292 Action, 2004-2008
  - DPT, 2004-2005

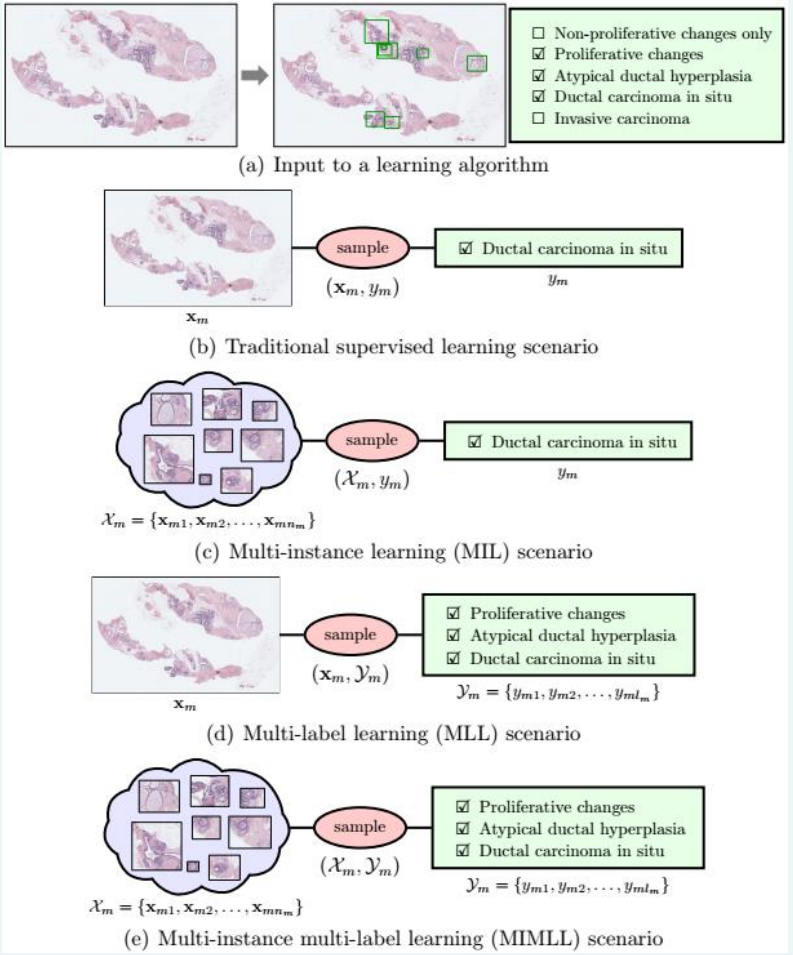
Medical Image Analysis



Whole slide image analysis
(100,000 x 100,000 pixels, 30 GB/image)



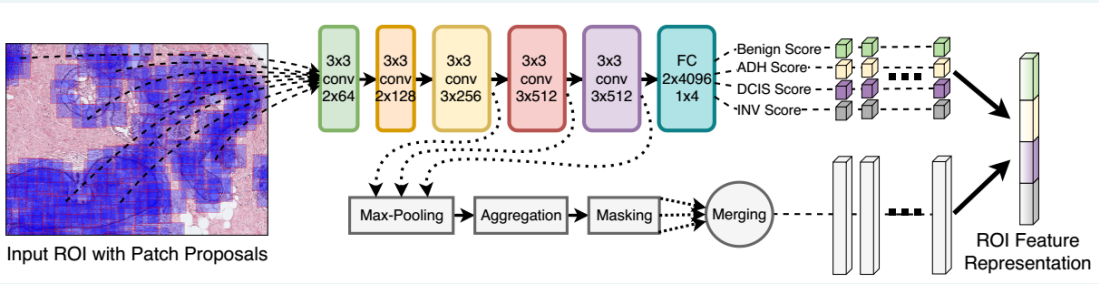
Deep networks for region of interest detection



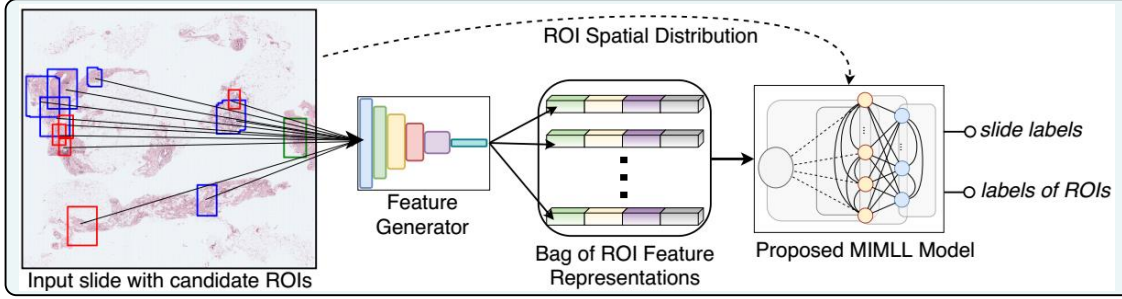
Different weakly supervised learning scenarios

Dr. Selim Aksoy

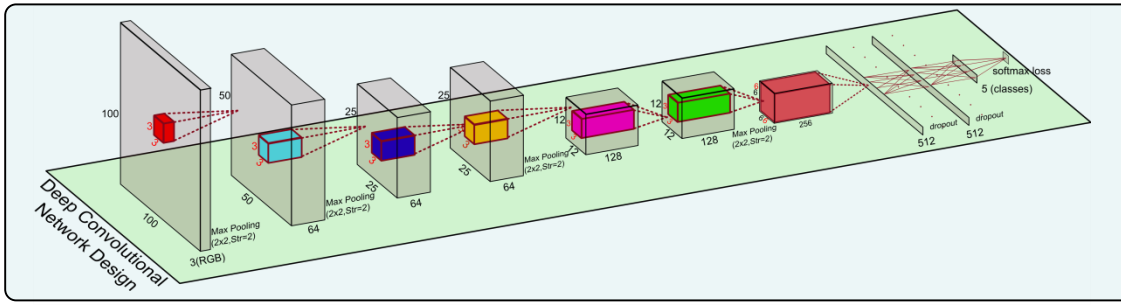
Medical Image Analysis



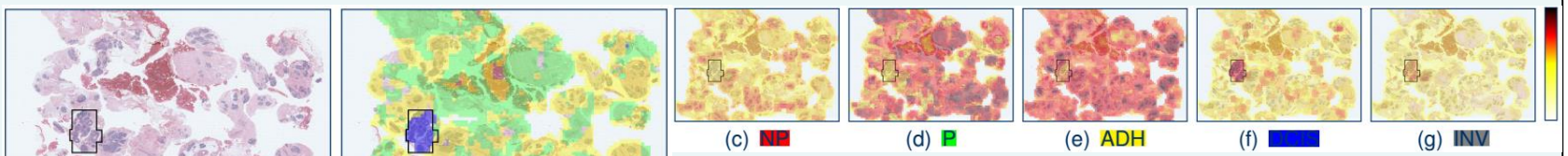
Deep feature representations



Conditional random fields for weakly supervised learning



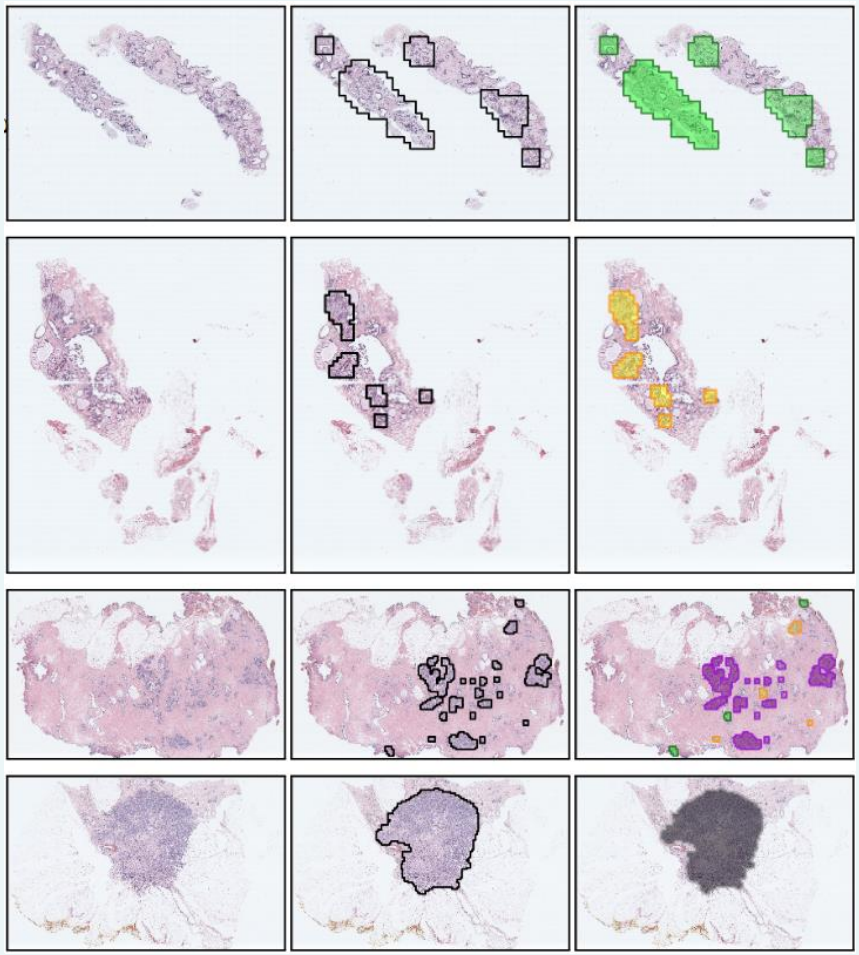
Convolutional neural networks for region of interest classification



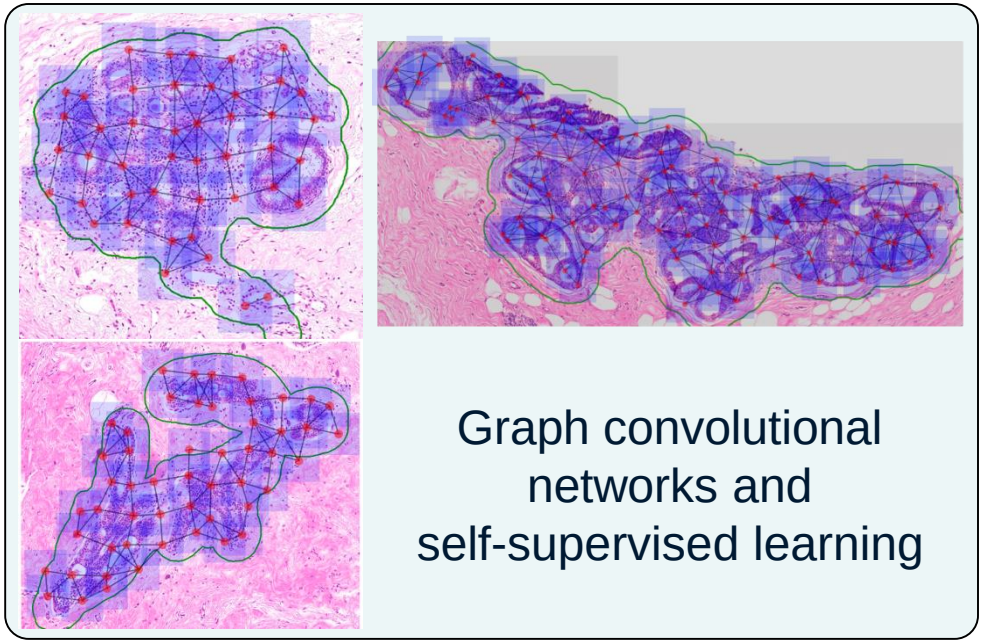
Computer aided diagnosis of breast biopsies

Dr. Selim Aksoy

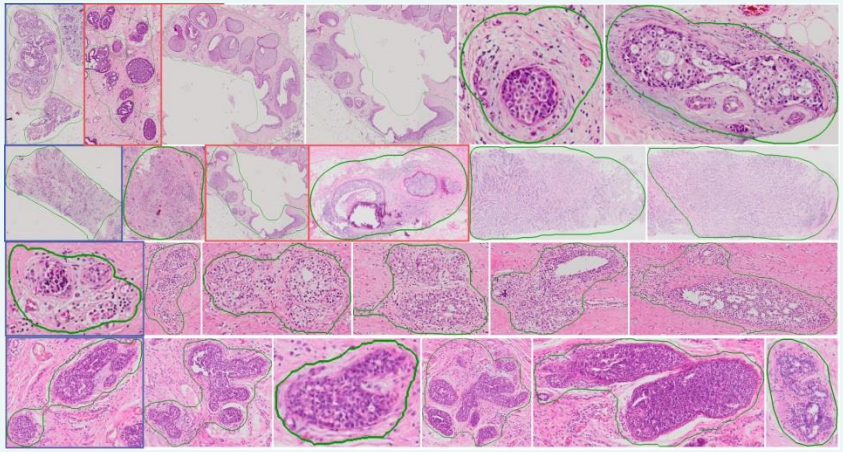
Medical Image Analysis



Simultaneous localization
and classification



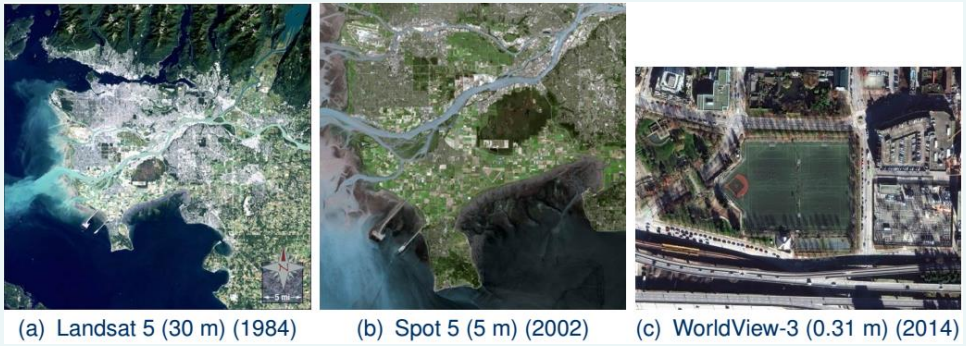
Graph convolutional
networks and
self-supervised learning



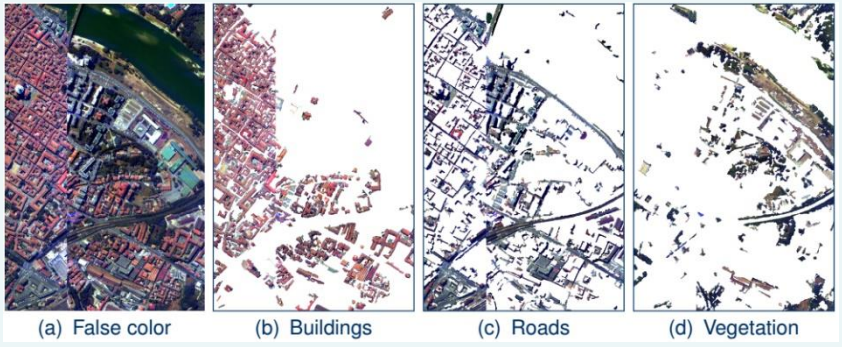
Content-based search of medical archives

Dr. Selim Aksoy

Remote Sensing Image Analysis

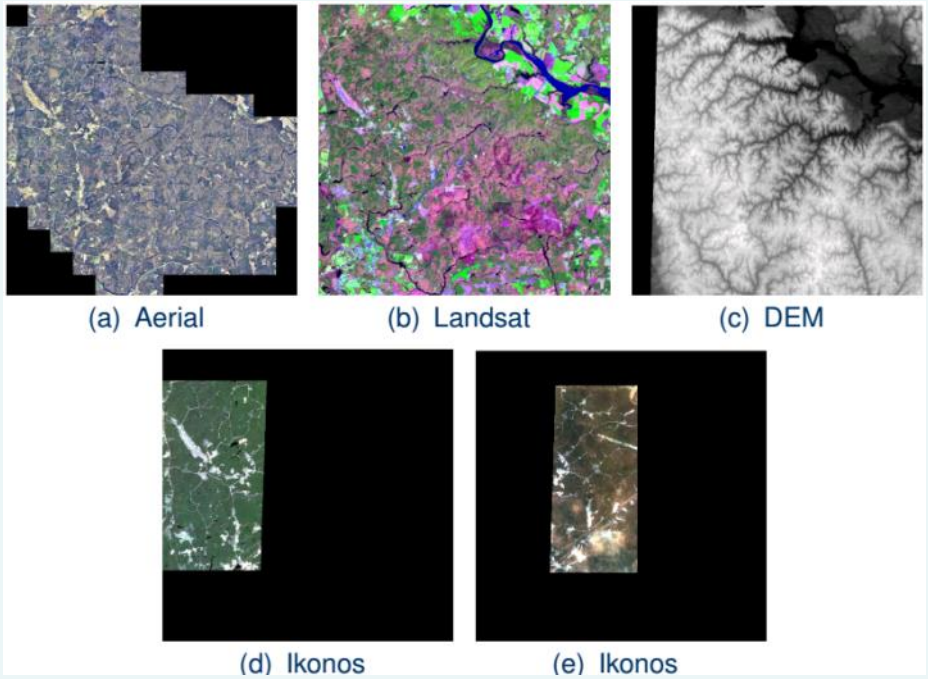


Increasing spatial resolution (300m ⇨ 1-2cm)



