Parameterized Complexity News

Newsletter of the Parameterized Complexity Community

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Enjoy the Newsletter

Congratulations to all for many awards and prizes including IPEC2021 awards, graduates, new jobs, and research. Read two research articles: *Clique-Width of Point Configurations* by Petr Hliněný and Abhisekh Sankaran, and *Tree-width dichotomy* by Vadim Lozin and Igor Razgon. Please add to the *FPT Complexity* Youtube Channel. Update Wikipedia with your new results. Follow fb page `@MikeFellowsFPT`. Send us news via Google form `https://forms.gle/sfZNzKFsbfqSywgy7` or directly to our emails. Please keep well. Take good care of yourselves. Enjoy a happy holiday season. Wishing you all the best from Frances.Rosamond@uib.no, Valia Mitsou vmitsou@irif.fr, Benjamin.Bergougnoux@uib.no and the News Team.

IPEC 2021 and 2022

The 17th International Symposium on Parameterized and Exact Computation (IPEC) will be held with ALGO 2022. A new change is that from 2022, IPEC reviewing will be double blind. Holger Dell and Jesper Nederlof are Program Co-Chairs.

The 16th IPEC was held September 6-10, 2021, virtually in Lisbon, Portugal. Website: algo2021.tecnico.ulisboa.pt/IPEC2021/. IPEC was expertly organized by the Program Committee Co-chairs: Meirav Zehavi (Ben-Gurion Univ of the Negev, Israel) and Petr Golovach (Univ of Bergen, Norway).

Please see the IPEC 2021 Business Meeting Report and the Publicity Report on the wiki, fpt.wikidot.com.

EATCS-IPEC Nerode Prize Winners

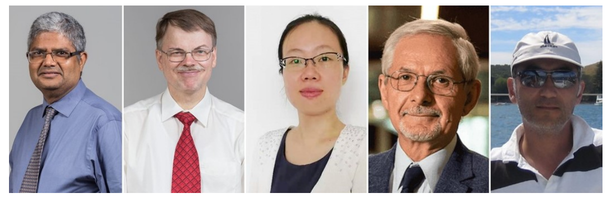

Figure 1: Winners of the EATCS-IPEC Nerode Prize. From left to right: Professors Sanjay Jain, Frank Stephan and Wei Li from the NUS Department of Mathematics, Professors Cristian Calude from the University of Auckland, and Bakhadyr Khoussainov from the University of Electronic Science and Technology of China and the University of Auckland.

CONGRATULATIONS TO THE 2021 NERODE PRIZE WINNERS.

The EATCS-IPEC Nerode Award Committee has selected the paper as the recipient of the EATCS-IPEC Nerode Prize 2021: *Deciding Parity Games in Quasi-polynomial Time* by Cristian Calude, Sanjay Jain, Bakhadyr Khoussainov, Wei Li and Frank Stephan. SIAM Journal of Computing, Special Issue dedicated to STOC 2017, pp. 152-188, 2020. The deep techniques in this paper inspired a long series of further improvements on the complexity of Parity Games and related problems. The paper is a true gem in multivariate algorithmic game theory.

The IPEC Symposium included an Invited Tutorial by Édouard Bonnet (CNRS, ENS Lyon, France) on the topic of Twin-width, for which he also won a French National Research Agency Young Researcher grant. See Édouard's

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article in the July 2021 Newsletter.

CONGRATULATIONS TO PACE AWARD WINNERS.

An Awards Ceremony was held for the Parameterized Algorithms and Computational Experiments challenge (PACE). Altogether 67 participants from 21 teams, 11 countries, and 3 continents submitted their implementations to the PACE competition. The PACE 2021 Report, written by Leon Kellerhals, Tomohiro Koana, André Nichterlein, and Philipp Zschoche (Technische Universität Berlin), is on the website www://pacechallenge.org and gives the ranking of the participating teams, the approaches used in the submitted solvers, the setup of the challenge and the selection of the benchmark instances. The 2021 challenge was devoted to engineer algorithms solving the NP-hard Cluster Editing problem, also known as Correlation Clustering: Given an undirected graph the task is to compute a minimum number of edges to insert or remove in a way that the resulting graph is a cluster graph, that is, a graph in which each connected component is a clique. The 2022 Challenge is described on the website. Many thanks to the NETWORKS project (http://thenetworkcenter.nl/) for sponsoring the PACE competition.

CONGRATULATIONS TO IPEC 2021 BEST PAPER AWARD WINNERS.

