Soohyun Park

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Citizenship **U.S. & Canada**

Education

University of Chicago 2018 – present
Ph.D. student in Mathematics (Advisor: Benson Farb)

Massachusetts Institute of Technology 2015 – 2017
M. S. in Mathematics (Advisor: Bjorn Poonen, degree received February 2018)
GPA: 5.0/5.0

Massachusetts Institute of Technology 2011 – 2015
B. S. in Mathematics GPA: 4.8/5.0

Research interests I'm interested in combinatorial questions connected to the algebraic geometry/topology of varieties/manifolds (or the converse). Examples include Euler characteristic-like invariants such as characteristic polynomials of linear subspace arrangements (e.g. encoded by simplicial complexes) and algebro-geometric properties of matroids. Some related problems involve h-vectors and combinatorial analogues of hypersurface independence conditions.

Preprints and papers

12. **S. Park, Matroidal Cayley-Bacharach and independence/dependence of geometric properties of matroids**, submitted

    We study the relationship between "geometric" properties of matroids and the matroidal Cayley-Bacharach property of degree a $MCB(a)$ defined by Levinson and Ullery. From the perspective of matroid polytopes/generalized permutohedra, we see from the case of nestohedra that the $MCB(a)$ property can have a natural description in terms of properties of polytopes while *not* being a combinatorial invariant of polytopes. On the other hand, there seem to be a close relationship between combinatorial properties in the case of paving matroids (which are conjecturally almost all matroids of a given rank) and supersolvable line/hyperplane arrangements. The paving matroids involve a relationship between the degree a and the Chow rings of matroids. Using supersolvable line arrangements, we find a family of matroids other than the case of representable matroids where the $MCB(a)$ property measures the failure of a set of points to impose independent conditions on the space of hypersurface of a given degree. In general, $MCB(a)$ for supersolvable hyperplane arrangements has a recursive property from $MCB(b)$ for lower degrees b and covers of appropriate subarrangements.

11. **S. Park, Anti-Ramsey theory problems, lattice point counts on polytopes, and Hodge structures on the cohomology of toric varieties**, submitted

    By "anti–Ramsey theory problems", we mean the number of edge colorings of graphs such that a specified subgraphs are *not* monochromatic. We find families of graphs and subgraphs such that this number is determined by a lattice point count. The idea is to combine a reinterpretation of simplicial chromatic polynomials and connections between h-vectors and lattice point counts of polytopes. Note that this follows up on our earlier work expressing simplicial chromatic polynomials in terms of "h-vectors of auxiliary simplicial complexes. As a result, we obtain a family of "anti-Ramsey" questions addressed using geometric/structural methods.

10. **S. Park, Matroids satisfying the matroidal Cayley–Bacharach property and ranks of covering flats**, submitted

    We first show that there are no nontrivial bounds on ranks of proper flats that cover the underlying set of a matroid satisfying the matroidal analogue of the Cayley-Bacharach property. This gives a negative answer to a question in recent work of Levinson and Ullery. Next, we look at the matroidal Cayley-Bacharach property from the point of view of polytopes associated with matroids that are studied. We consider a (generic) class of matroids where the matroidal Cayley-Bacharach property depends on a collection of set-theoretic properties depending on the ranks of the flats of the matroids arising from the polytopes.

9. **S. Park, Simplicial chromatic polynomials as Hilbert series of Stanley–Reisner rings**, submitted

    This project started with our initial observation that Euler characteristic-like invariants of ordered configuration spaces of distinct points on a manifold and can be altered to obtain chromatic polynomials of graphs. This means only preventing the coordinates corresponding to adjacent vertices from being equal to each other. As it turns out, properties of this modified configuration space such as this one were studied earlier by Eastwood and Huggett and there is a higher-dimensional version of this connection arising from simplicial complexes in work of Cooper-de Silva-Sazdanovic. This polynomial (the simplicial chromatic polynomial) is uniquely determined up to normalization by a deletion-contraction type relation. While they study the polynomial from a topological point of view, we find an explicit combinatorial interpretation for a large class of initial simplicial complexes. More specifically, we find that they arise from the Hilbert series of Stanley-Reisner rings associated to auxiliary simplicial complexes. In addition, *any* simplicial complex can be set to be the auxiliary simplicial complex of *some* simplicial complex.