Hyperspectral image analysis

Orchard segmentation and agricultural mapping

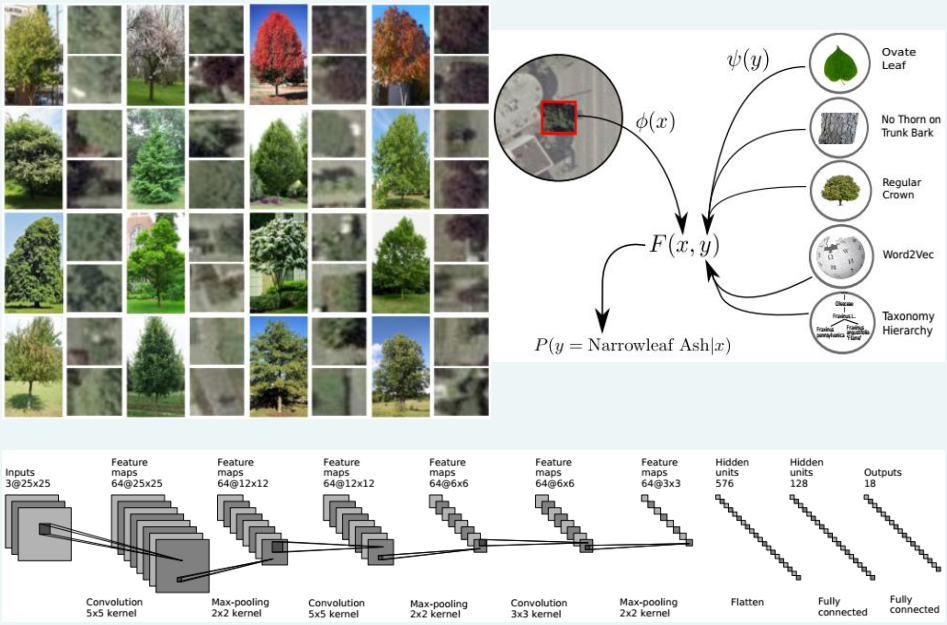


Multi-source fusion and missing data analysis

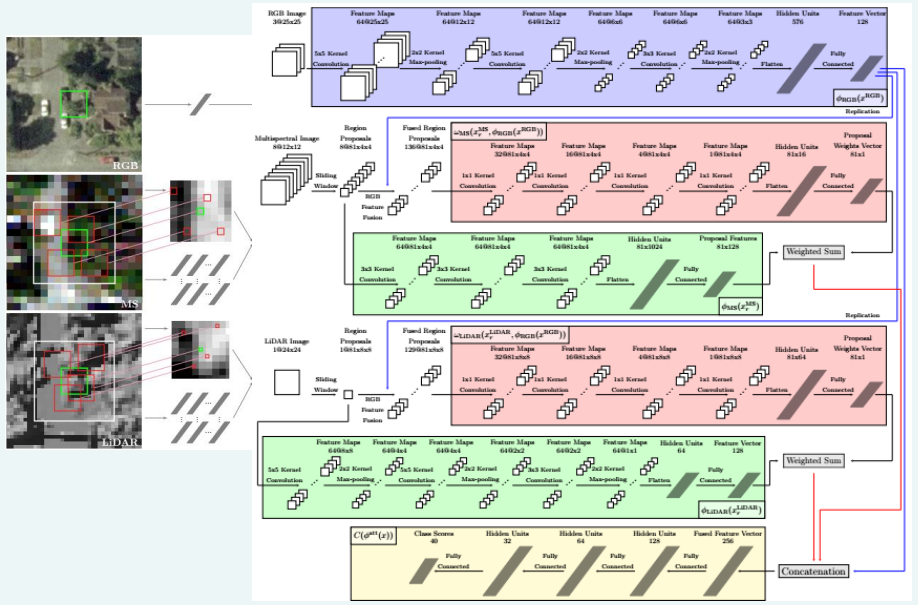
Dr. Selim Aksoy

Remote Sensing Image Analysis

Geospatial data mining



Zero-shot learning for object recognition



Attention model for multi-source fine-grained object recognition

Dr. Selim Aksoy

Can Alkan

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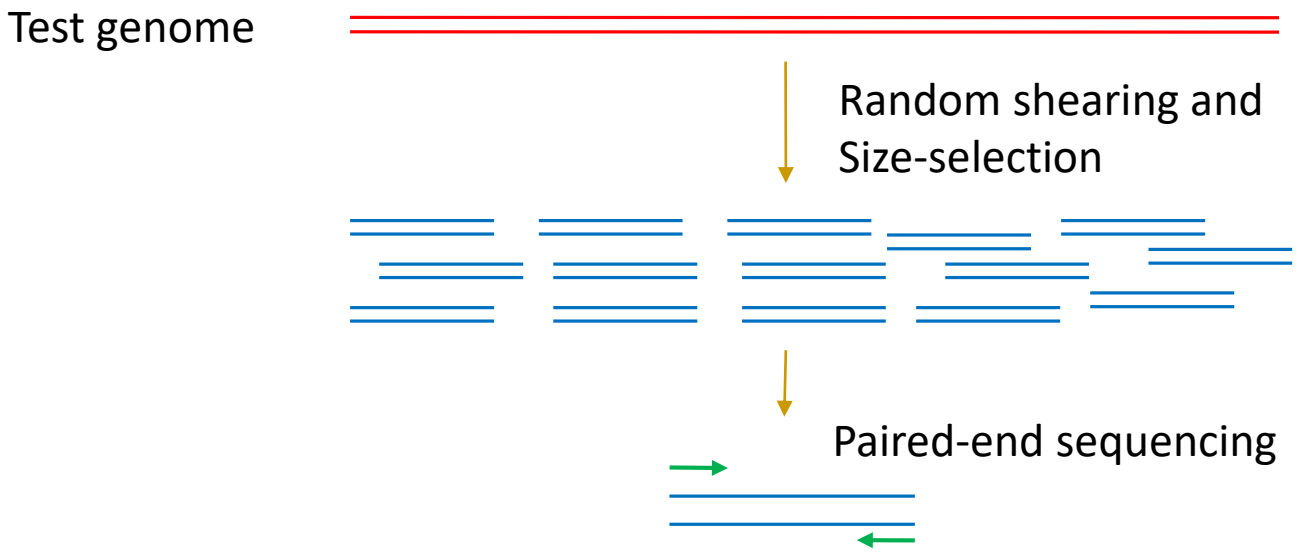
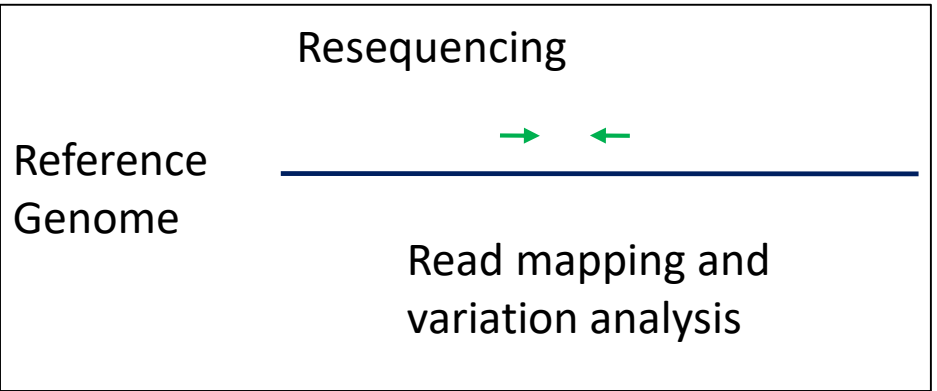
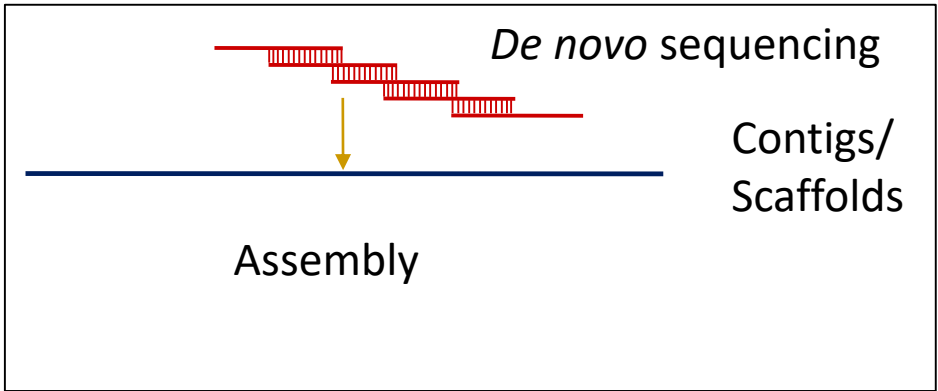
Lab for Bioinformatics and Computational Genomics

http://www.cs.bilkent.edu.tr/~calkan/compgen

Combinatorial algorithms to analyze high throughput sequence data to discover, genotype, and phase genomic variants, assemble genomes and transcriptomes.







Types of genomic variants

SNP: Single nucleotide polymorphism (substitutions)
Indel: Insertions and deletions of sequence of length 1 to 50 basepairs

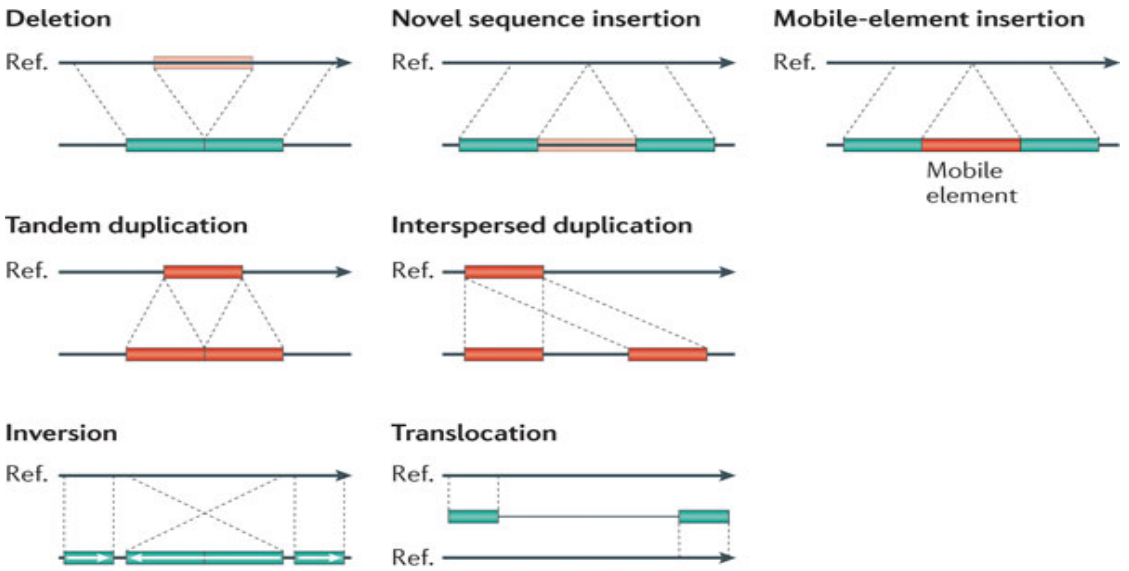
reference: C A C A G T G C G C - T
sample: C A C C G T G - G C A T

SNP *deletion* *insertion*

Short tandem repeats: microsatellites, minisatellites, alpha & beta satellites, etc.

reference: C A G C A G C A G C A G
sample: C A G C A G C A G *C A G* C A G

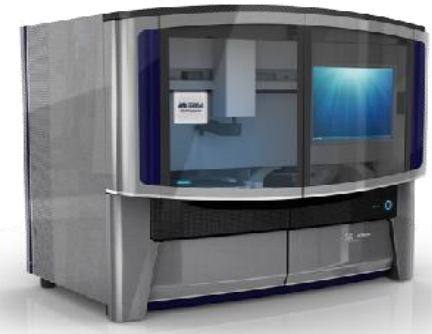
Structural variation:
Genomic alterations > 50 bp
Deletions, insertions, mobile elements, duplications, inversions and translocations



Nature Reviews | Genetics

Genome sequencers

Roche/454



AB SOLiD

Illumina MiSeq

Complete Genomics

Oxford Nanopore MinION

Illumina HiSeq2000

Pacific Biosciences RS

Oxford Nanopore GridION

Ion Torrent PGM

Ion Torrent Proton

… and more! All produce data with different properties.

Selected publications

Personalized copy number and segmental duplication maps using next-generation sequencing. *Nature Genetics,* Oct, 41(10):1061-1067, 2009.
*** Highlighted** in News and Views, "Mapping duplicated sequences", DY Chiang and SA McCarroll, *Nature Biotechnology,* Nov; 27(11):1001-2, 2009.

Combinatorial algorithms for structural variation detection in high throughput sequenced genomes. *Genome Research*, Jul, 19(7):1270-8, 2009.

Detection and characterization of novel sequence insertions using paired-end next-generation sequencing. *Bioinformatics,* May 15; 26(10):1277-83, 2010.

A draft sequence of the Neandertal genome *Science*, 7 May, 328 (5979):710-722, 2010.
Recipient of the 2010 AAAS Newcomb Cleveland Prize.

mrsFAST: a cache-oblivious algorithm for short-read mapping. *Nature Methods*, Aug;7(8):576-7, 2010.

A map of human genome variation from population-scale sequencing. 1000 Genomes Project Consortium. *Nature*, Oct 28;467(7319):1061-73, 2010.

Genetic history of an archaic hominin group from Denisova Cave in Siberia. *Nature*, Dec; 468(7327):1053-1060, 2010.

Limitations of next-generation genome sequence assembly. *Nature Methods,* 8(1):61-65, 2011.
* **Highlighted** in Commentary, "Assemblies: the good, the bad, the ugly", E. Birney, *Nature Methods*, 8(1):59-60, 2011.

Mapping copy number variation by population-scale genome sequencing. *Nature,* 470(7332):59-65, 2011.

Genome structural variation discovery and genotyping. *Nature Reviews Genetics,* May;12(5):363-76, 2011.

Sensitive and fast mapping of di-base encoded reads. *Bioinformatics*, Jul 15;27(14):1915-21, 2011.

Detection of structural variants and indels within exome data. *Nature Methods*, 9(2): 176-178, 2012.

Projects

- Discovery and characterization of genomic variation
  - Funded by EU Marie Curie Actions Career Integration Grant
- Algorithms and hardware designs for ultra-fast mapping of HTS reads to reference genome assemblies
  - Funded by US National Institutes of Health
- De novo and hybrid (multi-platform) sequence assembly.
- Genomic repeat discovery, classification and annotation.
- Distributed algorithms for genome assembly.

Positions available. Contact if you have B.Sc. or M.Sc. degree in computer science, computer engineering, electrical engineering, or mathematics, and if you are interested in combinatorial optimization, approximation algorithms, and graph theory. Strong programming skills in C/C++ are highly desired.

Successful applicants will also have a chance to contribute to many international consortiums such as the 1000 Genomes Project and the Genome 10K, and will involve in other international collaborations with researchers in Vancouver, Seattle, Barcelona, Bari, Pittsburgh, and more.

Basic understanding of biology/genetics/genomics is a *plus*, but **not required**.