CONGRATULATIONS to Vít Jelínek, Michal Opler, Jakub Pekarek (Charles University, Prague) who have been awarded the IPEC 2021 Student Best Paper Award for their paper, *Long Paths make Pattern-counting Hard, and Deep Trees Make it Harder.*

CONGRATULATIONS to Shaohua Li and Marcin Pilipczuk (University of Warsaw, Poland) who have been awarded an IPEC 2021 Best Paper Award for their paper, *Hardness of Metric Dimension in Graphs of Constant Treewidth.*

CONGRATULATIONS to Guillaume Ducoffe (University of Bucharest, Romania) who has been awarded an IPEC 2021 Best Paper Award for the paper, *Maximum Matching in almost linear time on the graphs of bounded clique-width.*

Jan Arne Telle awarded NRC grant

CONGRATULATIONS Jan Arne Telle (University of Bergen) Algorithms Group, who will lead the project "Machine Teaching for Explainable AI". The Research Council of Norway has decided to support the project with 10 million NOK through their Enabling technologies program. The project involves the companies Equinor and BKK AS and also includes Pekka Parviainen in the UiB Machine Learning Group. The project aims to develop methods to explain decisions based on use of Artificial Intelligence (AI) methods making the reasoning performed within the AI method understandable for a human. The companies involved are increasingly using AI methods in their operations and are eager to engage in the project since they see a need to better integrate AI methods in their operations.

Figure 2: Jan Arne Telle and Pekka Parnianinen.

Saket Saurabh win Bhatnagar Prize

CONGRATULATIONS to Saket Saurabh (Univ. Bergen and Institute of Mathematical Sciences Chennai) for winning India's highly prestigious Shanti Swarup Bhatnagar Prize in Science and Technology. Saket has made fundamental contributions to the area of Parameterized Complexity and for leading the field by initiating new research directions to the community. This is easily among the highest honors for scientific achievement in India.

Figure 3: Saket Saurabh.

Crampton, Eiben, Gutin, Karapetyan, Majumdar win Best Paper Award at SACMAT 2021

CONGRATULATIONS to Jason Crampton, Eduard Eiben, Gregory Gutin, Daniel Karapetyan, Diptapriyo Majumdar (Royal Holloway, University of London) who were awarded Best Paper Award at the 26th ACM Symposium on Access Control Models and Technologies

(SACMAT 2021). Their paper, *Valued Authorization Policy Existence Problem*, proves FPT and W[1]-hardness results for a new access control problem.

Figure 4: From left to right: Jason Crampton, Eduard Eiben, Gregory Gutin, Daniel Karapetyan, Diptapriyo Majumdar.

Best Paper Award winners at FCT 2021

CONGRATULATIONS TO FCT 2021 BEST PAPER AWARD WINNERS.

CONGRATULATIONS to Best Student Paper I award winners Ashwin Jacob, Diptapriyo Majumdar and Venkatesh Raman for *Faster FPT Algorithms for Deletion to Pairs of Graph Classes*.

CONGRATULATIONS to Best Student Paper II award winners Nicolas Maack, Hendrik Molter, Rolf Niedermeier and Malte Renken for *On Finding Separators in Temporal Split and Permutation Graphs*.

CONGRATULATIONS to Best Paper award winners Marc Neveling, Jörg Rothe and Robin Weishaupt for *The Possible Winner Problem with Uncertain Weights Revisited*.

Tree-width dichotomy

by Vadim Lozin (University of Warwick, UK) and Igor Razgon (Birkbeck University of London, UK).

A class of graphs, also known as a graph property, is a set of graphs closed under isomorphism. A property is *hereditary* if it is closed under taking induced subgraphs. The world of hereditary properties is rich and diverse, and it contains various classes of theoretical or practical importance, such as perfect graphs, interval graphs, permutation graphs, bipartite graphs, planar graphs, threshold graphs, split graphs, graphs of bounded vertex degree, graphs of bounded tree-width, etc. It also contains all classes closed under taking subgraphs, minors, induced minors, vertex-minors, etc.

Tree-width is a graph parameter, which is important in algorithmic graph theory because many problems that are NP-hard for general graphs become polynomial-time solvable for graphs of bounded tree-width. Many hereditary classes have been shown to be of bounded tree-width, such as outerplanar graphs [2] or graphs of bounded vertex degree that also have bounded chordality [3]. For many other classes, tree-width has been shown to be unbounded, which includes planar graphs and graphs of vertex degree at most 3 [8]. In the present paper, we characterize the family of hereditary classes of bounded tree-width by means of four critical properties. To better explain our approach, let us illustrate it with the following example.

