Fall Workshop on Algorithm and Computation

(FWAC 2018)

서울대학교 제 1 공학관(301 동) 105 호 | 2018.11.09-10 | 한국정보과학회 컴퓨터이론 연구회

Invited Talk

Variations of the Convex Kakeya Problem - Otfried Cheong (SCALGO & KAIST)

In 1917, Soichi Kakeya asked what is the smallest-area region Q in the plane in which a needle of length one can be turned continuously through 360 degrees. We are interested in the convex case, which turns out to be equivalent to the question: What is the smallest convex region Q that contains a segment of length one of every possible orientation? Such a set Q is called a translation cover (for the family of line segments of length one of every possible orientation). We show that this relationship between Kakeya's question and translation covers also holds for other shapes P to be turned. It is not known what the optimal region is for most P, but we can show that the inverse question, namely what is the largest-area P that can be turned through 360 degrees inside a given convex shape Q has a simple answer. Instead of translation covers, one can also study universal covers Q, where the given shapes are allowed to be place by any congruence. Many universal cover problems are still open - we look at a few cases on sets of triangles where we know the exact optimal answer.

Contributed Talks

Space complexity of PDEs - Svetlana Selivanova (KAIST)

We study algorithmic cost of solving (systems of) partial differential equations (PDEs), focusing on space (=``memory'') complexity, which is known to coincide with parallel time complexity. Considering systems of the form $\frac{\partial}{\partial t}\vec{u} = A\vec{u}$ with certain restrictions on the operator A, we show that the abstract Cauchy problem for such a system, with an initial condition $u(0) = \varphi$ can be solved approximately up to absolute error 2^{-n} within space $O(\log^2 n)$. In particular, it applies to linear linear ODEs as well as certain types of PDEs: linear Cauchy-Kovalevskaya type systems, with analytic initial data φ. A key ingredient of the proof is that the solutions to the considered Cauchy problems can be explicitly expressed as a convergent ``Taylor series'' of the corresponding linear operator. For correctly posed boundary-value problems with constant coefficients we prove ₩underline{polynomial space} complexity upper bounds for a broad class of systems (including symmetric hyperbolic systems $\vec{u}_t + \sum_{j=1}^{m} B_j \vec{u}_{x_j} = 0$, $B_j = B_j^*$, wave equation, heat equation etc.), with initial data φ in classes of continuously differentiable functions with polynomial-space computable second partial derivatives (including analytic functions). For boundary-value problems we use the difference schemes approach

Approximating a Planar Convex Set using a Sparse Grid - Antoine Vigneron (UNIST)

We show how to construct a set S of $O(1/e^{1.5})$ points such that for any convex set C contained in the unit square, the convex hull of the points in S that are contained in C has area at least $|C| - e$. We present two algorithmic applications, for geometric shape matching and area approximation

Quantitatively Admissible Representations and the “Main Theorem” of Type-2 Complexity Theory - Donghyun Lim(KAIST)

Choosing an encoding over binary strings is usually straightforward or inessential for computations over countable universes (like of graphs) but crucially affects already the mere computability of problems involving continuous data (like real numbers), and even more their complexity. We introduce, justify, and investigate ‘linear admissibility’ as condition for complexity-theoretically reasonable encodings of arbitrary compact metric spaces, quantitatively strengthening qualitative ‘admissibility’ due to Kreitz and Weihrauch (1985):

The Main Theorem of Computable Analysis asserts that a real function f is continuous iff there exists a continuous mapping on the Cantor space of infinite binary sequences translating codes (such as the signed-digit expansion) of real arguments x to codes of real values $f(x)$. Generalizing this characterization to functions $f: X \rightarrow Y$ between arbitrary topological T0 spaces X and Y , [KW85] had identified the technical condition of admissibility as essential for any computably ‘reasonable’ encoding (called representation in Type-2 Computability Theory) of X’s elements as infinite binary strings.

We generalize the signed-digit representation of the real unit interval, having a modulus of continuity linear in the entropy, to arbitrary compact metric spaces X. We establish this representation to satisfy a carefully crafted quantitative refinement of the aforementioned qualitative admissibility: (i) its modulus of continuity is optimal, i.e., linear in the metric entropy; and (ii) it is maximal with respect to reductions that are metrically optimal in the same sense. The category of such representations is shown closed under countable Cartesian products generalizing the Hilbert Cube. And we deduce a tight quantitative correspondence between the modulus of continuity of functions f among compact metric spaces on the one hand and on the other hand those of code-translating mappings (known as realizers) on Cantor space.