Shervin Rahimzadeh Arashloo

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Office: EA 429

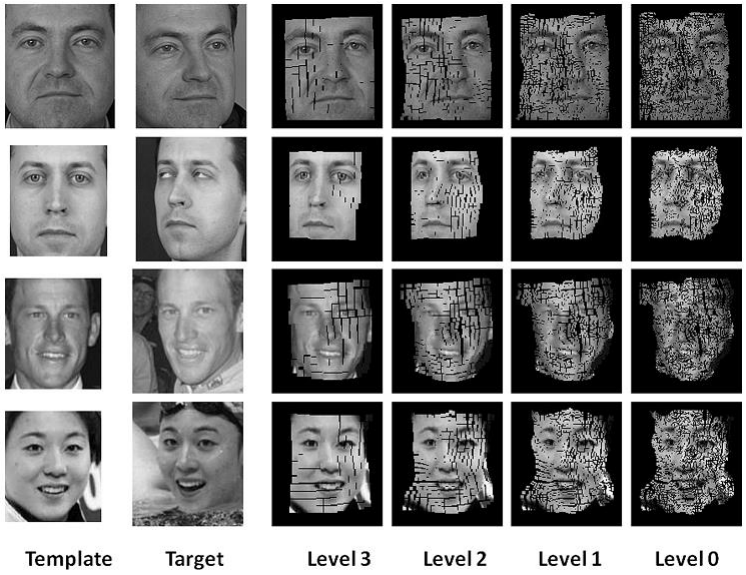
Research Interests

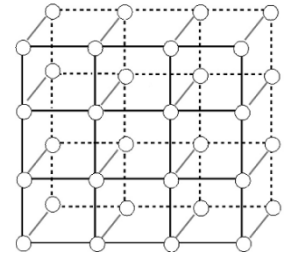
- Computer Vision
- Pattern Recognition
- Machine Learning

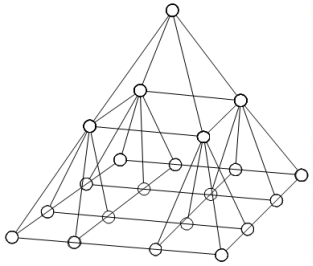
Current Research Topics

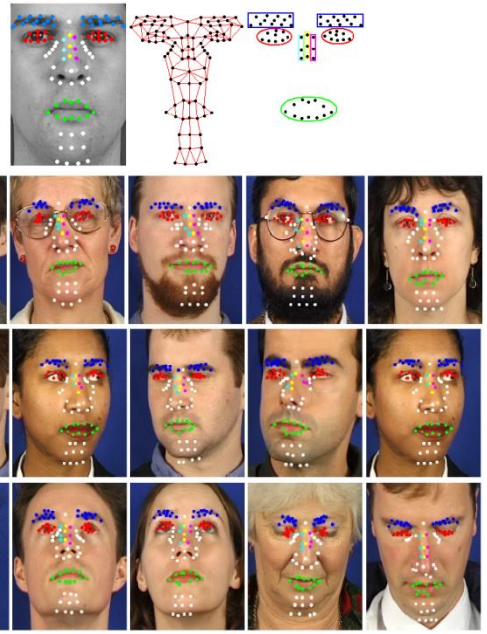
- Face Recognition
- Face Presentation Attack Detection
- Anomaly Detection

Unconstrained Face Recognition



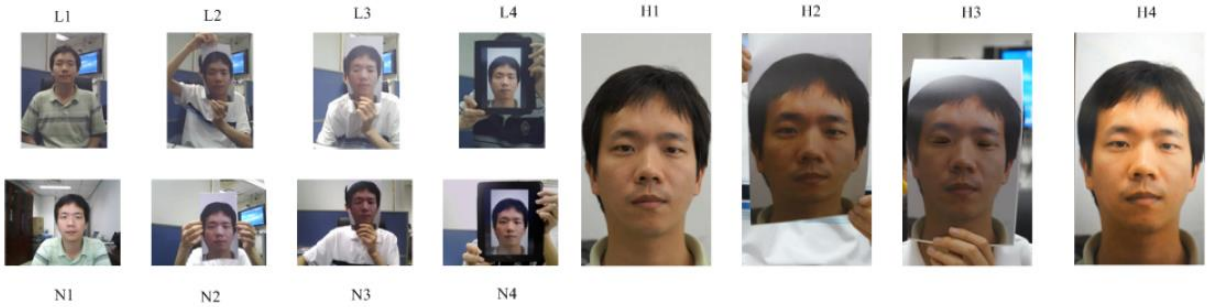


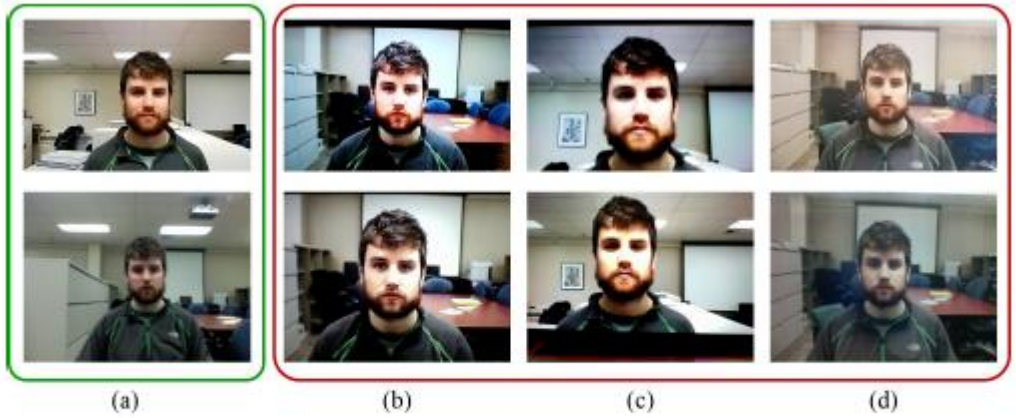




Face Presentation Attack Detection

Securing face recognition systems against security threats made by fake biometric traits





Sample data from the MSU dataset.(a) Genuine faces;

(b)-(d) Spoof faces.

Anomaly Detection

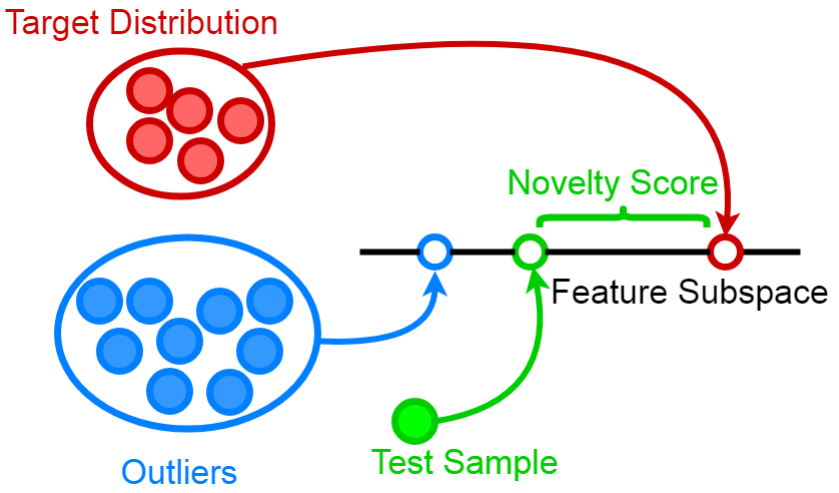
Developing novel methodologies along with applications to:

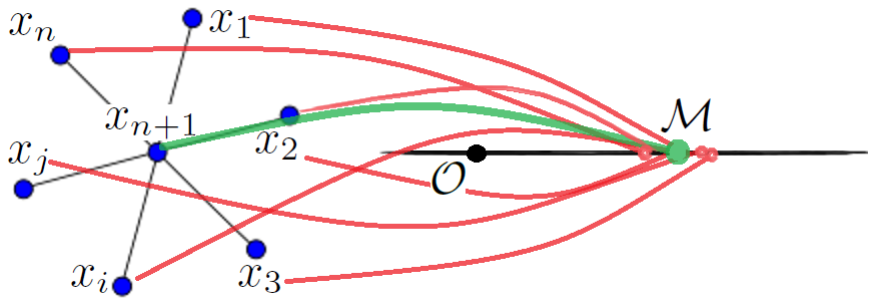
Surveillance

Novelty detection

Healthcare

etc.





Contact Address:
Prof. Cevdet Aykanat
aykanat@cs.bilkent.edu.tr

Bilkent University

High Performance Computing (HPC)

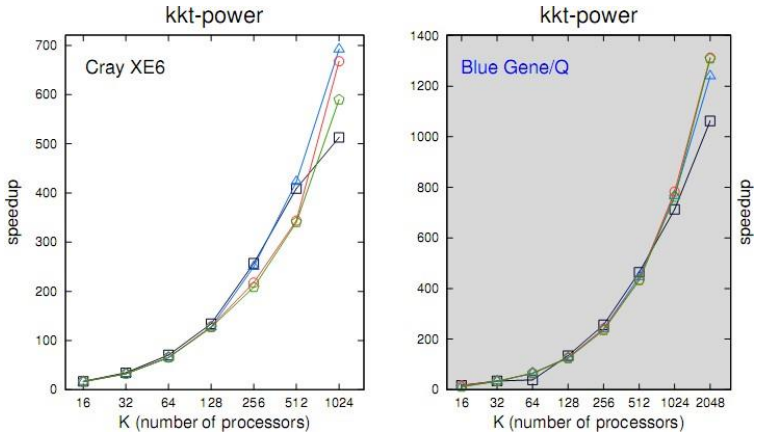
- Recent research interest and expertise
  - **Combinatorial scientific computing**
  - **Iterative solvers**: novel partitioning models, algorithms and software utilities for development of parallel iterative methods for linear-system solutions
  - Optimizing latency-centric communication metrics for petascaling **sparse solvers**
  - Partitioning **irregular domains** for large-scale parallel processing
  - Locality aware scheduling of irregular applications on **Many Core** architectures
  - Partitioning models for scaling 1D-, 2D- and 3D-parallel **sparse matrix-matrix multiply**
  - Partitioning large scale **social networks** and **graph databases**
  - **Parallel graph analytics** kernels for big data applications
  - **HPC** for **Machine Learning** and **ML** for **HPC**

• Partitioning methods for scalable sparse **Tensor decomposition**

• Scaling parallel **stochastic gradient descent** algorithms for **ML**

• Fast and efficient model parallelism for **Deep CNNs**

• Task leader in FP7 / Horizon2020 **PRACE** projects: 1IP, 2IP, 3IP, 4IP, 5IP



Speedup curves of Conjugate Gradient solver for different methods on a Cray and BlueGene/Q machine
(kkt-power matrix: 2 million rows, 12 million nonzeros)

Contact Address:
Prof. Cevdet Aykanat
aykanat@cs.bilkent.edu.tr
http://www.cs.bilkent.u.tr/~aykanat/

Recent Publications (2018-2021)

- True Load Balancing for Matricized Tensor Times Khatri-Rao Product, *Nabil Abubaker*, *Seher Acer*, *Cevdet Aykanat*, **IEEE Transactions on Parallel and Distributed Systems** vol. 32, no. 8, pp. 1974-1986, 2021.
- Fast Shared-Memory Streaming Multilevel Graph Partitioning *Oguz Selvitopi*, *Nazanin Jafari*, *and Cevder Aykanat*, **Journal of Parallel and Distributed Computing,** vol. 31, no. 8, pp. 140-151, 2021.
- Partitioning Models for General Medium-Grain Parallel Sparse Tensor Decomposition *M. Ozan Karsavuran*, *Seher Acer and Cevder Aykanat*, **IEEE Transactions on Parallel and Distributed Systems**, vol. 32, no. 1, pp. 147-159, 2021.
- Cartesian Partitioning Models for 2D and 3D Parallel SpGEMM Algorithms, *Gunduz V. Demirci and Cevder Aykanat*, **IEEE Transactions on Parallel and Distributed Systems**, vol. 31, no 12, pp. 2763-2775, 2020.
- Reordering Sparse Matrices into Block-Diagonal Column-Overlapped Form, *Seher Acer and Cevder Aykanat*, **Journal of Parallel and Distributed Computing,** vol**.** 140, pp. 99-109, 2020.
- Reduce Operations: Send Volume Balancing While Minimizing Latency, *M. Ozan Karsavuran*, *Seher Acer*, *and Cevder Aykanat*, **IEEE Transactions on Parallel and Distributed Systems**, vol. 31, no. 6, pp. 1461-1473, 2020.
- The Effect of Various Sparsity Sturcuters on Parallelism and Algorithms to Reveal Those Strctures, Oguz Selvitopi, Seher Acer, Murat Manguoglu and Cevdet Aykanat, **Parallel Algorithms in Computational Science and Engineering**, 35-62, 2020.
- Regularizing irregularly sparse point-to-point communications, *Oguz Selvitopi and Cevdet Aykanat* **Proceedings of the International Conference for High Performance Computing**, Networking, Storage and Analysis. ACM, 2019.
- A Hypergraph Partitioning Model for Profile Minimization, *Seher Acer, Enver Kayaaslan, Cevdet Aykanat*, **SIAM Journal on Scientific Computing**, vol. 41, no. 1, pp. A83-A108, 2019.
- Locality-aware and load-balanced static task scheduling for MapReduce, *Oguz Selvitopi, Gunduz V. Demirci, Ata Turk, Cevdet Aykanat*, **Future Generation Computer Systems**, vol. 90, pp. 49-61, 2019.
- Scaling Sparse Matrix-Matrix Multiplication in the Accumulo Database, *Gunduz V. Demirci, Cevdet Aykanat*, **Distributed and Parallel Databases**, pp 1-32, 2019.
- Spatiotemporal Graph and Hypergraph Partitioning Models for Sparse Matrix-Vector Multiplication on Many-Core Architectures, *Nabil Abubaker, Kadir Akbudak, Cevder Aykanat*, **IEEE Transactions on Parallel and Distributed Systems**, vol. 30, no. 2, pp. 445-458, 2019.
- A novel partitioning method for accelerating the block cimmino algorithm, *Sukru Torun, Murat Manguoglu, Cevdet Aykanat*, **SIAM Journal on Scientific Computing**, 40(6) C827-C850, 2018.
- Cascade-aware partitioning of large graph databases, *Gunduz V. Demirci, Hakan Ferhatosmanoglu, Cevdet Aykanat*, **The VLDB Journal**, pp. 1-22, 2018.
- Optimizing nonzero-based sparse matrix partitioning models via reducing latency, *Seher Acer, Oguz Selvitopi, Cevdet Aykanat*, **Journal of Parallel and Distributed Computing**, vol122, pp145-158, 2018.
- Improving medium-grain partitioning for scalable sparse tensor decomposition, *Seher Acer, Tugba Torun, Cevdet Aykanat*, **IEEE Transactions on Parallel and Distributed Systems**, vol. 29, no. 12, pp. 2814-2825, 2018.
- 1.5 D parallel sparse matrix-vector multiply, *Enver Kayaaslan, Cevdet Aykanat, Bora Ucar*, **SIAM Journal on Scientific Computing**, vol. 40, no. 1, pp. C25-C46, 2018.
- Partitioning models for scaling parallel sparse matrix-matrix multiplication, *Kadir Akbudak, Oguz Selvitopi, Cevdet Aykanat*, **ACM Transactions on Parallel Computing (TOPC)**, vol. 4, no. 3, pp. 13, 2018.