The bottom of the hierarchy of hereditary properties consists of classes containing finitely many graphs, i.e., classes where the number of vertices is bounded. According to Ramsey's Theorem, there exist precisely two minimal hereditary classes that are infinite: complete graphs and edgeless graphs. To put it differently, in the universe of hereditary classes the class of complete graphs and the class of edgeless graphs are minimal obstructions (minimal forbidden elements) for the family of classes of bounded vertex number.

The idea of minimal obstructions for *families of classes* generalizes the idea of minimal forbidden induced subgraphs for individual hereditary classes. This idea always works in a well-quasi-ordered world. For instance, the graph minor relation is known to be a well-quasi-order [10], and in the family of minor-closed classes of graphs the planar graphs constitute a unique minimal obstruction for classes of bounded tree-width [9]. However, the induced subgraph relation is not a well-quasi-order and in the universe of hereditary properties minimal classes outside of a particular family may not exist, in which case we employ the notion of boundary classes. This is a relaxation of the notion of minimal classes and it is defined as follows.

Let $\mathcal{A}$ be a family of hereditary classes closed under taking subclasses, and let $X_1 \supseteq X_2 \supseteq X_3 \supseteq \ldots$ be a chain of classes not in $\mathcal{A}$. The intersection of all classes in this chain is called a *limit* class and a minimal limit class is called a *boundary* class for $\mathcal{A}$. The importance of this notion is due to the fact that it plays the role of minimal obstructions for hereditary classes defined by finitely many forbidden induced subgraphs (finitely defined classes, for short). In other words, a finitely defined class X belongs to $\mathcal{A}$ if and only if X contains none of the boundary classes for $\mathcal{A}$.

The notion of boundary classes was formally introduced by Alekseev in [1], where he proved basic results related to this notion. However, implicitly this notion appeared earlier. For instance, if $\mathcal{A}$ is the family of hereditary classes of bounded chromatic number, then in the terminology of limit and boundary classes the famous result of Erdős [5] states that the class of forests is a limit class for $\mathcal{A}$, while the Gyárfás-Sumner conjecture [4] claims that this is a minimal limit, i.e., boundary, class for $\mathcal{A}$. Notice that for this family there is one more obstruction, the class of complete graphs, which is a minimal hereditary class of unbounded chromatic number.

Together, minimal hereditary classes and boundary classes are known as critical properties. In the present paper, we show that for the family of hereditary classes of bounded tree-width there are exactly four critical properties, which leads to the following dichotomy.

Theorem 1. *Let X be a hereditary class defined by a finite set F of forbidden induced subgraphs. There is a constant bounding the tree-width of graphs in X if and only if F includes a complete graph, a complete bipartite graph, a tripod (a forest in which every connected component has at most 3 leaves) and the line graph of a tripod.*

We observe that the class of tripods is a boundary class for SATISFIABILITY expressed in terms of incidence graphs [7], where an incidence graph of a CNF is a bipartite graph, in which the vertices in one part represent clauses, the vertices in the other part represent variables, and edges connect variables to clauses containing them (positively or negatively). Together with Theorem 1 this implies the following dichotomy for k-SAT.

Theorem 2. *(k-SAT dichotomy). Let X be a hereditary class of incidence graphs defined by a finite set F of forbidden induced bipartite subgraphs, and let $k \geq 3$. If $P \neq NP$, then k-SAT restricted to instances whose incidence graphs belong to X is polynomial-time solvable if and only if F contains a tripod.*

Proof. If F does not contains a tripod, then X contains the boundary class of tripods, in which case the problem is NP-complete [7]. Assume now that F contains a tripod. We can also assume without loss of generality that the complete bipartite graph with $k+1$ vertices in each part is forbidden, because this graph does not appear in the incidence graph of any instance of k-SAT. Finally, we know that X does not contain all complete graphs and all line graphs of tripods, because these graphs are not bipartite. Therefore, we conclude that the tree-width of graphs in X is bounded and hence the problem can be solved in polynomial time [6].

References

[1] V.E. Alekseev, On easy and hard hereditary classes of graphs with respect to the independent set problem. *Discrete Appl. Math.* 132 (2003), 17–26.

[2] H. L. Bodlaender, A partial k-arboretum of graphs with bounded treewidth. *Theoret. Comput. Sci.* 209 (1998), 1–45.