Relative Edit-Distance Problem of Input-Driven Languages - Hyunjoon Cheon (Yonsei University)

We study the relative edit-distance problem between input-driven languages. The class of input-driven languages is known as a robust subclass of context-free languages thanks to nice closure properties and decidable problems. For instance, the language inclusion (or equivalence) problem, which is crucial in many applications such as formal verification, is undecidable for context-free languages but, is EXPTIME-complete for input-driven languages. We prove that many results for the inclusion problem of pushdown automata (PDAs) carries over to input-driven pushdown automata (IDPDAs). The main contribution of the paper is to show that the input-driven languages are closed under the edit-distance neighbourhood and the IDPDAs for the neighbourhood can be constructed in time polynomial in the size of input IDPDAs with the fixed radius r. As a consequence, we also prove that the relative edit-distance problem for input-driven languages is decidable and in fact, EXPTIME-complete when the threshold is fixed.

Interval Gaussian Algorithm for Singular Interval Matrices - Sewon Park (KAIST)

Interval Gaussian Algorithm can fail even when all matrices in an interval matrix are regular; i.e., the interval determinant obtained by the Algorithm strictly contains the set of determinant of the input matrix and may even contain zero. It is a long time studied topic in Interval Computation when does the Interval Gaussian Algorithm succeeds.

The work considers a situation where an interval matrix contains a singular matrix with its rank known and aims to compute a set of interval vectors that contans kernel basis. Using Interval Gaussian Algorithm with full pivot searching, the work analyzeis (i) the overestimation (ii) condition of success, and (iii) its bit complexity using the minimum nonzero eigenvalue magnitude as the measure of singularity.

Stacking Terrains in Two and Three Dimensions - Seungjoon Lee (POSTECH)

We considered the problem of stacking two objects in two and three dimensions. The objects are given as terrains which represent the contacting surfaces between the two objects. We propose two criteria for an optimal stacking when only translation of a single terrain is allowed. We then present the algorithms to find the optimal stacking of the two criteria in two and three dimensions.

Space Complexity of Directed Reachability - Ivan Adrian Koswara (KAIST)

In the problem graph reachability, we are given a graph with two marked vertices s, t and we are asked if there is a path from s to t. The space complexity of this problem attracts interest. For undirected graphs, this has been solved, shown to be in $\boldsymbol{L}$ (can be solved deterministically in logarithmic space) by Reingold (2005); however, for the directed case, this is still open. The problem is complete for the class $\boldsymbol{NL}$ (nondeterministic logspace). Savitch's algorithm is a deterministic algorithm to solve this problem, but with space $O(\log^2 n)$. Recently, two new ideas have developed for complexity theory: unambiguous algorithm, a nondeterministic algorithm such that whenever it accepts an input, it only has one accepting path; and non-uniform computation, where we are given an advice from an oracle, where the advice may depend on the length of the input. $\boldsymbol{UL}$ is the class for unambiguous logspace, the variant of $\boldsymbol{NL}$ with unambiguous computation; it's easy to see that $\boldsymbol{L} \subseteq \boldsymbol{UL} \subseteq \boldsymbol{NL}$. Also, $\boldsymbol{UL}$ /poly is $\boldsymbol{UL}$ but with non-uniform computation where the advice has polynomial size. Reinhardt and Allender proved in 2000 that directed reachability is in $\boldsymbol{UL}$ /poly, and in fact $\boldsymbol{UL}$ / n^5, thus giving some advice $O(n^5)$ bits in length) in order to make accepting paths unique. Our goal is to find some tradeoff between Savitch's result and Reinhardt-Allender's result: to find unambiguous $o(\log^2 n)$ algorithm (improving Savitch) for the problem with advice $o(n^5)$ (improving Reinhardt-Allender).

Incremental Computation of Infix Probabilities for Probabilistic Finite Automata - Marco Cognetta (Yonsei University)

In natural language processing, a common task is to compute the probability of a given phrase appearing or to calculate the probability of all phrases matching a given pattern. For instance, one computes affix (prefix, suffix, infix, etc.) probabilities of a string or a set of strings with respect to a probability distribution of patterns.