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Recent Funded Projects

- **TUBITAK/COST Projects**

- 119E035: Parallel Stochastic Gradient Descent Algorithms for Large-Scale Recommendation Systems, 15/09/2019 - 15/02/2022
- 116E043: High Performance Tensor Decomposition Methods for Distributed and Shared Memory Parallel Systems, 01/05/2017 – 1/11/2019
- 115E212/COST-CA15109: Improving Sparse Matrix Based Graph Analytics Kernels for Big Data Applications, 01/09/2015 - 01/03/2018
- 114E545/COST-IC1406: Petascaling Sparse Iterative Solvers via Optimizing Multiple Communication Metrics, 01/04/2015 - 01/10/2017
- 112E120: Partitioning, Replication and Query Processing in Social Networks, 01/09/2012 - 01/09/2014

- **FP7/HORIZON-2020 Projects**

- PRACE 6IP 01/05/2019 – 01/05/2021
  - Task 7.4: Evaluation of Benchmark Performance
- PRACE 5IP 01/01/2017 – 01/05/2019
  - Task 7.2: Preparing for PRACE Exascale Systems
- PRACE 4IP 01/02/2015 - 01/05/2017
  - Task 7.2: Preparing for Future PRACE Exascale Systems
  - Task 4.3: On-line Training. Subtask: Evaluation of platforms for the CodeVault
- PRACE 3IP 01/08/2012 - 01/08/2014
  - D7.2.1 HPC Tools and Techniques
- PRACE 2IP 01/07/2011 - 01/07/2014
  - D12.5 Summary of Novel Programming Techniques Results (Taskleader)
- PRACE 1IP-Extension 01/07/2013 - 01/07/2014
  - D7.1.3 Application Enabling for Capability Science in the MIC Architecture
- PRACE 1IP 01/07/2010 - 01/07/2013
  - D7.5 HPC Programming Techniques (Task leader)

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Current Positions of Some Former PhD. Students

- Dr. Ozan Karsavuran, 2020. **Bilkent Universty,** Postdoctoral Researcher
- Dr. G. Vehbi Demirci, 2019. **University of Warwick,** Postdoctoral Researcher
- Dr. Seher Acer, 2017. **Oak Ridge National Lab.**, Research Scientist
- Dr. Oguz Selvitopi, 2017. **Lawrence Berkeley Nat. Lab.**, Research Scientist
- Dr. Şükrü Torun, 2017. **Yıldırım Beyazıt University**, Assistant Professor
- Dr. Kadir Akbudak, 2015. **University of Tennessee**, Research Scientist
- Dr. Enver Kayaaslan, 2013. **Google Switzerland**, Researcher
- Dr. Ertuğrul Tabak, 2013. **Aurea Software**, Software engineering manager
- Dr. Eray Özkural, 2013. **Celestial Intellect Cybernetics**, Software engineer
- Dr. Tayfun Küçükyılmaz, 2012. **TED University**, Assistant Professor
- Dr. Ata Türk, 2010. **Boston University**, Research Scientist,
- Dr. Engin Demir, 2009. **Hacettepe University**, Assistant Professor
- Dr. Barla Cambazoğlu, 2006. **RMIT University**, Senior Research Fellow
- Dr. Bora Uçar, 2005. **LIP ENS-LYON**, CNRS researcher.
- Dr. Ümit Çatalyürek, 1999. **Georgia Institute of Technology**, Professor
- Dr. Tahsin Kurc, 1997. **Stony Brook University**, Associate Professor

Bilkent Information Retrieval Group

Faculty
Fazlı Can
Seyit Koçberber

Graduate Students
Soheil Abadifard
Sepehr Bakhshi
Pouya Ghahramanian
Sanaz Gheibuni
Oğuzhan Özçelik
Onur Yıldırım

UG Student(s)
Enes Bektaş

Some Prev. Members
Alican Büyükçakır
Sevil Çalışkan
Sanem Elbaşı
Ömer Gözüaçık
Berkay Gülcan
Çağdaş Öcalan

Other Contributors
Hamed R. Bonab, Umass
Dilek Küçük, TÜBİTAK
Çağrı Toraman, ASELSAN

Research Interests

Information Retrieval (IR)

- Information Filtering
- News Aggregation and Categorization
- Turkish Text Mining
- Literature Analysis

Data Stream Mining

- Ensemble Models for Stream Classification
- Multi-label Classification
- Concept Drift Detection
- Multi-stream Processing
- Stance Detection

You are the right person for our group

- **If you are good at four core practices of computer science**
  - programming,
  - systems thinking,
  - modeling, and
  - innovation.
- **If you**
  - can dream,
  - can do, and
  - can write.

A. Ercument Cicek

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My research focuses on building algorithms for analyzing biological data using various biochemical networks. Even though it took 13 years and ~$1b to sequence the first genome, right now, it takes a day and ~$1k. This has resulted in accumulation of vast amounts of information. Consequently, biosciences have faced the problem of “big data”. Today, the bottleneck in the bio-research is the lack of computational power and algorithms that can efficiently analyze the data and make discoveries. Central dogma in molecular biology dictates the information flow from DNA -> RNA --> Protein --> Metabolite. Each layer introduces 20k, 100k, 1m, and 3k variables respectively. The search space for even a basic pattern discovery is clearly intractable. I design machine learning algorithms that use biological networks to prune the search space and discover biomarkers in particular for genetic Diseases.

A. Ercument Cicek
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Gene Discovery for Autism Spectrum Disorder

-Broken interplay between 1000 genes lead to autism.

-So far we have only discovered ~50 of them, Biological networks along with intelligent search algorithms needed to discover new genes to understand the genetic architecture.

A. Ercument Cicek
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cs.bilkent.edu.tr/~cicek

Using Dynamic Network Algorithms to Model Neurodevelopment.

-Autism is a neurodevelopmental disorder and affects evolving the gene interaction networks of the fetal period to early childhood.

-We design algorithms that analyze the dynamic networks to understand the functionality autism affects.

A. Ercument Cicek
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Metabolic Networks to Understand Cancer

Metabolites are the small compounds in the body and have been found to be key biomarkers to define certain tumors.

We use network algorithms and build online systems that analyze metabolic signatures in tumors and understand the differences within the subtypes of the same cancer.

A. Ercument Cicek

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Selected Publications:

- *De Novo Chip-Seq Analysis.* **Genome Biology** 2015, 16:205.
- *Insights into autism spectrum disorder genomic architecture and biology from 71 risk loci* **NEURON** 2015, 87(6):1215–33.
- *Exome analyses reveal new autism genes in synaptic, transcriptional, and chromatin networks.* **NATURE** 2014, 515(7526):209-15
- *MIRA: Mutual Information-based Reporter Algorithm for Metabolic Networks* **Bioinformatics** 2014, 30(12): i175-i184.
- *DAWN: A framework to identify autism genes and subnetworks using gene expression and genetics* **Molecular Autism** 2014 5:22.
- *ADEMA: An Algorithm to Determine Expected Metabolite Level Changes Using Mutual Information* **PLoS Computational Biology** 2013, 9(1) : e1002859.

Hamdi Dibeklioğlu

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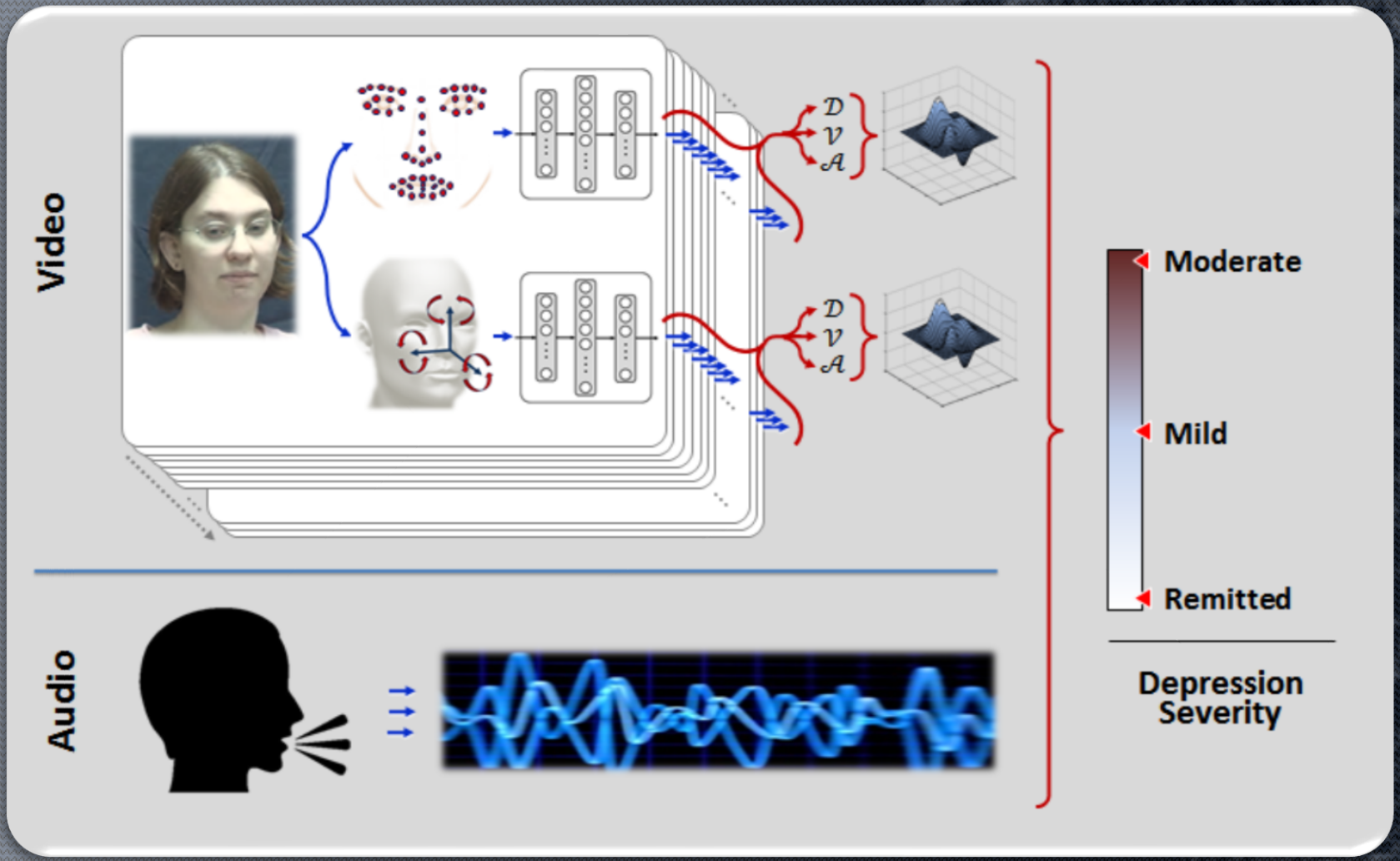
I work in the fields of Affective Computing, Computer Vision, and Pattern Recognition.

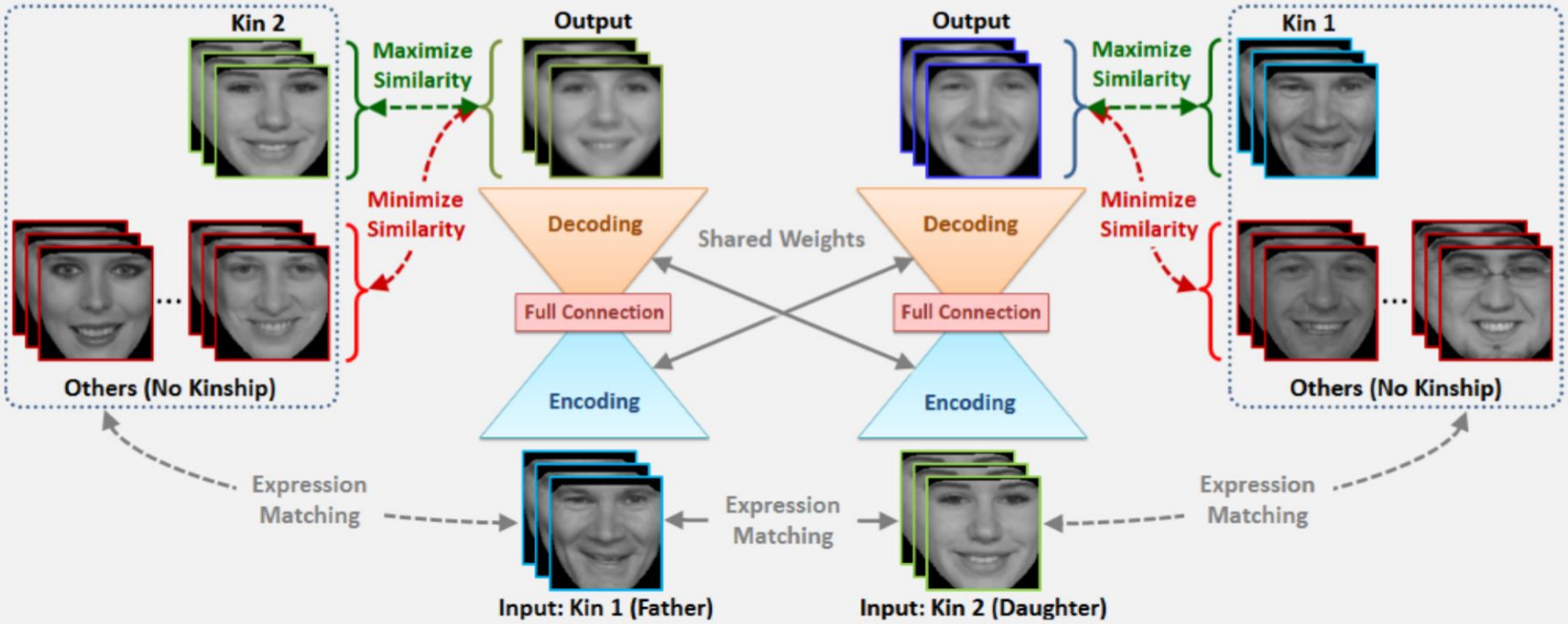
My current research mainly focuses on multimodal analysis of non-verbal human behavior (e.g. face analysis, gesture recognition, etc.) and deep learning of temporal representations.

Assessment of Depression Severity



dibeklioglu@cs.bilkent.edu.tr | http://www.cs.bilkent.edu.tr/~dibeklioglu/

Kinship Verification



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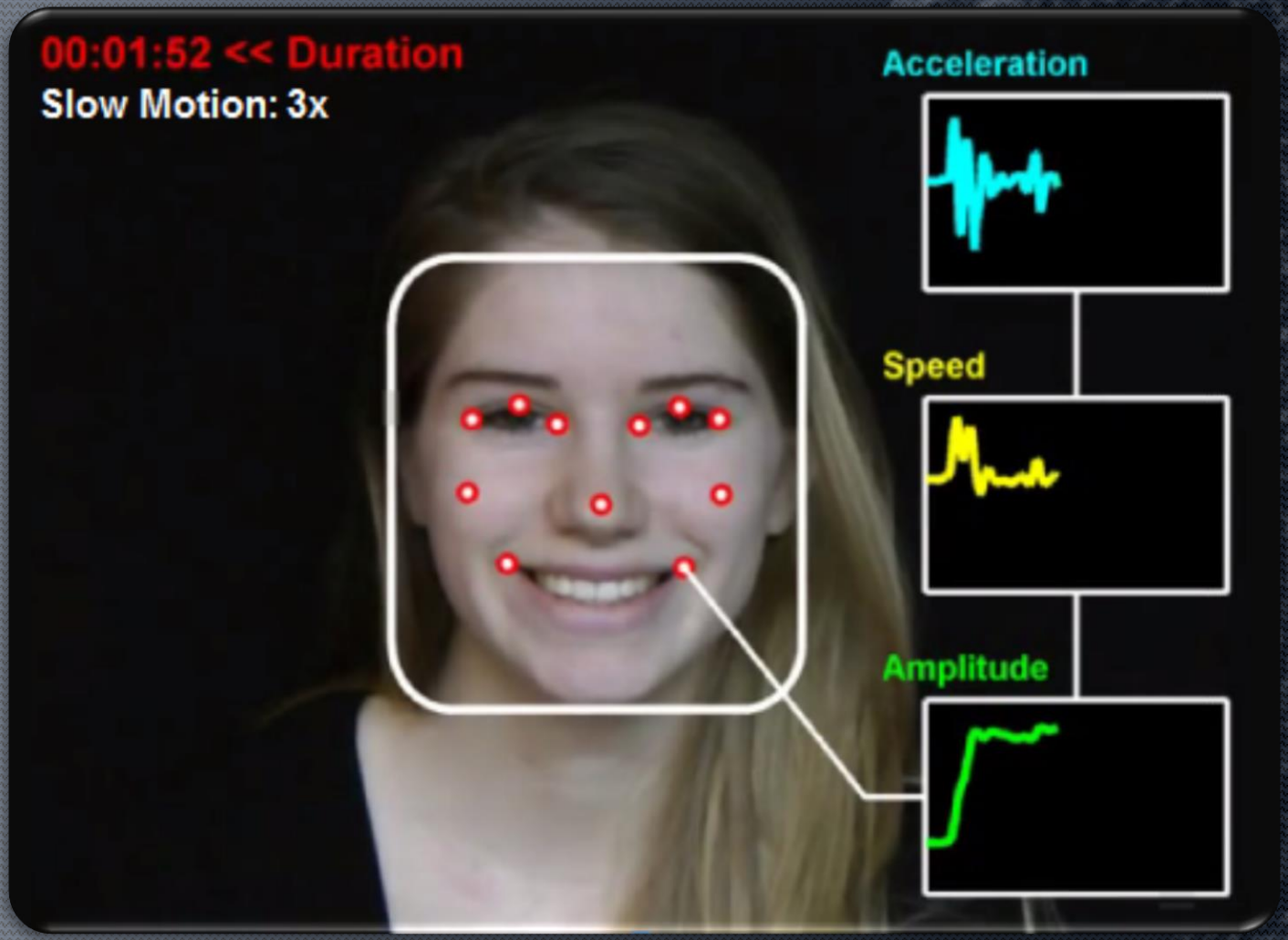
Age Estimation through Facial Dynamics



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Facial Expression Recognition

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Selected Publications

- *Dynamic multimodal measurement of depression severity using deep autoencoding*. **IEEE Journal of Biomedical and Health Informatics**, 2018, 22(2):525-536.
- *Multivariate time series classification using the hidden-unit logistic model.* **IEEE Transactions on Neural Networks and Learning Systems**, 2018, 29(4):920-931.
- *Visual transformation aided contrastive learning for video-based kinship verification*. **IEEE International Conference on Computer Vision**, 2017, 2459-2468.
- *Combining facial dynamics with appearance for age estimation.* **IEEE Transactions on Image Processing**, 2015, 24(6):1928-1943.
- *Recognition of genuine smiles.* **IEEE Transactions on Multimedia**, 2015, 17(3):279-294.

