# Fall Workshop on Algorithms and Computation (FWAC 2016)

**연세대학교 상남경영원 I 2016.11.11-12 I 기하학연구센터(GAIA), 한국정보과학회 컴퓨터이론 연구회**

### Invited Talk 1 - Shortest paths in weighted subdivisions

Antoine Vigneron (UNIST)

The Weighted Regions problem is a geometric version of the shortest path problem in weighted graphs. Given a polygonal (or polyhedral) subdivision such that each face is associated with a positive weight, the goal is to find an optimal path between two points, where the cost of the path within each face is the length of the path within this face multiplied by its weight.
We will review the main approaches for the 2-dimensional case: The continuous Dijkstra method, and discretization methods. Then we will present our recent work on the 3-dimensional case.

### Invited Talk 2 - LP-based algorithms for capacitated facility location

Hyung-Chan An (Yonsei University)

Linear programming has played a key role in the study of algorithms for combinatorial optimization problems. In the field of approximation algorithms, this is well illustrated by the uncapacitated facility location problem. A variety of algorithmic methodologies, such as LP-rounding and primal-dual method, have been applied to and evolved from algorithms for this problem. Unfortunately, this collection of powerful algorithmic techniques had not yet been applicable to the more general capacitated facility location problem. In fact, all of the known algorithms with good performance guarantees were based on a single technique, local search, and no linear programming relaxation was known to efficiently approximate the problem.
In this paper, we present a linear programming relaxation with constant integrality gap for capacitated facility location. We demonstrate that the fundamental theories of multi-commodity flows and matchings provide key insights that lead to the strong relaxation. Our algorithmic proof of integrality gap is obtained by finally accessing the rich toolbox of LP-based methodologies: we present a constant factor approximation algorithm based on LP-rounding.
(Joint work with Mohit Singh and Ola Svensson.)

### Invited Talk 3 - Theoretical Computer Science for Numerics

Martin Ziegler (KAIST)

Theoretical Computer Science provides the sound foundation and concepts underlying contemporary algorithm design and reliable software development -- for discrete problems: Problems in the continuous realm commonly considered in Numerical Engineering are largely treated by 'recipes' and 'methods' whose correctness and efficiency often rely on thin empirical evidence.
We extend and apply the rigorous theory of computation (specification, semantics, algorithm design, analysis, and proof of optimality) over discrete structures to continuous domains. For instance it turns out that famous complexity classes like P, NP, #P, and PSPACE naturally re-emerge in the setting of real numbers, sequences, continuous functions, operators, and Euclidean subsets -- including a reformulation of the Millennium Prize Problem as a numerical one. Our current work develops a computability and complexity classification for ordinary and partial differential equations, the latter having weak solutions naturally 'living' in Sobolev space.

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SPECIAL INTEREST GROUP ON THEORETICAL COMPUTER SCIENCE

**Invited Talk 4 - Visual object recognition and learning with minimal supervision**
Minsu Cho (POSTECH)

Object recognition is one of major problems in computer vision, that is highly challenging due to intra-class variations, background clutter, and occlusions present in real-world images and videos. While significant progress has been made in this area over the last decade, most state-of-the-art methods still rely on strong supervision, e.g., in the form of manually-annotated bounding boxes on target instances. Since such detailed annotations are expensive to acquire and also prone to unwanted biases and errors, avoiding strong supervision is a crucial issue for fully automatic learning machines. In this talk, I will briefly introduce current attempts to reduce the degree of supervision in object recognition, i.e., weakly-supervised or unsupervised object detection, describe their underlying assumptions, and discuss major issues in the state of the art. I will also introduce my recent approaches to this problem, and show how object matching, localization, and learning can be related each other.

# Contributed Talks.

(1) The farthest-point geodesic Voronoi diagram of points on the boundary of a simple polygon - Eunjin Oh (POSTECH)

Given a set of sites (points) in a simple polygon, the farthest-point geodesic Voronoi diagram partitions the polygon into cells, at most one cell per site, such that every point in a cell has the same farthest site with respect to the geodesic metric. We present an O(*(n+m)loglog n)*-time algorithm to compute the farthest-point geodesic Voronoi diagram for m sites lying on the boundary of a simple *n*-gon.