    Note that these polynomials are closely related to characteristic polynomials of diagonal/hypergraph linear subspace arrangements (or their associated polymatroids). Since they are determined by h-vectors of auxiliary simplicial complexes, we found some connections between these simplicial chromatic polynomials and other questions involving log concavity, symmetries between a polynomial and its reciprocal polynomial, and cyclotomic polynomials along the way.

8. **S. Park, Graph coloring-related properties of (generating functions of) Hodge–Deligne polynomials**, submitted

    We were considering some connections between Euler characteristic-like invariants (e.g. Hodge-Deligne polynomials) of configuration spaces and chromatic polynomials. It turns out that there is a connection between colorings of *directed* graphs and Hodge-Deligne polynomials as well. We take a look at what this means and how it relates to existing structures between Hodge numbers (e.g. birational invariants) and properties of configuration spaces.

7. **S. Park, Characterizing cubic hypersurfaces via projective geometry**, submitted

    Under certain numerical/generic conditions, we show that cubic hypersurfaces are characterized by a projective geometry construction. This uses a cut and paste relation (in the Grothendieck of varieties) of Galkin and Shinder matching pairs of points with an incidence correspondence involving the third point of intersection and the line spanned by the first two points (filtering out instances where the line is contained in the given variety). Weakening these conditions extends the possibilities to complete intersections of two quadric hypersurfaces or two quartic hypersurfaces. As a special case, we find generic hypersurfaces of a given degree satisfying this cut and paste relation must be cubic hypersurfaces.

6. **S. Park, Motivic limits for Fano varieties of k-planes, The Quarterly Journal of Mathematics, haac012 (2022)**

   We show that "most" of certain properties of Fano varieties of k-planes (k-planes contained in a given projective variety) are determined by symmetric products of points on the given variety, Grassmannians of appropriate dimensions, and incidence correspondences of points in linear subspaces. Examples of properties in question are those compatible with cut and paste constructions such as Poincare polynomials, Euler characteristics, and Hodge-Deligne polynomials. The main idea is to construct an approximate/motivic limit version of a relation of Galkin and Shinder in the Grothendieck ring of varieties. This means building a correspondence between points and incidence correspondences coming from the intersection of a variety in projective space with a linear subspace of complementary dimension and filtering out loci where this map is not a bijection (which includes terms from Fano varieties of k-planes).

5. **S. Park, Decomposability and Mordell-Weil ranks of Jacobians using Picard numbers**

   We study number field analogues of some questions of Ekedahl and Serre about the decomposability of Jacobians of curves C over number fields as a product of elliptic curves. The main case considered involves self-products E^g and we approach this question by studying the Picard numbers of self-products of the curves C involved under specialization to primes. This involves methods previously used by Costa, Elsenhans, and Jahnel to study those of K3 surfaces. As a result, we give bounds on the genus of such curves with respect to initial arithmetic invariants (e.g. norms of primes related to reduction properties or heights) and obtain infinite families where the reduction modulo a prime is maximal or minimal when such decompositions exist. In addition, we rule out cases where the curves have a large automorphism group. Finally, we show that Picard numbers of self-products of curves can also be used to study jumps of Mordell-Weil ranks via results of Ulmer on Mordell-Weil ranks of Jacobians over function fields and endomorphism rings.

4. **L. Chua, B. Gunby, S. Park, and A. Yuan, Proof of a conjecture of Guy on class numbers, International Journal of Number Theory, 11 (2015), pages 1345 – 1355.**

   We resolve a conjecture of Guy on a congruence between class numbers of quadratic fields $\mathbf{Q}(\sqrt{\pm\mathbf{p}})$ and continued fraction expansions of $\sqrt{p}$. The tools used were some algebraic number theory, results of Zagier connecting these class numbers with the continued fraction expansions, Jacobi symbols, and Dedekind sums. While this question is apparently about class numbers, it is interesting to note that the main ideas used are combinatorial arguments rather than the structure of the class group.