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i-Vis @ Bilkent

Information Visualization Research Lab at Bilkent University

Big data visualization & analytics, Pathway visualization & informatics, Graph drawing & layout, Graph database querying algorithms

Ugur Dogrusoz

*Click **here** for live/animated/full presentation*

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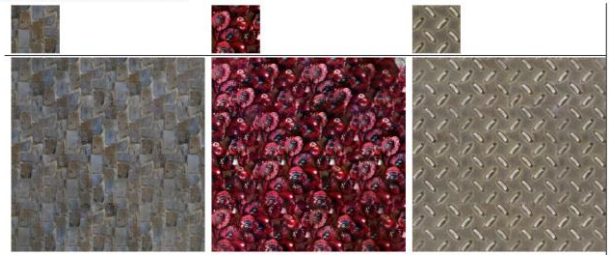
Image Synthesis with Deep Neural Networks

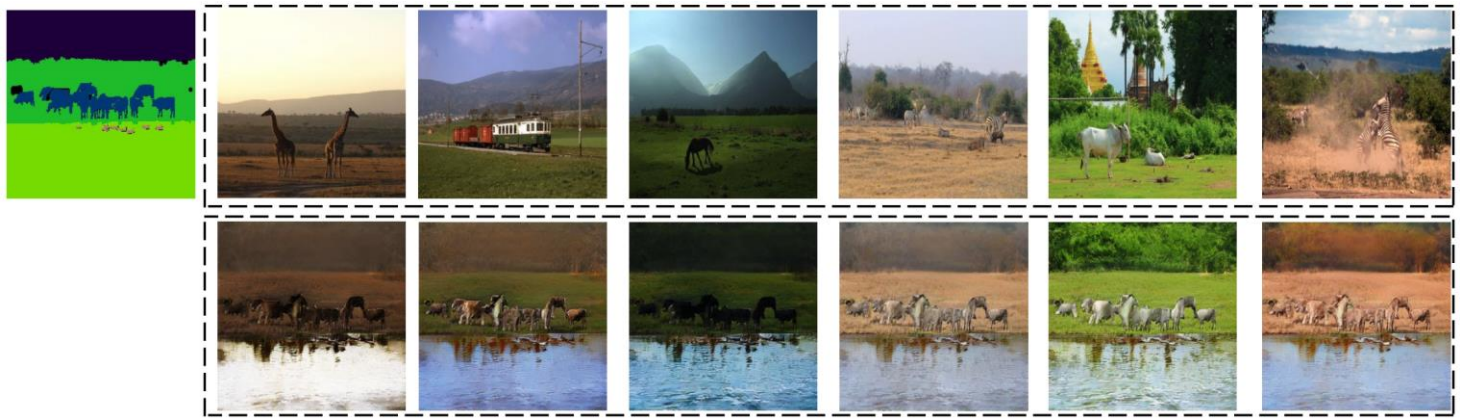
Image inpainting

Texture synthesis

Image synthesis

Image to image translation





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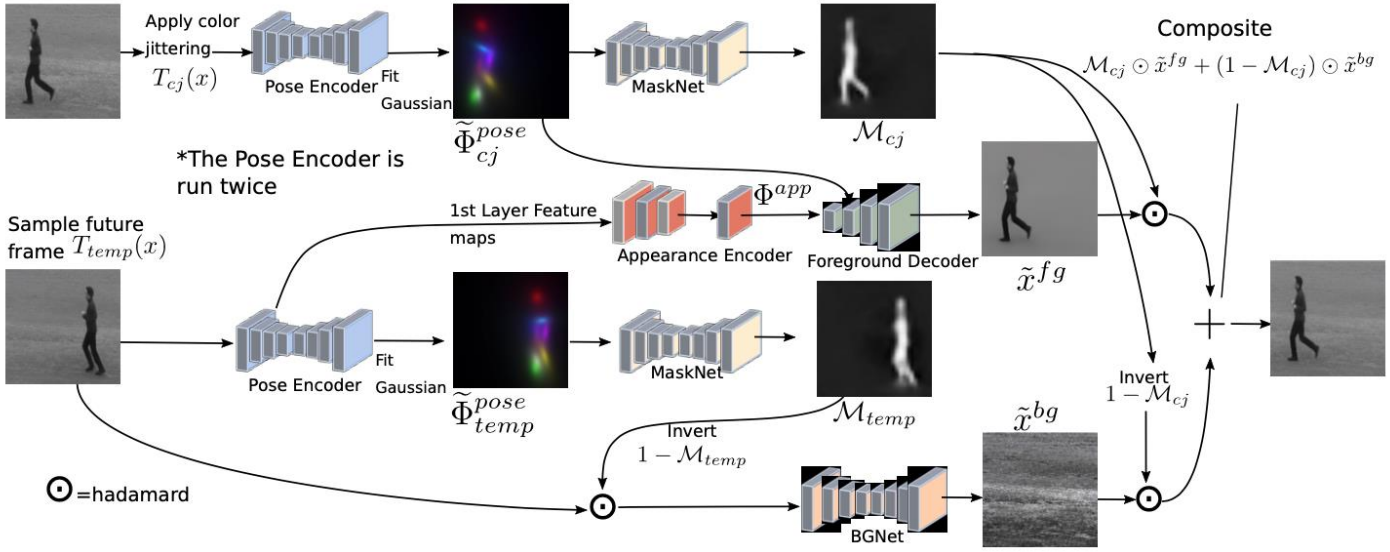
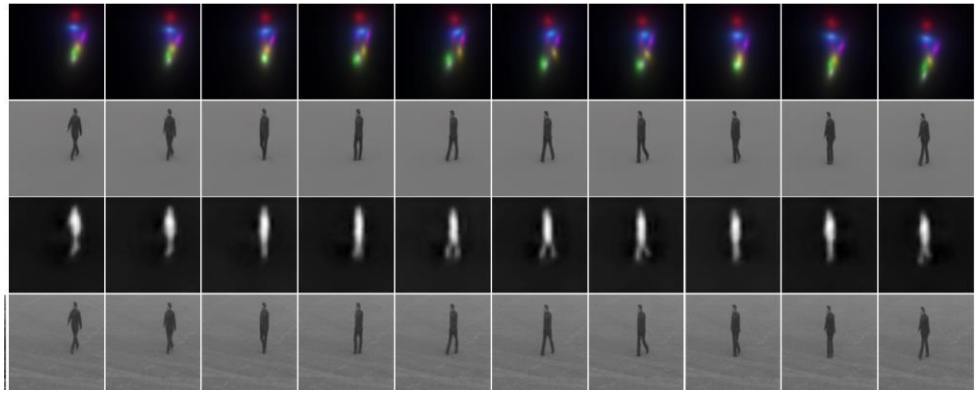
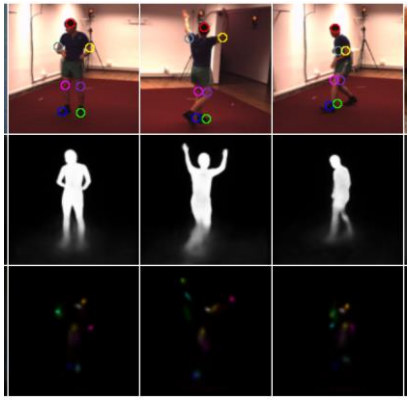
Unsupervised feature learning with Deep Neural Networks







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Unsupervised 3D image synthesis

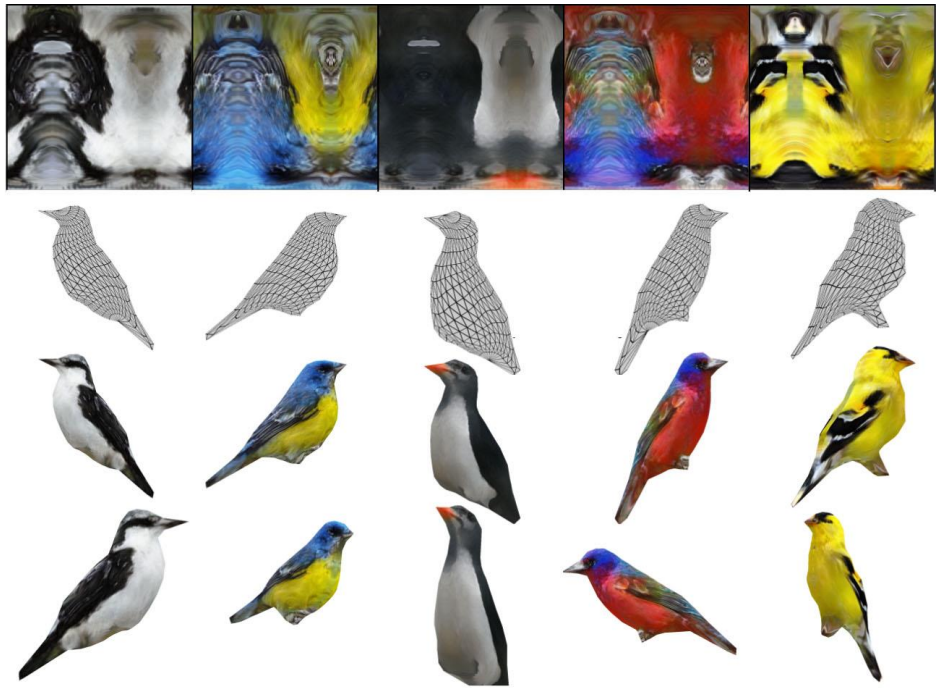

Image taken from : https://github.com/dariopavllo/convmesh/

Computer Graphics

Uğur Güdükbay

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Modeling and Visualization Research Group
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Computer Graphics

Computer Graphics Research Group at the Department of Computer Engineering at Bilkent University conducts research on different aspects of computer graphics.

Human Modeling and Animation

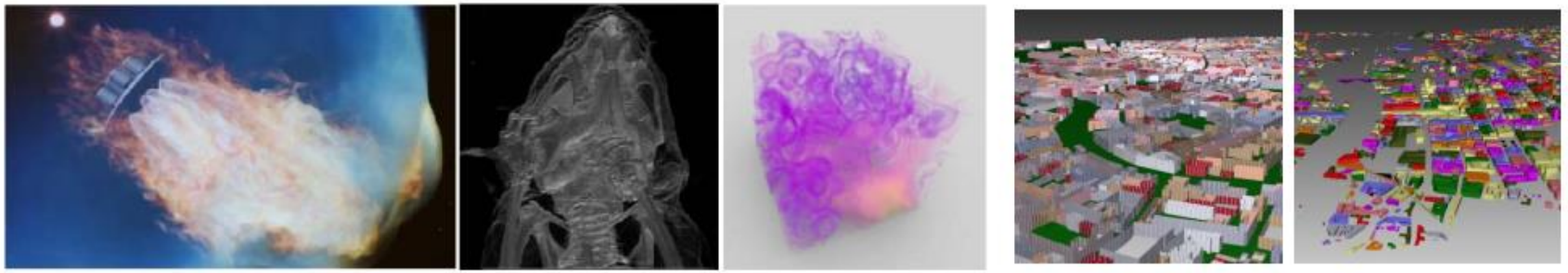
- Motion control, Realistic rendering, Facial animation, Hair simulation, Motion capture
- Augmented Reality
- Crowd simulation
- Agent Personality and Emotion Modeling
- Learning Personality and Emotions

Three-Dimensional (3D) Modeling

- Tetrahedralization of Large Models
- Terrain and Urban Scenes

Rendering

- Tetrahedralization-based Acceleration Structures for Raytracing
- Direct Volume Visualization Using Tetrahedralization-based structures



Çiğdem Gündüz Demir

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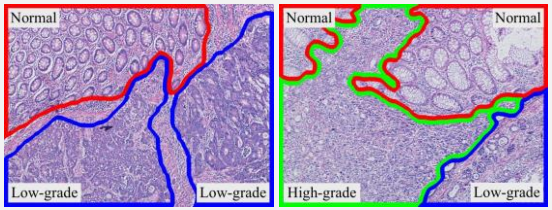
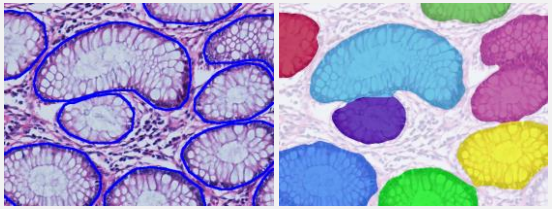
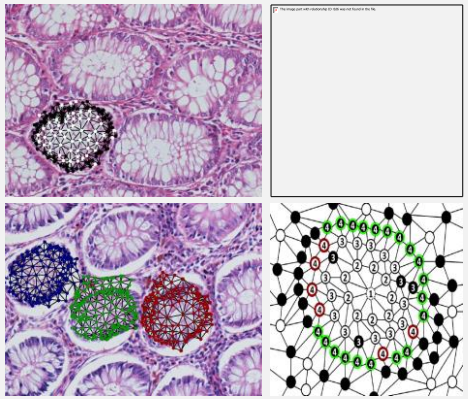
Digital pathology: classification and segmentation in biopsy images



End-to-end segmentation in biopsy images

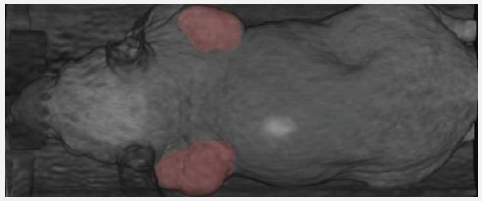


Gland/cell segmentation in colon tissues

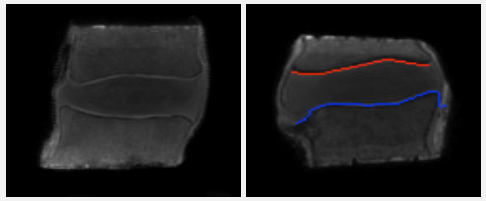


High-level representation of histopathological images and colon cancer classification

CT and MR image analysis for in vivo images

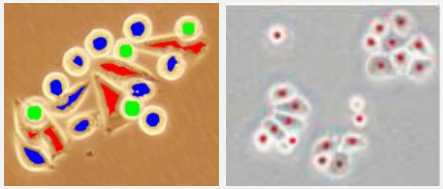


Subcutaneous tumor segmentation



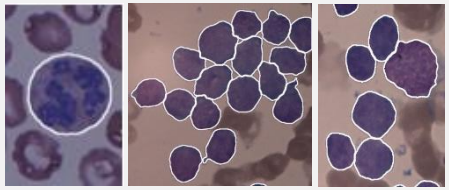
Cartilage endplate segmentation

High content screening: cell segmentation in microscopic images



Cell segmentation in phase contrast microscopy

Cell segmentation in fluorescence microscopy

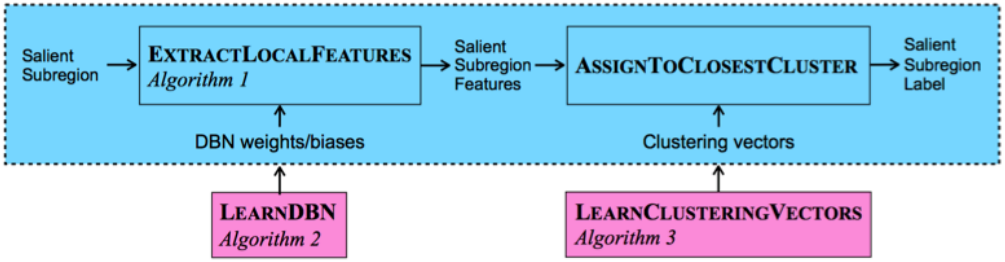


Cell segmentation in peripheral blood and bone marrow images

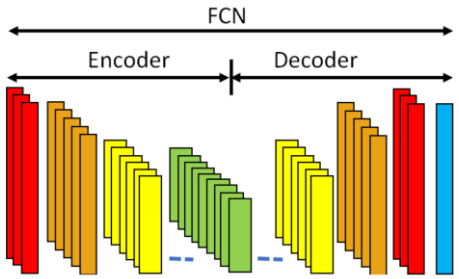
Deep Learning for Medical Image Analysis