[3] H. L. Bodlaender, D.M. Thilikos, Treewidth for graphs with small chordality. *Discrete Appl. Math.* 79 (1997), 45–61.

[4] M. Chudnovsky, P. Seymour, Extending the Gyárfás-Sumner conjecture. *J. Combin. Theory Ser. B* 105 (2014), 11–16.

[5] P. Erdős, Graph theory and probability. *Canadian J. Math.* 11 (1959), 34–38.

[6] G. Gottlob, S. Szeider, Fixed-parameter algorithms for artificial intelligence, constraint satisfaction, and database problems, *Comput. J.* 51 (2006), 303–325.

[7] V. Lozin, C. Purcell. Boundary properties of the satisfiability problems. *Inform. Process. Lett.* 113 (2013), 313–317.

[8] B. Reed, Treewidth and tangles: A new connectivity measure and some applications, in: London Math. Soc. Lecture Note Ser., vol. 241, Cambridge Univ. Press, Cambridge, 1997, pp. 87–162.

[9] N. Robertson, P.D. Seymour, Graph minors. V. Excluding a planar graph. *J. Combin. Theory Ser. B* 41 (1986), 92–114.

[10] N. Robertson, P.D. Seymour, Graph minors. XX. Wagner's conjecture. *J. Combin. Theory Ser. B* 92 (2004), 325–357.

Clique-Width of Point Configurations

by Petr Hliněný, *Masaryk University, Brno, CZ*, and Abhisekh Sankaran, *University of Cambridge, UK*.

This short article briefly outlines the ideas presented in a WG 2020 paper [2] co-authored by O. Çağırıcı, P. Hliněný, F Pokrývka and A. Sankaran, whose full version is conditionally accepted to JCT-B.

Points and order types. We introduce a new concept of clique-width applied to geometric *point sets (configurations) in the plane*. In order to capture the combinatorial properties of a point configuration, we actually build on the notion of an *order type* introduced by Goodman and Pollack [3]: the order type of a given set P of points assigns, to each ordered triple $(a, b, c) \in P^3$ of points, the orientation (either clockwise or counter-clockwise) of the triangle abc in the plane. More generally, if the point set P is not in a general position, the triple (a, b, c) may also be collinear (as the natural third option).

Knowing the order type of a point set P is sufficient to determine some useful combinatorial properties of P, such as the convex hull of P, among others. For example, problems of finding convex holes in P, dealing with the intersection pattern of line segments with ends in P, or of guarding a polygonal terrain with the vertices in P, can be solved by looking at the order type of P and not its geometric properties. That is why order types of points sets are commonly studied in computational geometry.

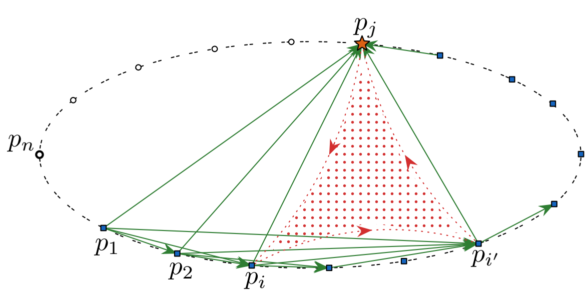
For the next definition, we "reduce" the order type of a set P simply to a ternary relation $\Omega \subseteq P^3$ such that $(a, b, c) \in \Omega$ iff the triangle abc is counter-clockwise. Note that abc is clockwise iff $(b, a, c) \in \Omega$, and abc is collinear iff $(a, b, c), (b, a, c) \notin \Omega$.

Clique-width. We assume the readers are well familiar with the notion of clique-width of graphs. An analogous *clique-width expression* for the order types of points sets can be defined, in agreement with the treatment by Blumensath and Courcelle [1], with the following operations:

(w1) Create a new point with single label i;
(w2) take the disjoint union of two (labeled) point sets;
(w3) for every two points, a of label i and b of label j $(i \neq j)$, give the ordered pair (a, b) binary label k;
(w4) for every three points, a, b, c such that c is of label i, and (a, b) is of (binary) label k, add to the structure Ω the triples (a, b, c), (b, c, a) and (c, a, b);
(w4') as in (w4), add the triples (b, a, c), (a, c, b), (c, b, a);
(w5) relabel all tuples of label i to label j of equal arity.

The *width* of an expression is then measured by the sum of arities of involved labels. The clique-width of a point set is the least width of an expression for the order type of the point set.