3. **L. Chua, S. Park, and G. Smith, Bounded gaps between primes in special sequences, Proceedings of the American Mathematical Society, 143 (2015), pages 4597 – 4611.**

   In Maynard's work on bounded gaps between primes, it was shown that any subset of the primes which is well-distributed in arithmetic progressions contains many primes which are close together. We adapt his method to show that there are bounded gaps between sequences of the form [bn], where b is an irrational number of finite type.

2. **S. Park, Arithmetic properties of generalized Fibonacci sequences**

   We consider a generalization of the Fibonacci sequence which shares some arithmetic properties with the original sequence. This includes a resolution to some conjectures of Chen, Moll, and Sagan on periodicity, d-adic valuations, and the behavior of an analogue of the Riemann zeta function. Also, we give an algebraic description of the periodicity property considered and study how it is distributed.

1. **S. Park, Discriminators of quadratic polynomials**
   For polynomials f and a positive integers n, we study the discriminator $D_f(n)$, which is the smallest number m such that $f(1),, f(n)$ are distinct mod m. This was first defined in the context of computing square roots of a long sequence of numbers for a computer simulation. While this quantity has been studied for certain classes of polynomials, it is very complicated in general. We focus on polynomials of the form $f(x) = x(dx1)$ where this problem is more tractable and extend results of Sun for $d = 2, 3$ where $D_f(n) = d^{\lceil \log_d n \rceil}$ to $d = 2^r$ for positive integers r. Afterwards, we also study cases where $d = p^r$ for other primes p (e.g. using bounds) and observe using computational methods that discriminator values are concentrated around prime powers even after increasing the size of the prime p or power r. This gives a potential method for generating prime numbers using discriminators of polynomials.

Talks/posters

Farb and Friends (UChicago)
Chicago, IL — January 25, 2023
Talk title: Symmetries unifying the continuous and discrete

KU-Jerusalem Lunch Seminar
January 19, 2023
Talk title: Cayley-Bacharach: Geometry to combinatorics (and vice versa)

AWM 2023 Joint Mathematics Meetings (JMM) Poster Session
January 6, 2023
Poster title: Matroidal Cayley-Bacharach and independence/dependence of geometric properties of matroids (`https://awm-math.org/meetings/awm-jmm/` and `https://www.jointmathematicsmeetings.org//jmm`)

Farb and Friends (UChicago)
Chicago, IL — November 16, 2022
Talk title: Redundancies of polynomial conditions and Lefschetz properties (`https://math.uchicago.edu/~farbandfriends/`)

UChicago undergraduate math club
Chicago, IL — October 26, 2022
Talk title: Combinatorial (in)variance of independence conditions on spaces of hypersurfaces

Copenhagen–Jerusalem Combinatorics Seminar
June 23, 2022
Talk title: Anti-Ramsey theory, lattice points on polytopes, and Hodge structures on toric hypersurfaces (`https://researchseminars.org/seminar/CJCS`)

GradMoCCA – A Graduate Meeting on Combinatorial Commutative Algebra
May 15, 2022
Talk title: Matroidal Cayley–Bacharach and ranks of covering flats (`https://www-users.cse.umn.edu/~mahrud/GradMoCCA/schedule/`)

Korea Institute of Advanced Study (KIAS)
Online (Zoom) April 14 (Chicago)/ April 15 (Seoul) 2022

Talk title: Simplicial chromatic polynomials as Hilbert series of Stanley–Reisner rings

Farb and Friends (UChicago)
Chicago, IL Fall 2021
Gave a talk on "generating" Fano varieties of s-planes on Grassmannians (with respect to the Plücker embedding) using other Grassmannians (`https://math.uchicago.edu/~farbandfriends`).

Farb and Friends (UChicago)
Online (Zoom) Spring 2021
Gave a talk on a result of Hirzebruch related to line arrangements in the plane in connection to a "uniformization" result (the Bogomolov–Miyaoka–Yau inequality) (`https://math.uchicago.edu/~tghyde/FarbAndFriends.html`).