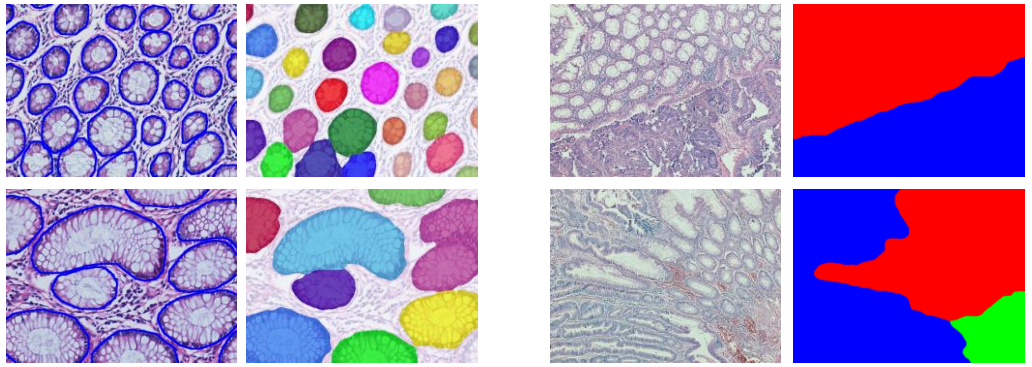
Digital Pathology

Unsupervised feature extraction via deep neural networks for histopathological image representation and classification



End-to-end gland and tissue segmentation using fully convolutional networks

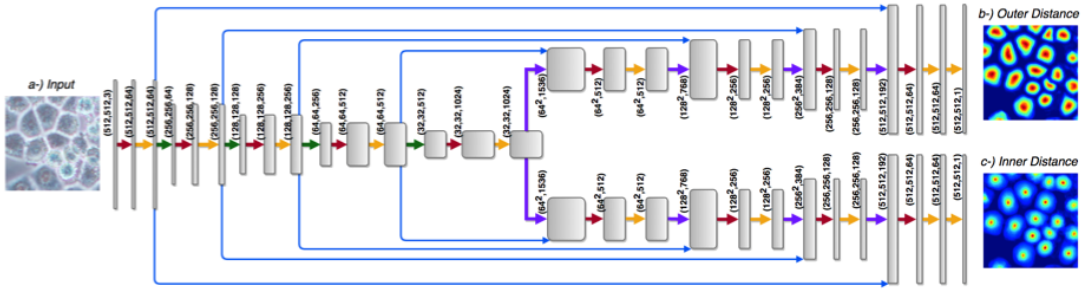


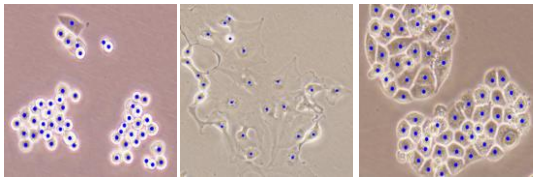


Deep Learning for Medical Image Analysis

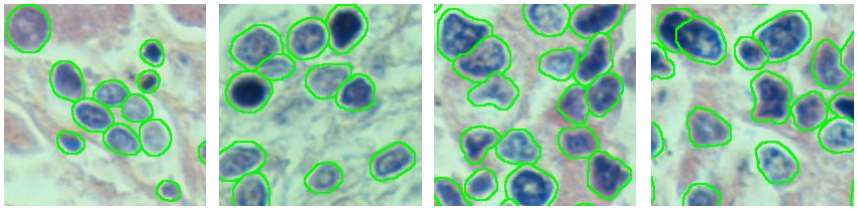
Cell Segmentation

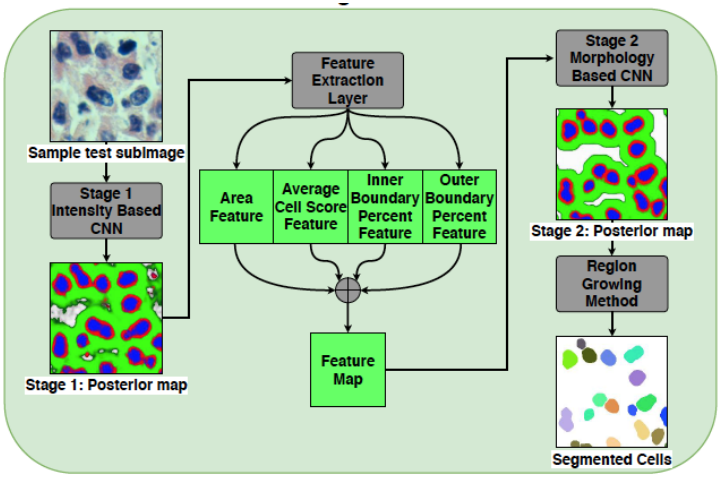
Multi-task models for cell detection in live cell microscopy





Two-stage convolutional neural networks for cell nucleus segmentation in tissue images





Machine Learning and Data Mining

Current research topics include

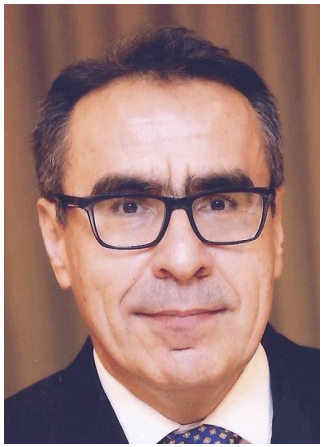
Learning to

- rank instances
- model risk factors
- estimate risks
- suggest to increase success

Application areas: Medical, Social Networks

Networks and Systems Research Group

http://www.cs.bilkent.edu.tr/~korpe/nsrg/



Faculty Member
Ibrahim Korpeoglu
Professor
Dept of Computer Engineering
Bilkent University

Email: korpe@cs.bilkent.edu.tr
Web: http://www.cs.bilkent.edu.tr
Office: Engineering EA 401
Phone: 290 2599

- **Research Areas:**
  - Computer Networks
  - Wireless Networks
  - Sensor Networks
  - P2P Networks
  - Computer Systems
  - Distributed Systems
  - Cloud Computing
  - Internet of Things
  - Big Data Systems

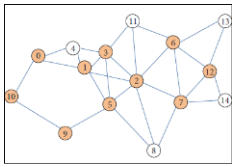
Working on Problems and Projects related with Computer Networks and Computer Systems

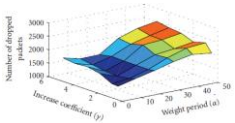
Networks and Systems Research Group

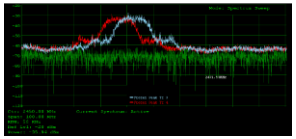
Sample Current Work

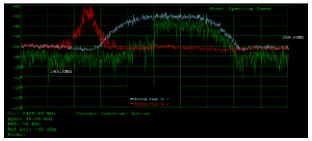
- **Wireless Mesh Networks**

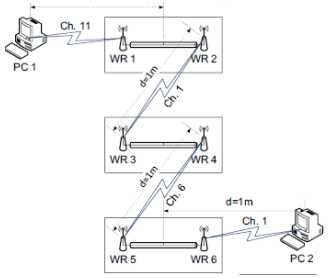
  - Routing
  - Channel assignment
  - Interference modeling
  - Interference mitigation

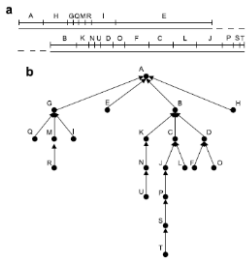






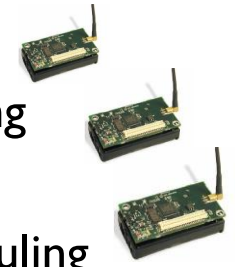




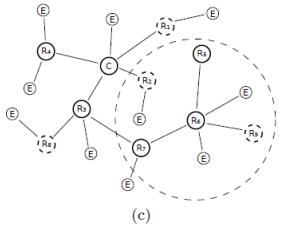


  - Testbeds
- **Cloud Computing**
  - Resource allocation
  - VM placement
  - Network virtualization
  - Network embedding
  - Mobile Edge Computing

- **Sensor Networks**



  - Energy efficient routing
  - Activity scheduling
  - Channel access scheduling
  - ZigBee wireless technology
  - ZigBee routing
- **P2P Networks**



  - Query forwarding
  - Free riding
  - File sharing and lookup
- **Internet of Things**
  - Data and Application Placement

Networks and Systems Research Group

Sample Funded Projects

- Efficient **Resource Allocation in Heterogeneous Cloud Infrastructures**
  Sponsor: TUBITAK
- Supporting Real-time Traffic in **Wireless Ad Hoc and Sensor Networks**
  Sponsor: TUBITAK
- *Bluetooth Scatternet Construction* and Bluetooth Applications
  Sponsor: TUBITAK
- Network Middleware for Environmental Monitoring and Control with **Wireless Ad hoc, Mesh and Sensor Networks**
  Sponsor: IBM Corporation
- Intel WCNC, **Wireless Networking** Curriculum Enhancement Project
  Sponsor: Intel Corporation
- FIRESENSE Fire Detection and Management through a **Multi-Sensor Network** for the Protection of Cultural Heritage Areas from the Risk of Fire and Extreme Weather Conditions
  Sponsor: European Commission FP7 Programme, ENV
- Network of Excellence in **Wireless Communications** (NEWCOM and NEWCOM++)
  Sponsor: European Commission FP7 Programme, ICT

Networks and Systems Research Group

Sample Publications

- Cem Mergenci, Ibrahim Korpeoglu, **Fly-path: Traffic-based Multi-hop Routing Approach for Hybrid Wireless Data Centers**, *Computer Communications*, vol. 170, March 2021
- Fatih Deniz, Hakki Bagci, Ibrahim Korpeoglu, Adnan Yazici, **Energy-Efficient and Fault-Tolerant Drone-BS Placement in Heterogeneous Wireless Sensor Networks**, *Wireless Networks*, Springer, November 2020.
- Cem Mergenci, Ibrahim Korpeoglu, **Generic Resource Allocation Metrics and Methods for Heterogeneous Cloud Infrastructures**, *Journal of Network and Computer Applications*, Volume 146, November, 2019.
- Firat Karatas, Ibrahim Korpeoglu, **Fog-Based Data Distribution Service (F-DAD) for Internet of Things (IoT) Applications**, *Future Generation Computer Systems*, Volume 93, pages 156-169, April 2019. Hidayet Aksu, Ibrahim Korpeoglu, Ozgur Ulusoy, **An Analysis of Social Networks based on Tera-scale Telecommunication Datasets**, *IEEE Transactions on Emerging Topics in Computing*, Volume 7, Issue 2, pages 349-360, April-June 2019.
- Metin Tekkalmaz, Ibrahim Korpeoglu, **Distributed Power-Source-Aware Routing in Wireless Sensor Networks**, *ACM-Springer Wireless Networks Journal*, 22(4), pages 1381-1399, May 2016.
- Hakki Bagci, Ibrahim Korpeoglu, Adnan Yazici, **A Distributed Fault-Tolerant Topology Control Algorithm for Heterogeneous Wireless Sensor Networks**, *IEEE Transactions on Parallel and Distributed Systems*, 26(4), April 2015.
- Hidayet Aksu, Mustafa Canim, Yuan-Chi Chang, Ibrahim Korpeoglu, Ozgur Ulusoy, **Distributed k-Core View Materialization and Maintenance for Large Dynamic Graphs**, *IEEE Transactions on Knowledge and Data Engineering*, 26(10), pages 2439-2452, 2014.

More information at the group website: http://www.cs.bilkent.edu.tr/~korpe/nsrg/

Özgür S. Öğüz

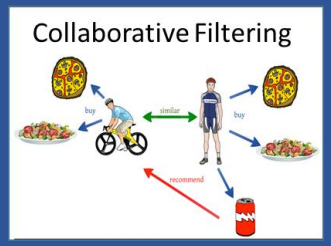
- Recently joined the CS department in January 2022.
- Office: EA529
- Phone: 2903398

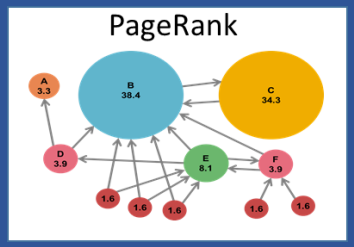
Mustafa Ozdal

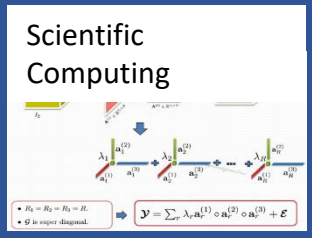
www.cs.bilkent.edu.tr/~mustafa.ozdal

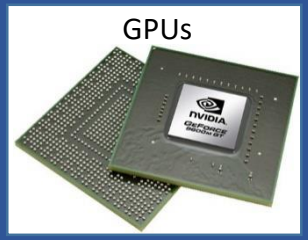
High-Performance and Energy Efficient Computing

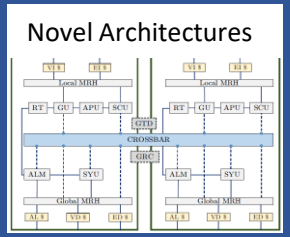
Algorithms, Systems, and Applications











Mustafa Ozdal

www.cs.bilkent.edu.tr/~mustafa.ozdal

Active projects:

- Energy efficient FPGA accelerators for big data applications *(supported by European Commission, in collaboration with Intel, Oregon)*
- Parallelizing Collaborative Filtering algorithms for recommender systems
- Parallel and vectorized scientific computing algorithms
- Optimizing memory architecture for graph analytics applications for large datasets.

I am interested in graduate student candidates who have one or more of the following:

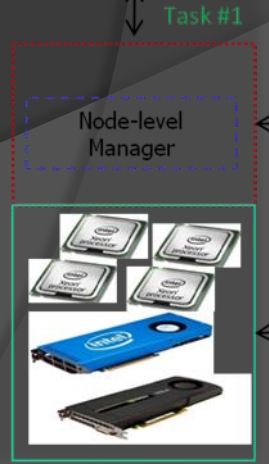
- Strong algorithmic background and analytical skills
- Interest in solving programming puzzles
- C++ programming skills
- Experience with multi-core, GPU, and/or FPGA programming

For more information, see www.bilkent.edu.tr/~mustafa.ozdal. You can send an email to mustafa.ozdal@cs.bilkent.edu.tr to set up an appointment.

Özcan Öztürk

Office: EA 421 Phone: 290-3444
Email: ozturk@cs.bilkent.edu.tr
URL: http://www.cs.bilkent.edu.tr/~ozturk

- **Computer architecture** - memory scheduling, memory hierarchy design, metrics to consider energy, performance, reliability....
- **Multicore/Manycore architecture** - design of multicore systems, application mapping, data mapping, communication
- **Heterogeneous computing** - heterogeneous multicore design, core and cache selection, application execution
- **Parallel programming/systems/applications** - OpenMP, MPI, GPGPU, application characterization, automatic parallelization, scheduling
- **Cloud computing** - at the system level and architectural optimizations, heterogeneity aware scheduling
- **Embedded computing** - energy, performance, ...
- **Compiler optimizations** - code modifications and optimizations to generate better applications



Current Projects

- Heterogeneous Multicore Design
  Funding: **EC FP7**
- Parallelization for Heterogeneous Multicore Architectures
  Funding: **IBM**
- Utilizing Accelerator Technologies in the Cloud
  Funding: **Türk Telekom**
- Parallelizing Data Mining applications using GPUs
  Funding: **Nvidia**
- **Accelerator Design for Graph Parallel Applications**
  Funding: **Intel**