(2) Obstructing Visibilities with One Obstacle - Jiwon Park (KAIST)

Obstacle representations of graphs have been investigated quite intensely over the last few years. We focus on graphs that can be represented by a single obstacle. Given a (topologically open) non-self-intersecting polygon $C$ and a finite set $P$ of points in general position in the complement of $C$, the *visibility graph* $G_C(P)$ has a vertex for each point in $P$ and an edge $pq$ for any two points $p$ and $q$ in $P$ that can *see* each other. We draw $G_C(P)$ straight-line and call this a *visibility drawing*. Given a graph $G$, we want to compute an obstacle representation of $G$, that is, an obstacle $C$ and a set of points $P$ such that $G = G_C(P)$. The complexity of this problem is open, even when the points are exactly the vertices of a simple polygon and the obstacle is the complement of the polygon---the *simple-polygon visibility graph problem*.

There are two types of obstacles; *outside* obstacles lie in the unbounded component of the visibility drawing, whereas *inside* obstacles lie in the complement of the unbounded component. We show that the class of graphs with an inside-obstacle representation is incomparable with the class of graphs that have an outside-obstacle representation. We further show that any graph with at most seven vertices has an outside-obstacle representation, which does not hold for a specific graph with eight vertices. Finally, we show NP-hardness of the *outside-obstacle graph sandwich problem*: given graphs $G$ and $H$ on the same vertex set, is there a graph $K$ such that $G \subseteq K \subseteq H$ and $K$ has an outside-obstacle representation. Our proof also shows that the *simple-polygon visibility graph sandwich problem*, the *inside-obstacle graph sandwich problem*, and the *single-obstacle graph sandwich problem* are all NP-hard.

(3) Invitation to Fixed-Parameter Algorithms - Jisu Jeong (KAIST)

Fixed-Parameter Algorithm is an algorithm that can solve a given problem in time $f(k)n^c$ where $f$ is a function, $k$ is a parameter, $c$ is a constant, and $n$ is the size of the input. Here is an example. VERTEX COVER problem asks the minimum size of a vertex cover of an input graph. $k$-VERTEX COVER problem is a decision problem that asks whether an input graph has a vertex cover of size $k$. There exists an Fixed-Parameter Algorithm that can solve $k$-VERTEX COVER problem in time $O(kn)$. In this talk, I will give some examples and introduce our results. This is a joint work with Jan Arne Telle, Sigve Hortemo Sæther, Eunjung Kim, Sang-il Oum.

(4) Bundling Two Simple Polygons to Minimize Their Convex Hull - Jongmin Choi (POSTECH)

Given two simple polygons $P$ and $Q$ in the plane, we study the problem of finding a placement $\phi P$ of $P$ such that $\phi P$ and $Q$ are disjoint in their interiors and the convex hull of their union is minimized. We present exact algorithms for this problem that use much less space than the complexity of the Minkowski sum of $P$ and $Q$. When the orientation of $P$ is fixed, we find an optimal translation of $P$ in $O(n^2m^2 \log n)$ time using $O(nm)$ space, where $n$ and $m$ ($n \geq m$) denote the number of edges of $P$ and $Q$, respectively. When we allow reorienting $P$, we find an optimal rigid motion of $P$ in $O(n^3m^3 \log n)$ time using $O(nm)$ space. In both cases,

we find an optimal placement of $P$ using linear space at the expense of slightly increased running time. For two polyhedra in three dimensional space, we find an optimal translation in $O(n^3m^3 \log n)$ time using $O(nm)$ space or in $O(n^3m^3(m + \log n))$ time using linear space.

(5) The Number of Holes in the Union of Translates of a Convex Set in Three Dimensions - Otfried Cheong (KAIST)

(Joint work with Boris Aronov, Michael Gene Dobbins, Xavier Goaoc.)

We show that the union of n translates of a convex body in $\mathbb{R}^3$ can have $\Theta(n^3)$ holes in the worst case, where a hole in a set X is a connected component of $\mathbb{R}^3 \setminus X$. This refutes a 20-year-old conjecture. As a consequence, we also obtain improved lower bounds on the complexity of motion planning problems and of Voronoi diagrams with convex distance functions.

(6) Implementation and Empirical Evaluation of two Algorithms for Computing Characteristic Polynomials' Coefficients in Exact Real Arithmetic - Sewon Park (KAIST)

We consider the computational problem of calculating the characteristic polynomial's coefficients of a given matrix in exact real arithmetic. We adopt the setting of Recursive Analysis with undecidable tests for equality; hence calculating a Frobenius normal form is infeasible. Instead, recall two exact methods over continuous data types: R.R. Silva (1998)'s method of linear recurrence of traces of matrix powers and a polynomial interpolation method equipped with a Gaussian elimination. In order to seek their bit-complexities, we implement and evaluate both methods under various conditions on iRRAM: a framework for a computation over continuous data types on the object-oriented programming language C++.