Farb and Friends (UChicago)
Online (Zoom) Winter 2021
Gave a talk on Larsen–Lunts' result connecting stable birationality and the structure of the Grothendieck ring of varieties (`https://math.uchicago.edu/~tghyde/FarbAndFriends.html`).

Benson Farb's working group (UChicago)
Online (Zoom) Winter 2021
Gave a talk on Kotschick–Schreieder and Paulsen–Schreieder's work on universal linear combinations/polynomial combinations of Betti and Hodge numbers of (linear combinations of) Kähler manifolds (`http://math.uchicago.edu/~farbgroup/`).

Madison Moduli Weekend
Online (Zoom) Fall 2020
Gave a lightning talk titled "Cut and paste relations and cubic hypersurfaces" related to current work (`https://sites.google.com/wisc.edu/madisonmoduliweekend/home?authuser=0`)

Benson Farb's working group (UChicago)
Chicago, IL Spring 2020
Gave a talk on Sturmfels' exposition of Bernstein's result relating common roots of polynomials and mixed volumes of Newton polytopes (`http://math.uchicago.edu/~farbgroup/2020-spring/`)

Benson Farb's working group (UChicago)
Chicago, IL Winter 2020
Gave a talk on current work involving motivic statistics and Chow hypersurfaces parametrizing intersections with low–dimensional linear subspaces (`http://math.uchicago.edu/~farbgroup/2020-winter/`)

Pizza Seminar (UChicago)
Chicago, IL Fall 2019
Gave a talk called "Lotteries for lazy people" – see abstract on `https://math.uchicago.edu/~pizzaseminar/`

Benson Farb's working group (UChicago)
Chicago, IL Fall 2019
Gave a talk on Galkin–Shinder's proof that there are 27 lines on a cubic surface using $Y - F(Y)$ relation in the Grothendieck ring of varieties

Hodge theory learning seminar (UChicago)
Chicago, IL Spring 2019
Gave a talk on Lefschetz pencils (e.g. decomposition of cohomology into invariant and vanishing parts, Picard-Lefschetz theorem).

Curves and L-functions (ICTP)
Trieste, Italy Summer 2017
Gave a talk on a research project done at the conference "Curves and L-functions" (`https://people.maths.bris.ac.uk/~matyd/Trieste2017.html`) at the ICTP (Title: "Generic rank of a family of elliptic curves" – see link on website for slides)

Where Geometry meets Number Theory
Gothenburg, Sweden Summer 2017
Gave research talk at Per Salberger's birthday conference (Note: Subject of actual talk was different from the one planned. Title: "Manin-Mumford for Shimura varieties and decomposable Jacobians"

Harvard Algebraic Geometry Learning Seminar
Cambridge, MA Fall 2016
Gave a talk on differentials on toric varieties in learning seminar on toric varieties (`http://www.math.harvard.edu/agls/archive/fall2016.html`)

MIT STAGE
Cambridge, MA Fall 2016
Gave a talk on functions on an analytic curve (Baker, Payne Rabinoff, Section 5) in seminar on tropical geometry (`http://math.mit.edu/nt/index_stage.html`)

Joint Math Meetings (JMM)
Baltimore, MD January 2014
Presented results on summer research project in combinatorial number theory at a conference.

Teaching

UChicago Math Department
Chicago, IL Winter 2023
Caculus II (Math 15200 – Section 13) Instructor, lectures and problem sessions (same as recitations below)

UChicago Math Department
Chicago, IL Fall 2022
Caculus I (Math 15100 – Section 13) Instructor, lectures and problem sessions (same as recitations below)

UChicago Math Department
Chicago, IL Winter 2022
Caculus II (Math 15200 – Section 11) Instructor, lectures and problem sessions (same as recitations below)

UChicago Math Department
Chicago, IL Fall 2021
Caculus I (Math 15100 – Section 11) Instructor, lectures and problem sessions (same as recitations below)