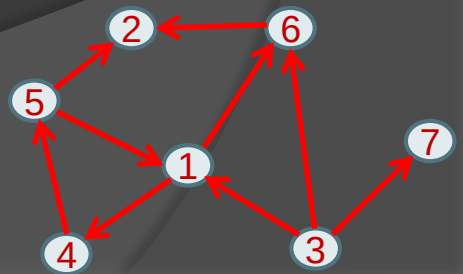
SEVENTH FRAMEWORK PROGRAMME

IBM

TÜRK TELEKOM

intel

NVIDIA CUDA RESEARCH CENTER



Eray Tüzün

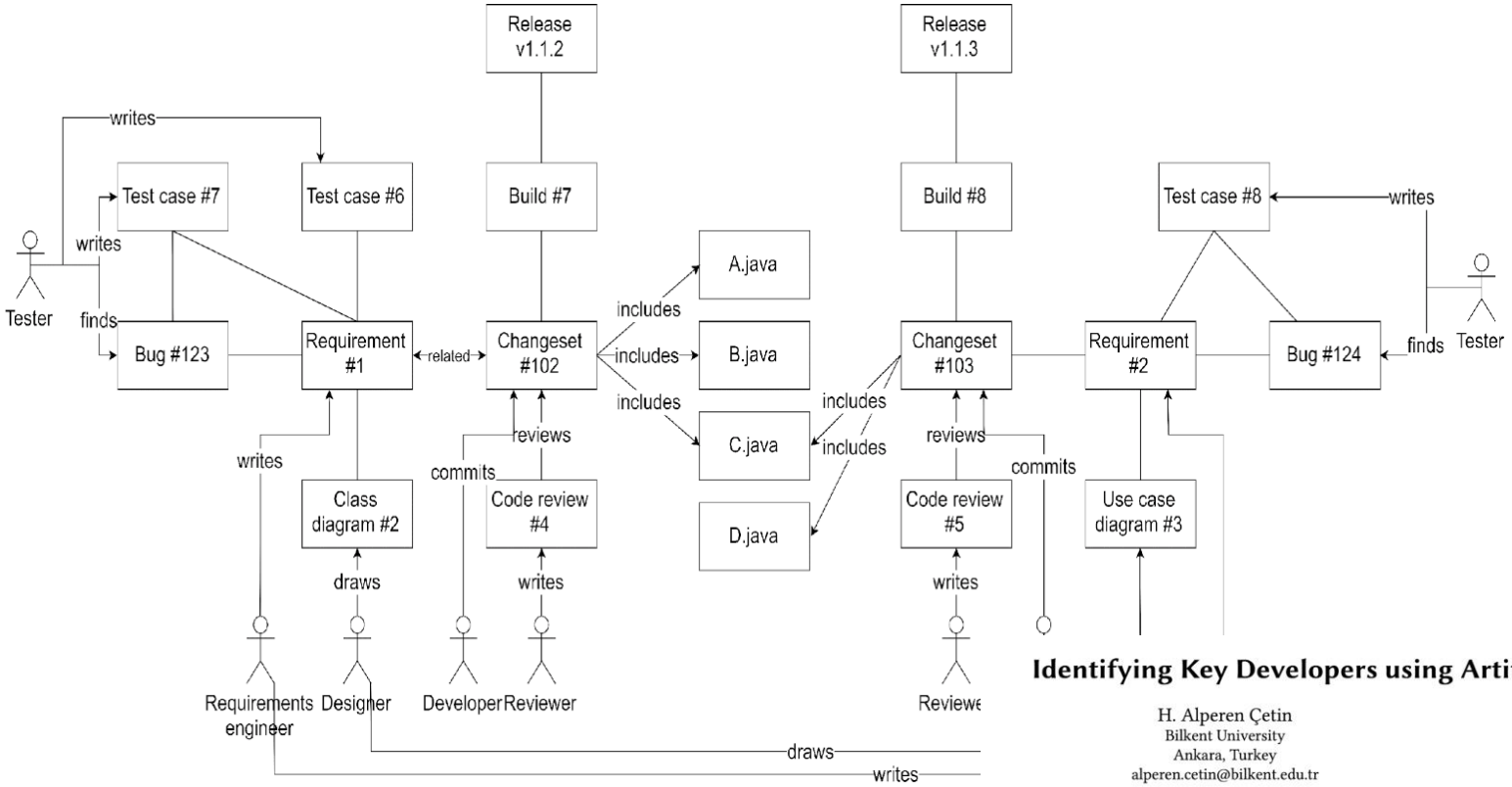
Bilkent University Software Engineering and Data Analytics Research Group
eraytuzun@cs.bilkent.edu.tr
http://www.cs.bilkent.edu.tr/~eraytuzun
Office: EA-501

Research Areas

- Software Analytics / Intelligence
- Machine Learning & Data Science for Software Engineering
- Software Product Line Engineering
- Gamification / Serious Games

Interested in being part of our research group? Please contact us at eraytuzun@cs.bilkent.edu.tr

Mining Software Engineering data



Analyzing Developer Contributions using Artifact Traceability Graphs

H.Alperen Cetin, Eray Tuzun

Bilkent University

Ankara, Turkey

Abstract

Software artifacts are the by-products of the development process. Throughout the life cycle of a project, developers produce different artifacts such as source files and bug reports. To analyze developer contributions, we construct artifact traceability graphs with these artifacts and their relations using the data from software development and collaboration tools.

Identifying Key Developers using Artifact Traceability Graphs

H. Alperen Çetin
Bilkent University
Ankara, Turkey
alperen.cetin@bilkent.edu.tr

Eray Tüzün
Bilkent University
Ankara, Turkey
eraytuzun@cs.bilkent.edu.tr

ABSTRACT

Developers are the most important resource to build and maintain software projects. Due to various reasons, some developers take more responsibility, and this type of developers are more valuable and indispensable for the project. Without them, the success of the project would be at risk. We use the term *key developers* for

1 INTRODUCTION

Software development mainly depends on human effort. In a project, some developers take more responsibility, and the success rate of the project heavily depends on these developers. Thus, they are valuable and essential to develop and maintain the project, in other words, they are the *key developers* of the project.

Information and Software Technology 130 (2021) 106455

Contents lists available at ScienceDirect

Information and Software Technology

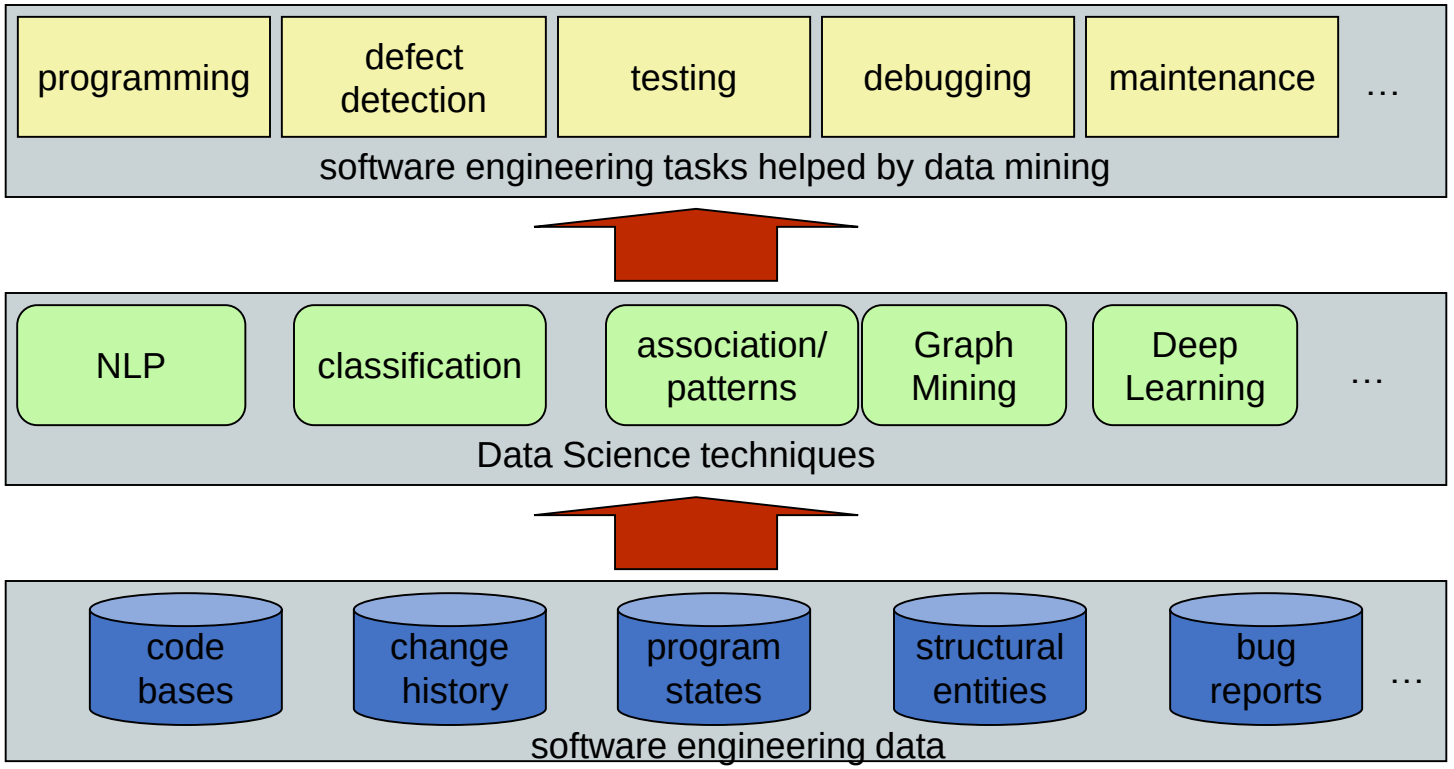
journal homepage: www.elsevier.com/locate/infsof

RSTrace+: Reviewer suggestion using software artifact traceability graphs

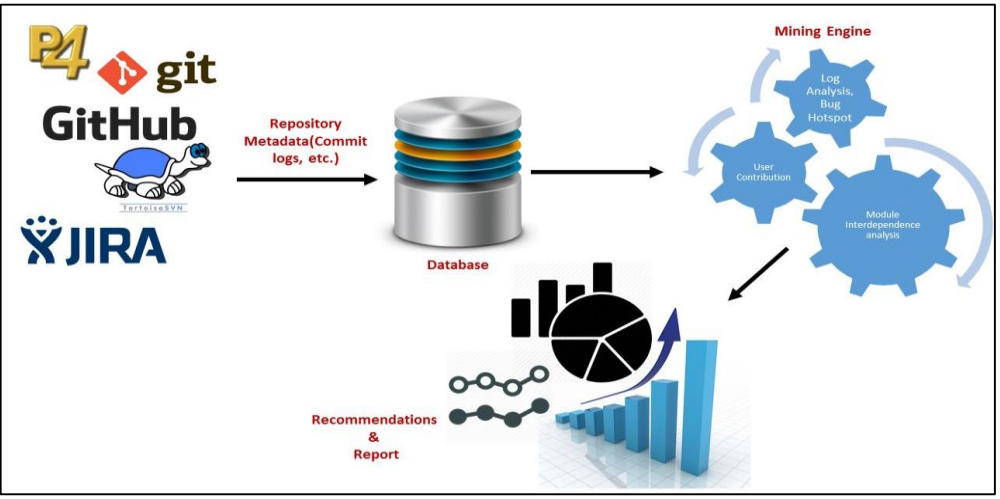
Emre Sülün *, Eray Tüzün, Uğur Doğrusöz

Department of Computer Engineering, Bilkent University, Ankara, Turkey

Overview of Data Science in SE



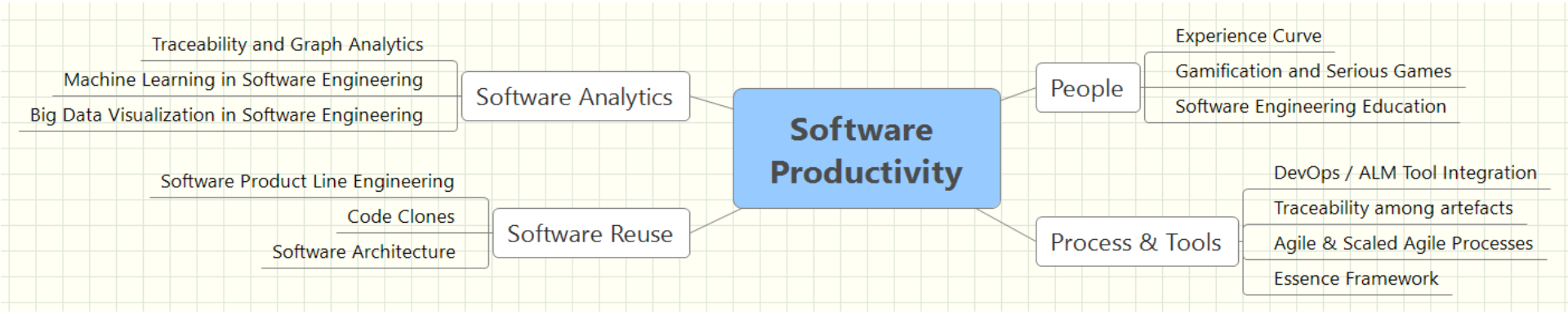
Software Analytics & Software Productivity



"*practice offering software practitioners (not just developer) up-to-date and pertinent information to support their daily decision-making processes and Software Intelligence should support decision-making processes throughout the lifetime of a software system*"

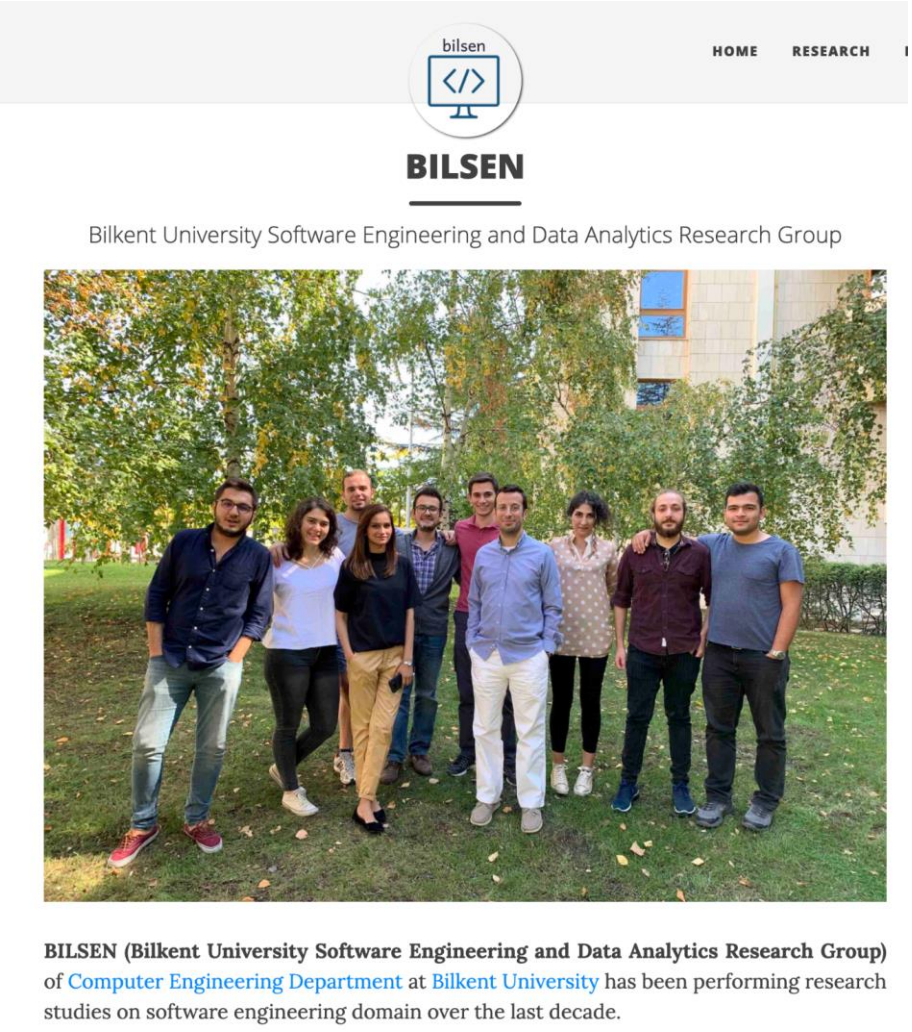
Ahmed E. Hassan and Tao Xie

Guess the location of undetected bugs
Who should fix this bug?
Who should review this pull request?
Which files are more likely to be buggy?
…



Recent Publications

- *Ground Truth Deficiencies in Software Engineering: When codifying the past is counterproductive. Eray Tüzün, Hakan Erdoğmuş, Maria Teresa Baldassare, Michael Felderer, Robert Feldt, Burak Turhan. IEEE Software, 2021*
- *What makes Agile Software Development Agile? HELENA Consortium. IEEE Transactions on Software Engineering, 2021*
- *RSTrace+: Reviewer Suggestion using Software Artifact Traceability Graphs. Emre Sülün, Uğur Doğrusöz, Eray Tüzün. Information and Software Technology, 2021*
- *Bus Factor In Practice. E Jabrayilzade, M Evtikhiev, E Tüzün, V Kovalenko, 44th International Conference on Software Engineering, 2022*
- *Bug Tracking Process Smells in Practice, Erdem Tuna, Vladimir Kovalenko, Eray Tüzün, 44th International Conference on Software Engineering, 2022*
- *Analyzing Developer Contributions using Artifact Traceability Graphs. Alperen Çetin, Eray Tüzün. Empirical Software Engineering, 2022*
- *Closing the gap between software engineering education and industrial needs, Vahid Garousi, Görkem Giray, Eray Tüzün, Cagatay Catal, Michael Felderer , IEEE Software, 2020*
- *Identifying Key Developers using Artifact Traceability Graphs. Alperen Cetin, Eray Tüzün. PROMISE, 2020*
- *Towards a taxonomy of code review smells, Emre Dogan, Eray Tüzün, Information Software and Technology, 2021*



Bilkent University Software Engineering and Data Analytics Research Group (BILSEN)

https://bilsengroup.github.io

Graduate Students

- Barış Ardıç, MSc
- Utku Ünal, MSc (METU)
- Shirin Pirouzkhah, MSc
- Khushbakht Ali, MSc
- Emre Sülün, MSc
- Elgun Jabrayilzade, MSc
- Erdem Tuna, MSc

Interested in being part of our research group? Please contact us at eraytuzun@cs.bilkent.edu.tr

@eraytuzun
http://twitter.com/eraytuzun

Data Science Research

Özgür Ulusoy

http://www.cs.bilkent.edu.tr/~oulusoy/

- Text-to-SQL Systems
- Web Search Engines
- Multimedia Database Systems
- Social Network Analysis
- Resourse Optimization in WSNs

Text-to-SQL Systems

- Keyword Mapping
- Explainable Text-to-SQL
- Query Recommendation

Text-to-SQL Systems

Keyword Mapping - mapping between tokens in the query and relational database elements

- **Keyword mapping formulated as sequence tagging problem in NLP**
- **An end-to-end keyword mapper (DBTagger)**

- A. Usta, A. Karakayalı, Ö. Ulusoy**, '***DBTagger: Multi-Task Learning for Keyword Mapping in NLIDBs Using Bi-Directional Recurrent Neural Networks'***, Very Large Databases (VLDB) Conference**, 2021**.**

Text-to-SQL Systems

Explainable Text-to-SQL - based on Explainable AI

- **Explaining the decisions made by the keyword mapping system using LIME**
- **A novel wrapper around LIME**
- **Using a schema graph to explain join-path inference**

- A. Usta, A. Karakayalı, Ö. Ulusoy, '*xDBTagger: explainable natural language interface to databases using keyword mappings and schema graph'*, **VLDB Journal**, 2024.

