KTH Teknikvetenskap

Protokoll

Närvarande: Leif Kari
Sören Östlund
Sofia Nyström
Fredrik Viklund
Stefan Hallström
Kristina Edström
Ulrica Edlund
Anna Delin
Anna-Karin Burström

1. Mötets öppnande

Ordförande Leif Kari förklarar mötet öppnat.

2. Anmälda förhinder

Anna Wahl, Björn Önfelt och Theodor Staffas har anmält förhinder.

3. Val av justeringsperson

Sofia Nyström utses till justeringsperson.

4. Fastställande av föredragningslista [bilaga 1]

Föredragningslistan fastställs utan ändringar.

5. Föregående protokoll (strategiskt rådsmöte 3 maj 2018)

Protokollet från strategiska rådsmötet 3 maj 2018 läggs till handlingarna.

6. Anmälningar

Endast ett licentiatseminarium sedan förra mötet.

7. Rekryteringsärenden, fakultetsförnyelse och jämställdhet

a. Rapport av pågående ärenden [bilaga 2]

Anna Delin föredrar aktuella rekryteringsärenden, befordringsärenden och docentprövningar.

b. Biträdande lektor i Matematik med inriktning mot geometri och matematisk statistik i artificiell intelligens [bilaga 3]

Anna Delin föredrar ärendet.

Strategiska rådet beslutar

att tillstyrka ärendet.

c. Biträdande lektor i Matematik med inriktning mot sannolikhetsteori och kombinarotik inom artificiell intelligens [bilaga 3]

Anna Delin föredrar ärendet.

Strategiska rådet beslutar

att tillstyrka ärendet.

8. Omorganisation av mekanik-området

Leif Kari presenterar bakgrunden till beslutet och hur långt arbetsgruppen kommit i arbetet.

9. Aktiva åtgärder

Regeringen har beslutat att samtliga myndigheter ska arbeta med aktiva åtgärder för att motverka diskriminering. Synpunkter på vad SCI-skolan bör arbeta med förutom det som tagits fram centralt skickas till Leif Kari.

10. Övriga frågor

Tider för hösten möten:

Måndag 3 sept 15-17

Måndag 15 okt 10-12

Måndag 19 nov 13-15

11. Mötets avslutande

Leif Kari förklarar mötet avslutat.

Vid protokollet

Anna-Karin Burström

Justeras

Leif Kari

Sofia Nyström

Föredragningslista

*= bilaga finns

1. Mötets öppnande
2. Anmälda förhinder
3. Val av justeringsperson
4. Fastställande av föredragningslista
5. Föregående protokoll (rådsmöte 3 maj 2018)
6. Anmälningar*
7. Rekryteringsärenden, fakultetsförnyelse och jämställdhet
    a. Rapport av pågående ärenden*
    b. Biträdande lektor i Matematik med inriktning mot geometri och matematisk statistik i artificiell intelligens*
    c. Biträdande lektor i Matematik med inriktning mot sannolikhetsteori och kombinarotik inom artificiell intelligens*
8. Omorganisation av Mekanik-området
9. Handlingsplan aktiva åtgärder
10. Övriga frågor
11. Mötets avslutande