Note that (w3) is necessary to be compatible with [1]. To illustrate the definition, see the following picture of a strictly convex point set; in an expression (of width 4), we iteratively add the points $p_1, p_2, \ldots$, and when adding p_j, we create binary labels (p_i, p_j) (green) for $i < j$ using the unique label (red) of p_j, and add the triples $(p_i, p_{i'}, p_j)$ according to the green and red labels:



MSO logic. Bounding the clique-width of a point set allows us to solve MSO-expressible problems in linear-time FPT (see again [1]). To illustrate what can be described in this language, we express the property that a point $y \in P$ belongs to the convex hull of a set $X \subseteq P$:

$$\begin{aligned}\mathrm{convhull}(X, y) \equiv\ & y \in X \ \vee\ \forall x \in X\, \forall x' \in X \\ & \big[\big(x \neq x' \wedge \forall z \in X \neg\Omega(x', x, z)\big) \\ & \ \to \neg\Omega(x', x, y)\big]\end{aligned}$$

See [2] for a list of problems concerning, e.g., geometric partitioning or visibility problems to which the language can be applied to.

Further research. We would like to investigate if the clique-width of a given point set can be approximated in FPT (or XP) time with the clique-width as the parameter. Such approximation is known in the case of graphs as graph clique-width is related to rank-width and to binary matroids, but this graph approach does not extend easily.

Another interesting direction of research is to expand the range of expressed geometric problems, in particular to metric problems, and to investigate possible "reduced" order-type structures which encode only selected triples of a point set. More details can be found in [2].

References

[1] Achim Blumensath and Bruno Courcelle. Recognizability, hypergraph operations, and logical types. *Inf. Comput.*, 204(6):853–919, 2006.

[2] Onur Çagirici, Petr Hliněný, Filip Pokrývka, and Abhisekh Sankaran. Clique-width of point configurations. In *WG*, volume 12301 of *Lecture Notes in Computer Science*, pages 54–66. Springer, 2020.

[3] Jacob E. Goodman and Richard Pollack. Upper bounds for configurations and polytopes in R^d. *Discrete & Computational Geometry*, 1:219–227, 1986.

FPT Complexity Youtube Channel

Send your presentations to the FPT COMPLEXITY Youtube Channel.

Contact Jungho Ahn (junghoahn@kaist.ac.kr), student of Sang-il, who has volunteered to organize an FPT COMPLEXITY Youtube channel and has already gathered quite a large playlist. Please inform Jungho of videos that you would like posted.

Some videos about parameterized complexity can also be found on the Youtube channel of IMSC and the Youtube channel of MathNet Korea organized by Sang-il Oum (KAIST).

Frontiers of Parameterized Complexity online talk series

Frontiers of parameterized complexity online talk series are about the latest discoveries in the field. All are welcome to attend these online talks and interact with the speaker and other attendees remotely via Zoom.

Talks will be held every Thursday at 17:00 Bergen time (GMT+1). More information about this can be found on this website. Join the talk every Thursday at 17:00 Bergen time. The link to join the zoom talk is https://uib.zoom.us/j/4231169675.

Meeting ID: 423 116 9675. Password: Name of the W[1]-complete problem, six letters, all capital. Set of pairwise adjacent vertices.

To get a glance of what has happened so far, see the list of previous talks (https://frontpc.blogspot.com/2020/) and their video recordings at our YouTube channel Frontiers of Parameterized Complexity.

To receive notifications of the talk announcements, please send an email at rsharma@mpi-inf.mpg.de with the subject 'Subscribe FrontPC' (Not needed if you are already subscribed to these notifications). For further questions, please contact one of the following.

Roohani Sharma, Max Planck Institute for Informatics: rsharma@mpi-inf.mpg.de, Saket Saurabh, Institute of Mathematical Science, saket@imsc.res.in, Fedor Fomin, University of Bergen, fomin@ii.uib.no.

Social Choice Seminar Series For upcoming seminars on social choice and time slots where you can volunteer to give a talk, see this website.

JOBS

Please add your open positions to the JOBS page of the wiki (fpt.wikidot.com). For example, There is a postdoc opening within the School of Computing at the University of Leeds. The position is part of the EPSRC funded project (EP/V00252X/1) on the "Next Generation of Algorithms for Mixed Integer Linear Programming (MILP)" led by Dr. Sebastian Ordyniak.