The problem of computing infix probabilities of strings when the pattern distribution is given by a probabilistic context-free grammar or by a probabilistic finite automaton is already solved, yet it was open to compute the infix probabilities in an incremental manner. The incremental computation is crucial when a new query is built from a previous query. We tackle this problem and suggest a method that computes infix probabilities incrementally for probabilistic finite automata by representing all the probabilities of matching strings as a series of transition matrix calculations. We show that the proposed approach is theoretically faster than the previous method and, using real world data, demonstrate that our approach has vastly better performance in practice.

Random Functions in exact real computation - Hyunwoo Lee (KAIST)

We contribute to the algorithmic foundation of numerics. A real number, as a fast converging Cauchy sequence, can be randomly generated when an infinite sequence of random bits is provided. Such a random real number generator can be and is implemented in iRRAM, a C++ library for Exact Real Computation where a real number is offered as an abstract datatype **REAL**. The work aims to extend the random real numbers to randomly distributed real functions in C[0,1]. As an example, the work considers the sample paths of Wiener process.

Improved Pattern-Scan-Order Algorithms for String Matching - Cheol Ryu (Seoul National University)

The pattern scan order is a major factor affecting the performance of string matching algorithms. Depending on the pattern scan order, one can reduce the number of comparisons in a window or increase the shift length. Classical algorithms for string matching determine the pattern scan order only using the characteristics of a text and a pattern. However, if we additionally use the scan results at the time we determine each scan position of the pattern, we can improve the performance of string matching. In this paper we propose new pattern-scan-order algorithms that maximize shift lengths using scan results. We present the theoretical analysis and experimental results that these algorithms run faster than previous algorithms on average.

Computability of Haar Averages - Dongseong Seon (KAIST)

This work is in the extension of real computation. It generalizes the problem of computing integrals of functions on the real interval. Haar's theorem states that for compact topological groups, there uniquely exists an invariant integral. Based on this theorem, the work extends the domain of integrand from reals to continuous spaces. This presentation gives an algorithm that solves this problem with natural assumptions and an attempt to analyze the complexity of this problem.

Interval Piercing and Disjoint Union of Cliques - Jongmin Choi (POSTECH)

We consider the disjoint union of cliques problem and its variants. In the disjoint union of cliques problem (shortly, DUC), we are given a graph $G = (V, E)$ and an integer k, and we are to find a set C of k disjoint cliques of G such that $\sum_{c \in C} |c|$ is maximized. A set of cliques are called disjoint if a node of G belongs to at most one of the cliques. Jansen proposed algorithms that take for interval graphs $O(k|V|^2)$ time. In this paper, we present algorithms that improve the results by Jansen. Our algorithms take for interval graphs $O(k|V| \log|V| + |E|)$ time.

Friday, November 09 - FWAC 2018	
Session 1 - Chair:	
14:00 - 15:00	**Invited Talk: Variations of the Convex Kakeya Problem** Otfried Cheong
15:00 - 15:20	**Space complexity of PDEs** Svetlana Selivanova
15:20 - 15:40	**Approximating a Planar Convex Set using a Sparse Grid** Antoine Vigneron
15:40 - 16:00	Coffee Break
Session 2 - Chair:	
16:00 - 16:20	**Quantitatively Admissible Representations and the "Main Theorem" of Type-2 Complexity Theory** Donghyun Lim
16:20 - 16:40	**Relative Edit-Distance Problem of Input-Driven Languages** Hyunjoon Cheon
16:40 - 17:00	**Interval Gaussian Algorithm for Singular Interval Matrices** Sewon Park
17:00 - 17:20	**Stacking Terrains in Two and Three Dimensions** Seungjoon Lee
17:20 - 18:00	Poster Session
18:00 - 20:00	Dinner
Saturday, November 10 - FWAC 2018	
Session 3 - Chair:	
09:00 - 09:20	**Space Complexity of Directed Reachability** Ivan Adrian Koswara
09:20 - 09:40	**Incremental Computation of Infix Probabilities for Probabilistic Finite Automata** Marco Cognetta
09:40 - 10:00	**Random Functions in exact real computation** Hyunwoo Lee
10:00 - 10:20	**Improved Pattern-Scan-Order Algorithms for String Matching** Cheol Ryu
10:20 - 10:40	**Computability of Haar Averages** Dongseong Seon
10:40 - 11:00	**Interval Piercing and Disjoint Union of Cliques** Jongmin Choi
11:00 - 11:20	Coffee Break
11:20 - 12:00	Poster Session