KTH, SE-100 44 Stockholm. Tel: 08-790 7602
E-post:akbu@kth.se www.kth.se/sci

Bilaga 2

Namn HL	Ärendetyp	Namn på individ/ärende	Skola	Dnr	Status
Dilek	Befordran, lektor till professor	Berk Hess	SCI	VL-2017-0210	Sakkunniggranskning
Dilek	Befordran, lektor till professor	Jonas Weissenrieder	SCI	VL-2018-0002	Sakkunniggranskning
Katarina	Befordran, lektor till professor	Philipp Schlatter	SCI	VL-2017-0221	Sakkunniggranskning
Petra	Befordran, Bitr. lektor till lektor	Josefin Larsson	SCI	VL-2017-0196	Sakkunniggranskning
Katinka	Befordran, Bitr. lektor till lektor	Martin Månsson	SCI	VL-2017-0229	Sakkunniggranskning
Katarina	Befordran, Bitr. lektor till lektor	Carlos Casanueva	SCI	VL-2017-0185	Befordringsnämnden klar ärendet skickat till skolan för beslut.
Petra	Befordran, Bitr. lektor till lektor	Sara Zahedi	SCI	VL-2017-0183	BN möte 9/5
Dilek	Befordran, Bitr. lektor till lektor	Ilaria Testa	SCI	VL-2018-0051	Skolan måste komma med nytt förslag på sakkunniga.
Petra	Befordran, lektor till professor	Carlota Canalias	SCI	VL-2017-0184	AU - ärendet bordlagt 27/3, ny sakkunnig behöver utses. Info mailad skolan 3/4
Katarina	Bitr. lektor till lektor	Chong Qi	SCI	VL-2017-0188	Sakkunniggranskning
	Bitr. lektor till lektor	Patrick Henning	SCI	VL-2018-0053	Överlämnat till UF 24/4
Katarina	Affilierad fakultet	Michael Uhlin (förlängning)	SCI	VL-2018-0039	Allt klart, men avtal måste komma in
Katarina	Lektorat, utlyst	Lektor i matematisk statistik	SCI	VL-2017-0096	Pierre Nyqvist och Sigrid Källblad ska anställas.
Kia	Biträdande lektor	Biträdande lektor i flygteknik	SCI	S-2016-1309	Mariani Raffaello och Evelyn Otero har anställts.
Kia	Biträdande lektor	Biträdande lektor i tillämpad fysik m inr mot experimentell kvantfotonik	SCI	S-2018-0111	Tjänsten ska annonseras.
Kia	Lektor	Lektor i matematik	SCI	VL-2017-0009	Maria Gualdani och Karim Adiprasito ska anställas.

Docentärenden

Pågående ärenden			
Ilaria Testa	docentintervju preliminärt datum 30 maj		
Kevin Schnelli	docentintervju ska planeras in		
Walter Villanueva	docentintervju ska planeras in		
Ivan Stenius	docentintervju 25/5		
Lilian Mathiesen	Överlämnades till UF 19 feb		
Martin Månsson	Väntar på skolans brev och förslag på sakkunnig		
Sara Zahedi	docentintervju ska planeras in		
Lucie Delamotte	docentintervju ska planeras in		
Jens Bardarson	Överlämnades till UF 12 mars	togs på AU 27/3	

Anställningsprofil för biträdande lektor i matematik

Ämnesområde
Matematik med inriktning i geometri och matematisk statistik i artificiell intelligens.

Ämnesbeskrivning
Ämnet ska tolkas i bred mening med fokus på grundläggande forskning inom geometri och matematisk statistik för bättre framtida förståelse av artificiell intelligens. Exempel på områden är algebraisk topologi, topologisk dataanalys, algebraisk geometri, representationsteori, matematisk statistik och stokastisk geometri.

Arbetsuppgifter
I tjänsten ingår forskning, undervisning, handledning och viss administration. Även undervisning med upp till 30% av arbetstiden ingår i tjänsten.
Anställningen ingår i en WASP-satsning gällande matematik inom artificiell intelligens och den biträdande lektorn blir ansvarig för en liten forskargrupp med minst en postdoktor och en doktorand.

Kandidaten förväntas bidra till verksamheten inom WASP-programmet och dess nationella aktiviteter samt inom matematikinstitutionen inklusive Brummer & Partners MathDataLab. Engagemang för den nya specialiseringen mot matematisk datavetenskap inom masterprogrammet i beräkningsmatematik och tillämpad matematik förväntas också.

Den biträdande lektorn kommer att ges möjlighet att vidareutveckla sin självständighet som forskare och få meriter som kan ge behörighet för en annan läraranställning där högre krav på behörighet är ställda (se 4 kap. 12 a § högskoleförordningen).
Den biträdande lektorn kommer att kunna ansöka om befordran till lektor i enlighet med 4 kap. 12 c § högskoleförordningen.

Behörighet

Behörig att anställas som biträdande lektor är den som har avlagt doktorsexamen i matematik eller tillämpad matematik, eller har motsvarande vetenskaplig kompetens. Främst bör den komma i fråga som har avlagt doktorsexamen eller har nått motsvarande kompetens högst fem år innan tiden för ansökan av anställningen som biträdande lektor har gått ut. Även den som har avlagt doktorsexamen eller har uppnått motsvarande kompetens tidigare kan dock komma i fråga om det finns särskilda skäl. Med särskilda skäl avses ledighet på grund av sjukdom, föräldraledighet eller andra liknande omständigheter.

Bedömningsgrunder

Som bedömningsgrunder vid anställning som biträdande lektor vid KTH gäller de bedömningsgrunder som anges i avsnitt 1.3. i KTH:s anställningsordning i förhållande till fastställd anställningsprofil.