UChicago Math Department
Online (Zoom) Spring 2021
Calculus II (Math 13200) TA, problem sessions (same as recitations below, wrote quizzes and gave lectures), office hours

UChicago Math Department
Online (Zoom) Winter 2021
Calculus I (Math 13100) TA, problem sessions (same as recitations below, wrote quizzes and gave and lectures), office hours

UChicago Math Department
Chicago, IL Spring 2020
Analysis in R^n I (Math 20300) College Fellow/TA, problem sessions (same as recitations below)

UChicago Math Department
Chicago, IL Winter 2020
Honors Calculus II (Math 16200) College Fellow/TA, holding office hours and problem sessions (same as recitations below)

UChicago Math Department
Chicago, IL Fall 2019
Directed Reading Program (DRP) mentor for an undergraduate, covering "The Red Book of Varieties and Schemes" by David Mumford.

UChicago Math Department
Chicago, IL Fall 2019
Introduction to probability (STAT 25150) College Fellow/TA, holding office hours and problem sessions (same as recitations below)

MIT Math Department
Cambridge, MA Fall 2017
Teaching assistant for multivariable calculus (18.02), held recitations and office hours

MIT Math Department
Cambridge, MA Summer 2017
Mentored an undergraduate on a project in analytic number theory (`https://math.mit.edu/research/undergraduate/urop-plus/documents/2017/Zeff.pdf`)

MIT Math Department
Cambridge, MA February 2017 – May 2017
Grader for elliptic curves course (18.783 – `http://math.mit.edu/classes/18.783/2017/`) and held office hours

MIT Math Department
Cambridge, MA September 2016 – December 2016
Grader for number theory (18.785 – `http://math.mit.edu/classes/18.785/2016fa/index.html`) and held office hours, gave a guest lecture on totally ramified extensions and Krasner's lemma

MIT Math Department
Cambridge, MA June 2016 – August 2016
Mentored an undergraduate on a project on formal duality and energy-minimizing configurations with an example related to sphere packing (`https://math.mit.edu/research/undergraduate/urop-plus/documents/2016/Xia.pdf`)

MIT Math Department
Cambridge, MA December 2015 – January 2016
Typed a portion of the course notes for Fall 2015 algebraic geometry course (18.725 – `https://ocw.mit.edu/courses/mathematics/18-725-algebraic-geometry-fall-2015/`) to appear on MIT OCW website.

University of Minnesota Duluth REU Visitor/research mentor
Duluth, MN Summer 2014
Assisted REU students with discrete math research (usually combinatorics or number theory), provided feedback for presentations and general research advice

MIT Math Department Grader
Cambridge, MA Fall 2012
Grader for undergraduate abstract algebra course (18.701)

Spirit of Math Schools Assistant Teacher
Toronto, Canada Fall 2010
Assistant Teacher for class of 6th graders

Conferences

Workshop on Lefschetz Properties in Algebra, Geometry, Topology and Combinatorics (upcoming) Toronto, Canada May 2023

2023 Joint Mathematics Meetings (upcoming)
Boston, MA January 2023

The Circle at Infinity: An international colloquiumin honor of Curtis T. McMullen
Cambridge, MA June 2022

Göran Gustafsson Symposium
Institut Mittag–Leffler, Sweden May 2022

Open Problems in Algebraic Combinatorics (OPAC)
Minneapolis, MN May 2022

GradMoCCA – A Graduate Meeting on Combinatorial Commutative Algebra
Minneapolis, MN May 2022

Current Developments in Mathematics (CDM) 2021
Cambridge, MA March 2022

EDGE Days 2020
Online (Zoom) December 2020

Madison Moduli Weekend
Online (Zoom) September 2020

Monodromy and Galois groups in enumerative geometry and applications (ICERM Workshop)
Online (Zoom) August – September 2020

Simons conferences – Rationality
Online (Zoom) July 2020

FRG Workshop on Stability, Moduli Spaces and Applications (UIC)
Chicago, IL December 2019