Text-to-SQL Systems

Query Recommendation

- A ranking method to create a list of suggested queries
- Distributed representations for database tuples, trained on a relational database
- Graph convolutional networks (GCNs) to learn distributed representations

Web Search Engines

- **Learning to Rank for Educational Web Search**
- **Diversification of Search Results**
- **Efficiency and Scalability Issues**

http://www.cs.bilkent.edu.tr/~bilweb

Web Search Engines

Learning to Rank for Educational Web Search - machine-learned ranking models

- **A rich set of features employed in educational search**
- **Domain knowledge utilized to build query-dependent ranking models**

- A. Usta, R. Ozcan, I. S. Altingovde, Ö. Ulusoy, '*Learning to Rank for Educational Search Engines'*, **IEEE Transactions on Learning Technologies**, 2021.

Web Search Engines

Diversification of Search Results

- **Multidimensional result diversification**
- **Supervised learning methods for search result diversification**
- **Impact of index pruning on diversification performance**

- S. Yigit-Sert, I.S. Altingovde, C. Macdonald, I. Ounis, Ö. Ulusoy, '*Explicit diversification of search results across multiple dimensions for educational search'*, **Journal of the Association for Information Science and Technology (JASIST)**, 2021.
- S. Yigit-Sert, I.S. Altingovde, C. Macdonald, I. Ounis, Ö. Ulusoy, '*Supervised approaches for explicit search result diversification*', **Information Processing & Management**, 2020.

Web Search Engines

Efficiency and Scalability Issues

- **Methods and algorithms for caching, indexing, and query processing in search engines**

- E. Sarıgil, I. S. Altingovde, R. Blanco, B. Cambazoglu, R. Ozcan, Ö. Ulusoy, '*Characterizing, predicting, and handling web search queries that match very few or no results*', **Journal of the Association for Information Science and Technology (JASIST)**, 2018.
- E. Sarıgil, O. Yılmaz, I. S. Altingovde, R. Ozcan, Ö. Ulusoy, '*A "Suggested" Picture of Web Search in Turkish*', **ACM Transactions on on Asian and Low-Resource Language Information Processing,** 2016.
- R. Ozcan, I. S. Altingovde, B. B. Cambazoglu, Ö. Ulusoy, '*Second Chance: A Hybrid Approach for Dynamic Result Caching and Prefetching in Search Engines*', **ACM Transactions on the Web**, 2014.

Multimedia Databases

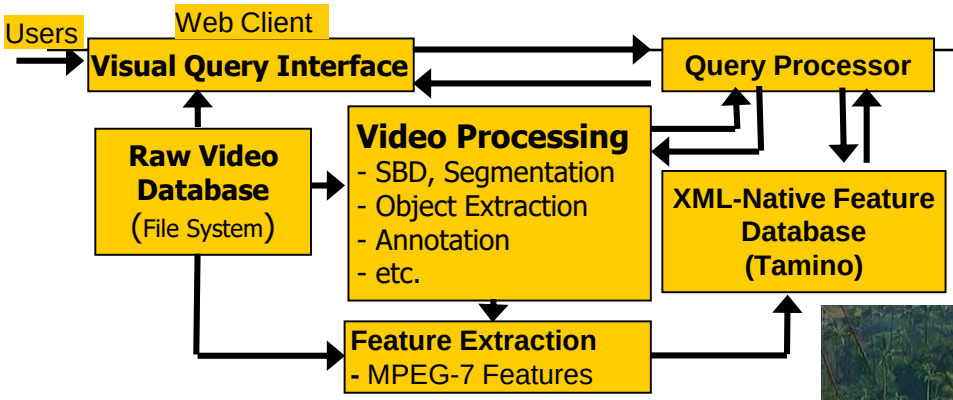
(joint work with Prof. Uğur Güdükbay)

- Video Retrieval Systems
- Mobile Visual Search
- Learning Visual Similarity for Image Retrieval

http://www.cs.bilkent.edu.tr/~bilmdg

Multimedia Databases

BilVideo-7: An MPEG-7 Compatible Video Retrieval System



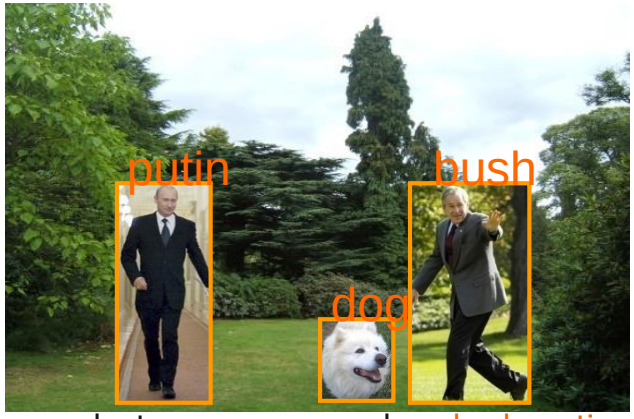
ISO/IEC JTC1/SC29 WG11 MPEG MOVING PICTURE EXPERTS GROUP

Automatic processing:
segmentation, tracking, feature extraction, annotation, indexing

segmentation

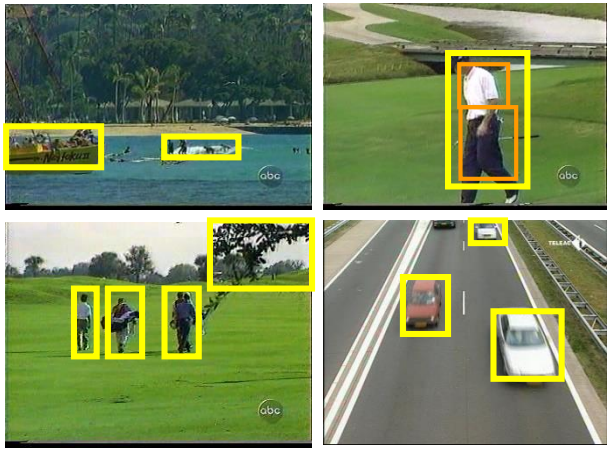
Powerful querying capability for video data

- keyword and content-based queries
- spatio-temporal object queries



Example query formulation

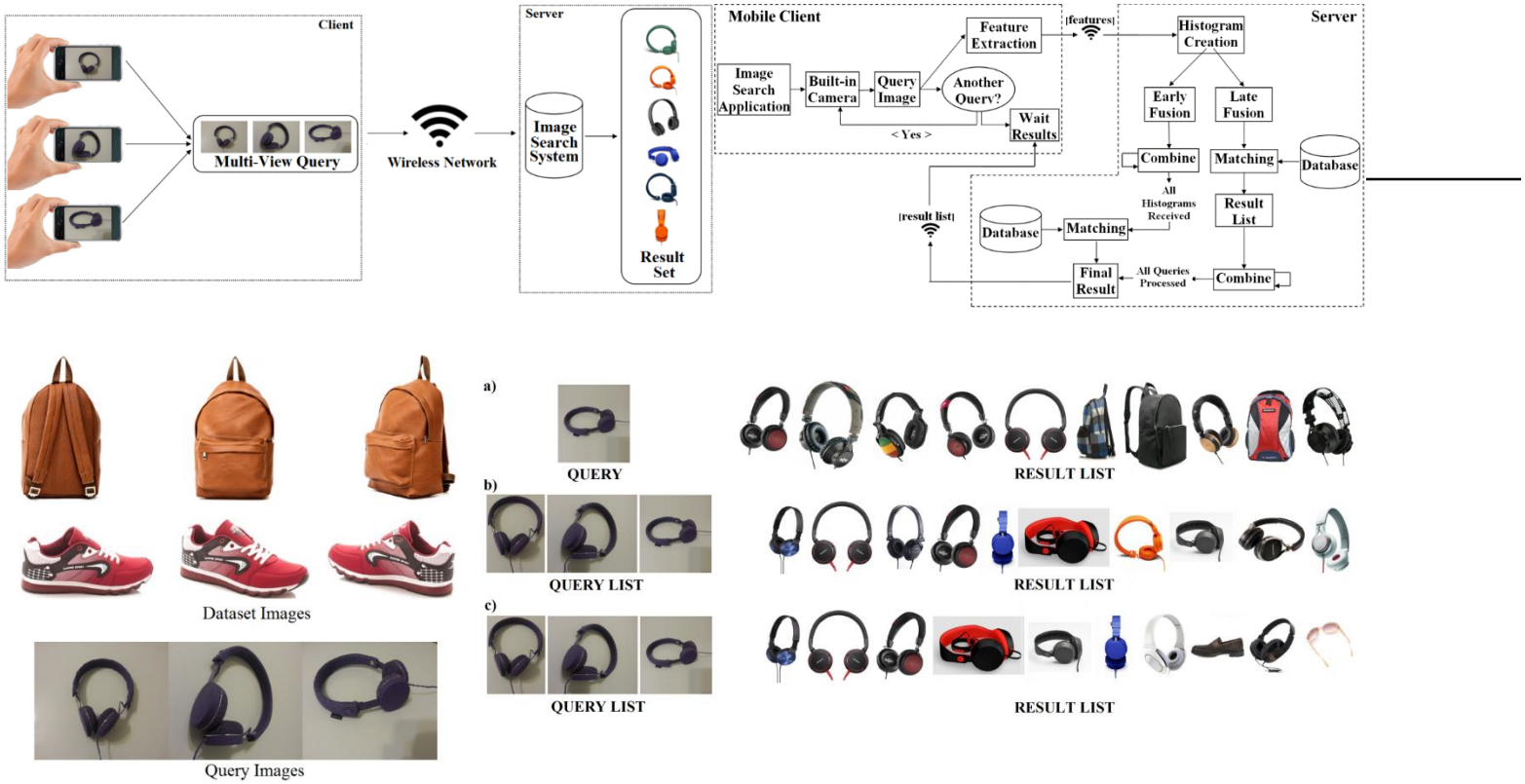
keywords: trees, greenery, sky – bush, putin, dog



Salient video object extraction

Multimedia Databases

Mobile Image Search Using Multi-View Object Image Queries

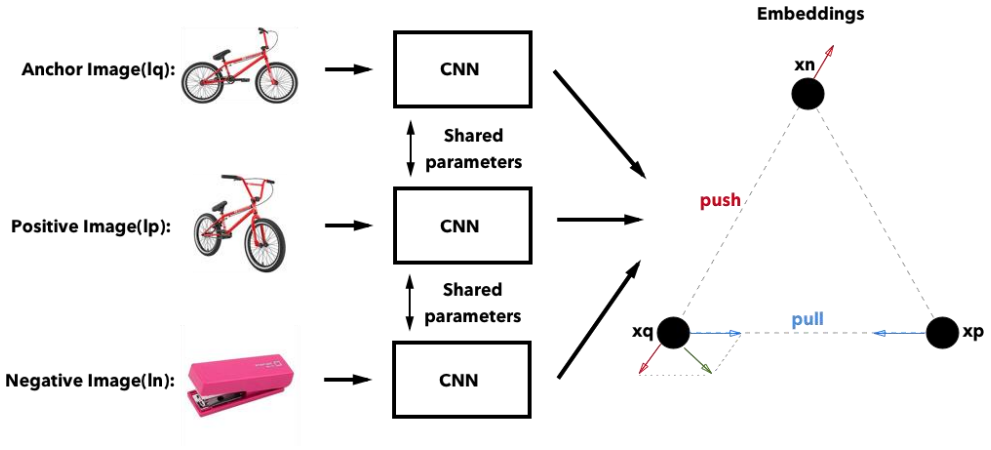


- F. Calısır, M. Bastan, Ö. Ulusoy, U. Güdükbay, '*Mobile Multi-View Object Image Search'*, **Multimedia Tools and Applications**, 2017.

Multimedia Databases

Learning Visual Similarity for Image Retrieval with CNNs

- **Learning efficient visual similarity for image retrieval by revealing resemblances and differences between product images**



Triplet loss

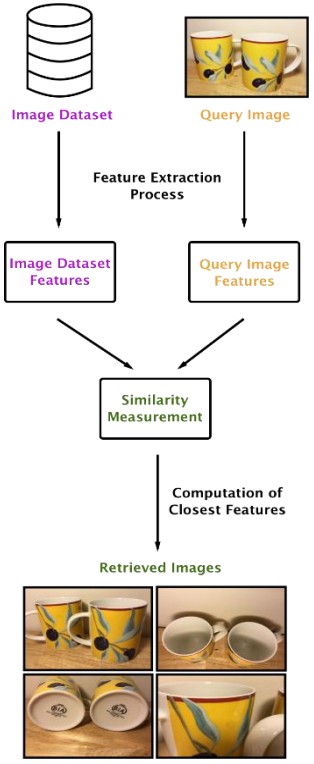


Image retrieval process

- D. Durmus, U. Güdükbay, Ö. Ulusoy, '*Learning visual similarity for image retrieval with global descriptors and capsule networks*', **Multimedia Tools and Applications**, 2024.

Social Network Analysis

- **Misinformation Propagation in Social Networks**
- **Social Network Data Analysis on Big Data Processing Platforms**

Social Network Analysis

Misinformation Propagation in Social Networks

- **Misinformation problem modelled as a game based on the notion of cooperative games**
- **Agents defined to maximize the total reward**
- **A blockchain - machine learning hybrid approach for addressing misinformation in a crowdsourced environment**

- T. Yilmaz, Ö. Ulusoy, '*Misinformation Propagation in Online Social Networks: Game Theoretic and Reinforcement Learning Approaches*', **IEEE Transactions on Computational Social Systems**, 2023.

Social Network Analysis

Social Network Data Analysis on Big Data Processing Platforms

(joint work with Prof. İbrahim Körpeoğlu)

- **Community detection formulated as a multi-k-core problem**
- **Distributed multi-k-core construction and maintenance algorithms running on a big data platform**

- H. Aksu, I. Körpeoğlu, Ö. Ulusoy, '*An Analysis of Social Networks based on Tera-scale Telecommunication Datasets*', **IEEE Transactions on Emerging Topics in Computing**, 2019.
- H. Aksu, M. Canim, Y. C. Chang, I. Körpeoğlu, Ö. Ulusoy, '*Distributed k-Core View Materialization and Maintenance for Large Dynamic Graphs*', **IEEE Transactions on Knowledge and Data Engineering**, 2014.

Resourse Optimization in Wireless Sensor Networks

(joint work with Prof. İbrahim Körpeoğlu)

- **Application placement with shared monitoring points in WSNs**
- **Application scheduling with multiplexed sensing of monitoring points in WSNs**

- M. C. Cavdar, I. Körpeoğlu, Ö. Ulusoy, '*Application Scheduling with Multiplexed Sensing of Monitoring Points in Multi-purpose IoT Wireless Sensor Networks*', **IEEE Transactions on Network and Service Management**, 2024.
- M. C. Cavdar, I. Körpeoğlu, Ö. Ulusoy, '*Application placement with shared monitoring points in multi-purpose IoT wireless sensor networks*', **Computer Networks**, 2022.