(7) Implementation of Robot Journalism Framework based on Combinatory Categorical Grammar - Seungwoo Shin (KAIST)

Recently, robot journalism have been a big issue in natural language processing. However, most of the robot journalism frameworks applied the static template method, which lacks variety of the text. In order to enhance diversity of generated text, this paper applies various natural language generation methods. As a result, this paper proposes framework for generating article that explains a baseball game. Overall process of framework suggested in this paper is as following. First, analyze game record to extract events in the match, and apply support vector machine to select events that should be included in the article. Second, generate paragraph structures based on the static template. Third, generate sentence using combinatory categorical grammar(CCG) based on modal logic. The resulting articles are evaluated by professional baseball journalists.

(8) Pseudoknot-Generating Operation - Da-Jung Cho (Yonsei University)

A pseudoknot is a crucial intra-molecular structure formed primarily in RNA strands and closely related to important biological processes. This motivates us to define an operation that generates all pseudoknots from a given sequence and consider algorithmic and language theoretic properties of the operation. We design an efficient algorithm that decides whether or not a given string is a pseudoknot of a regular language $L$. Our algorithm runs in linear time if $L$ is given by a deterministic finite automaton. We study closure and decision properties of the pseudoknot-generating operation. For DNA encoding applications, pseudoknot structures are undesirable. We give polynomial-time algorithms that check whether or not a regular language $L$ contains a pseudoknot or a pseudoknot generated by some string of $L$. Furthermore, we show that the corresponding questions for context-free languages are undecidable.

(9) Nondeterministic seedless oritatami systems and hardness of testing their equivalence - Hwee Kim (Yonsei University)

The oritatami system (OS) is a model of computation by cotranscriptional folding, being inspired by the recent experimental success of RNA origami to self-assemble an RNA tile cotranscriptionally. The OSs implemented so far, including binary counter and Turing machine simulator, are deterministic, that is, uniquely fold into one conformation, while nondeterminism is intrinsic in biomolecular folding. We introduce nondeterminism to OS (NOS) and propose an NOS that chooses an assignment of Boolean values nondeterministically and evaluates a logical formula on the assignment. This NOS is seedless in the sense that it does not require any initial conformation to begin with like the RNA origami. The NOS allows to prove the co-NP hardness of deciding, given two NOSs, if there exists no conformation that one of them folds into but the other does not.

| Friday, November 11 - FWAC 2016 | |
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| Session 1 - Chair: Heejin Park | |
| 14:00 - 15:00 | **Invited Talk 1: Shortest paths in weighted subdivisions**<br>Antoine Vigneron |
| 15:00 - 15:20 | **The farthest-point geodesic Voronoi diagram of points on the boundary of a simple polygon**<br>Eunjin Oh |
| 15:20 - 15:40 | **Obstructing Visibilities with One Obstacle**<br>Jiwon Park |
| 15:40 - 16:00 | Coffee Break |
| Session 2 - Chair: Sang Won Bae | |
| 16:00 - 17:00 | **Invited Talk 2: LP-based algorithms for capacitated facility location**<br>Hyung-Chan An |
| 17:00 - 17:20 | **Invitation to Fixed-Parameter Algorithms**<br>Jisu Jeong |
| 17:20 - 17:40 | **Bundling Two Simple Polygons to Minimize Their Convex Hull**<br>Jongmin Choi |
| 17:40 - 18:00 | **The Number of Holes in the Union of Translates of a Convex Set in Three Dimensions**<br>Otfried Cheong |
| 18:30 - 20:00 | Dinner |
| **Saturday, November 12 - FWAC 2016** | |
| Session 3 - Chair: Yo-Sub Han | |
| 09:00 - 10:00 | **Invited Talk 3: Theoretical Computer Science for Numerics**<br>Martin Ziegler |
| 10:00 - 10:20 | **Implementation and Empirical Evaluation of two Algorithms for Computing Characteristic Polynomials' Coefficients in Exact Real Arithmetic**<br>Sewon Park |
| 10:20 - 10:40 | **Implementation of Robot Journalism Framework based on Combinatory Categorical Grammar**<br>Seungwoo Shin |
| 10:40 - 11:00 | Coffee Break |
| Session 4 - Chair: Hee-Kap Ahn | |
| 11:00 - 12:00 | **Invited Talk 4: Visual object recognition and learning with minimal supervision**<br>Minsu Cho |
| 12:00 - 12:20 | **Pseudoknot-Generating Operation**<br>Da-Jung Cho |
| 12:20 - 12:40 | **Nondeterministic seedless oritatami systems and hardness of testing their equivalence**<br>Hwee Kim |