The project focuses on the development of novel algorithms and algorithmic lower bounds for MILP based on the principles of parameterized complexity (PC). Towards this aim we will develop novel ways to measure and exploit the structure of MILP instances based on decompositional, backdoor, and hybrid approaches. We will also explore how the novel algorithmic lower bounds and upper bounds can best be exploited for various problems in TCS, AI, and ML. Informal inquiries to sordyniak@gmail.com are welcome.

Out and About - Moving Around

Fedor Fomin (Univ Bergen) is taking part in Hausdorff Institute of Mathematics trimester on Discrete optimization and organizing there a workshop on Parameterized complexity and discrete optimization.

Serge Gaspers has been appointed Full Professor at UNSW Sydney (University of New South Wales), Australia. Congratulations, Serge!

Daniel Marx, (Max Planck Institute for Informatics) gave an invited Plenary address at the 23rd International Symposium on Fundamentals of Computation Theory in September.

Tomáš Masařík has accepted a position on Michał's Pilipczuk grant as a postdoc (until February) and then switching to a position of Assistant Professor. Congratulations, Tomáš!

News from UESTC, Chengdu, China

This is an update about the new Algorithms and Logic Lab at the University of Electronic Science and Technology of China (UESTC), a Class A Double First Class public technological university located in Chengdu, Sichuan, China.

1) Bakh Khoussainov is now at UESTC.

2) Despite the pandemic, the lab did well with seminars, hiring an assistant professor, 2 postdocs, and secretary. We have a strong group of PhD and Master students. See https://tcs.uestc.edu.cn<https://tcs.uestc.edu.cn>

3) The next few years, we plan to hire bright and talented young researchers in algorithms and logic. Please spread the word.

4) Once travelling is easier, we look forward to visitors for potential collaborations and your lectures. We also plan to host a few conferences and schools.

5) We would like to host an online algorithm and logic course, say 20 or so hours course, at a graduate level. If you are interested, please let us know. We will be happy to discuss the details.

All the best, Bakh Khoussainov <bmk@cs.auckland.ac.nz> and Mingyu Xiao <myxiao@gmail.com>

CONGRATULATIONS New PhDs

Figure 5: Dr. Kristine Knudsen.

Kristine Vitting Klinkby Knudsen, *Parameterized problems on (Di)graphs*, University of Bergen and University of Southern Denmark.
Advisors:Jørgen Bang-Jensen (SDU), Fedor Fomin (UiB).
Cosupervisor: Saket Saurabh (UiB).
Congratulations, Dr. Vitting Klinkby Knudsen.

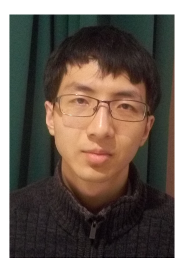


Figure 6: Dr. Shaohua Li.

Shaohua Li, *Parameterized algorithms for connectivity, separation, and modification problems in graphs*, Warsaw University.
Advisor: Professor Marcin Pilipczuk.

Dr. Li has accepted a postdoc position in the group of Prof. Daniel Marx at CISPA Helmholtz Center for Information Security in Saarbrucken.
Congratulations, Dr. Li!

Creative Mathematical Sciences Communication (CMSC)

Creative Mathematical Sciences Communication (CMSC)
April 20-23, 2022 at the University of Bergen, Norway
Website: cmsc-uib.org

NO REGISTRATION FEE, SPACE LIMITED. REGISTER TO ATTEND

Join scientists, researchers, teachers and artists in developing new ways of communicating mathematical and computational thinking, including computing activities across the curriculum, at every level. We welcome contributions in art forms such as dance, art, theatre ... many ways to communicate science to the public.

The CMSC conference series has three aims.

(1) To create new ways of communicating computational thinking, modelling, and algorithms and producing new activities with the philosophy of "Computer Science Unplugged!"
(2) To encourage researchers to provide open problems from their area that are accessible to authentic engagement by kids, and to explore ways of mentoring their work.
(3) To CELEBRATE when outreach results in greater progress in science. Outreach can be a two-way street.

CMSC aims to provide materials and learning scenarios to teach kids without computers, following the Computer Science Unplugged philosophy (www.csunplugged.org). Modeling, clever information representation, the design and analysis of algorithms, all have the potential to unlock a great amount of creativity. Let's attract children to open problems, to dare reach for gold. We aim to create more activities as iconic as the Sorting Network.

Contact: Frances.Rosamond at UiB.no

Figure 7: Dance&Story, Crypto, Sorting Network.