Facets of Algebraic Geometry
Ann Arbor, MI October 2019

PIMS Workshop on Arithmetic Topology
Vancouver, Canada June 2019

Midwest Representation Stability Research Meeting 2019
Chicago, IL April 2019

D-Modules and Hodge Theory
Chicago, IL November 2018

Algebraic Geometry Northeastern Series (AGNES) Fall 2017
Boston, MA October 2017

Curves and L-functions (ICTP)
Trieste, Italy August – September 2017

Where Geometry meets Number Theory
Gothenburg, Sweden July 17 – 19, 2017

Positivity in Arithmetic and Geometry
Orsay, France May 28 – June 2, 2017

Algebraic Geometry Northeastern Series (AGNES) Spring 2017
Stony Brook, NY April 2017

Arizona Winter School 2017
Tucson, AZ — March 2017

Algebraic Geometry Northeastern Series (AGNES) Fall 2016
Amherst, MA — November 2016

Algebraic Geometry Northeastern Series (AGNES) Spring 2016
New Haven, CT — April 2016

Arizona Winter School 2016
Tucson, AZ — March 2016

Summer research programs

Emory University REU — Research Student
Atlanta, GA — June – July 2014

- Conducted research on analytic and algebraic number theory at the summer research program run by Professor Ken Ono (2 papers accepted for publication)
- Nominated to present results at Research Experiences for Undergraduates Symposium (REUS) in Arlington, Virginia

University of Minnesota Duluth REU — Research Student
Duluth, MN — June – August 2013

- Conducted research on combinatorial number theory at the summer research program run by Professor Joseph Gallian
- Presented results at 2014 Joint Mathematics Meetings (JMM) in Baltimore

Activities

Farb and Friends — Co-organizer
Chicago, IL — Fall 2021 – Spring 2022
Co-organized and gave talks for an informal seminar organized by the Farb working group for graduate students and postdocs to share expository talks in a low-stakes environment (`https://math.uchicago.edu/~farbandfriends/`)

AWM x SWiM mentorship program
Winter 2022 – present

MSRI Summer School on Algebraic Curves (delayed due to COVID–19) Summer 2020
Was accepted to MSRI Summer School on algebraic curves, but not sure what will happen due to COVID–19 situation

Farb Working Group — Fall 2019 – Spring 2020
Organized and gave talks for Benson Farb's working group, maintained website

UChicago Directed Reading Program — Fall 2019
Mentored an undergraduate covering "The Red Book of Varieties and Schemes" by David Mumford

MIT Directed Reading Program January 2015
Read about topics in analytic number theory in Davenport's *Multiplicative Number Theory* with a graduate student mentor

Student Colloquium for Undergraduates in Mathematics (SCUM) 2014 – 2015
Organize talks by undergraduates on math topics which interest them (may or may not be original research), Treasurer

MIT Undergraduate Society of Women in Mathematics (USWIM) 2012 – 2015

- Outreach Chair (2012 - 2013), External Public Relations Chair (2014 - 2015)
- Helped organize Math in Industries panel/recruiting event, brought D.E. Shaw & Co. into panel
- Helped organize math treasure hunt for girls in grades 6 – 10 (SUMiT)
- Volunteered at Math Prize for Girls

Undergraduate Math Association (UMA) 2011 – 2015

- Editor for UMA Magazine (wrote a math article and compiled math articles, sent out and made graphics for a survey)
- Vice President (2014 – 2015) - organized lectures by professors on their research
- Helped organize inaugural Harvard-MIT Undergraduate Mathematics Symposium (HMUMS) (`http://web.mit.edu/clian/www/symposium/index.html`)
- Helped start mentorship program for undergraduates in 2015 – 2016 year, currently assigned a student to mentor

Fellowships

McCormick Fellowship from UChicago (received in 2018, to use in 2019 – 2021)

GAANN Fellowship from the Department of Education (2018 – 2019)

Skills and Interests

Sage, Python, LaTeX, some MAGMA

Fluent in English and Korean, intermediate (passed DSD2 – B2/C1) proficiency in German, basic proficiency in French, proficient in Latin (2011 Classical Association of Canada Latin Sight Competition Honourable Mention)