Det är av *högsta betydelse* att den sökande har

- vetenskaplig skicklighet visad genom vetenskaplig publicering inom ämnesområdet.
- potential till meritering för högre läraranställning. Häri inbegrips potential till självständig utveckling som forskare och lärare inom aktuellt ämnesområde samt förmåga till etablering, förnyelse och utveckling av ämnesområdet.
- Internationell forskningserfarenhet och potential att stärka forskningsområdet inom Sverige.

Det är av *näst högsta betydelse* att den sökande har

- intresse för och insikter rörande pedagogisk utveckling inom ämnesområdet.
- postdoktorsvistelse i annan forskningsmiljö än det lärosäte den sökande disputerat vid.
-

Det är *även av betydelse* att den sökande har

- intresse för och insikter rörande ledarskap i akademin, samverkan med det omgivande samhället, samt medvetenhet om mångfalds- och likabehandlingsfrågor med särskilt fokus på jämställdhet.
- graden av administrativ skicklighet och annan skicklighet.

Särskilda bedömningsgrunder för befordran till lektor

Vid prövning av ansökan om befordran till lektor kommer den sökandes förmåga att självständigt initiera och driva forskning av hög vetenskaplig kvalitet, publicerad i internationella tidskrifter och konferensvolymer samt sökandes förmåga att erhålla finansiering av forskningsverksamhet att bedömas. Av högsta betydelse är den sökandes förmåga att självständigt etablera nya samarbeten och forskningsinriktningar. Av högsta betydelse är även att den sökande har visat skicklighet i undervisning samt handledning. Av högsta betydelse är den sökandes förmåga att undervisa på svenska.

Biträdande lektor i matematik med inriktning i geometri och matematisk statistik i artificiell intelligens.

Kungliga Tekniska högskolan, Skolan för teknikvetenskap

KTH är ett av Europas ledande tekniska universitet och en viktig arena för kunskapsutveckling. Som Sveriges största universitet för teknisk forskning och utbildning samlar vi studenter, forskare och fakultet från hela världen. Vår forskning och utbildning omfattar såväl naturvetenskap som alla grenar inom teknik samt arkitektur, industriell ekonomi, samhällsplanering, teknisk historia och filosofi.

Skolan för teknikvetenskap bedriver frontlinjeforskning inom ett brett fält, från forskning inom grundläggande ämnen som fysik och matematik, till teknisk mekanik med tillämpningar inom bland annat flygteknik och fordonsteknik. Skolan driver och utvecklar civilingenjörsutbildningarna Teknisk Fysik och Farkostteknik, liksom utbildningsprogrammet Öppen ingång och ett flertal masterprogram.

Centret Wallenberg AI, Autonomous Systems, and Software Program (WASP) lanserar ett program för att utveckla matematiken inom AI, med målet att främja kompetensen inom AI i Sverige. Anställningen erbjuder en unik karriärmöjlighet, där innehavaren ska ha möjlighet att identifiera och utveckla forskningsområden, samt upprätta en långsiktig forskningsagenda som bidrar till KTHs och WASPs stora utmaningar inom matematik för AI.
Med anställningen följer forskningsresurser som innefattar finansiering för 5 post-doc år och en doktorand, samt projektrelaterade kostnader motsvarande 60 tkr/år.

Ämnesområde

Matematik med inriktning i geometri och matematisk statistik i artificiell intelligens.

Ämnesbeskrivning

Ämnet ska tolkas i bred mening med fokus på grundläggande forskning inom geometri och matematisk statistik för bättre framtida förståelse av artificiell intelligens. Exempel på områden är algebraisk topologi, topologisk dataanalys, algebraisk och tropisk geometri, representationsteori, matematisk statistik och stokastisk geometri.

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Fackliga representanter

Du hittar kontaktuppgifter till fackliga representanter på KTH:s webbsida.

Ansökan

Utforma din ansökan enligt KTH:s cv-mall för anställning av lärare. Du som sökande har huvudansvaret
för att ansökan är komplett utifrån annonsen och cv-mallen. Ansökan ska vara KTH tillhanda senast sista
ansökningsdagen och du ansöker via KTH:s rekryteringsverktyg.

Övrigt

Tidsbegränsat till: Anställningen är tillsvidare, dock längst sex år, och kan förnyas om det på grund av lärarens sjukfrånvaro, föräldraledighet eller andra särskilda skäl krävs ytterligare tid för att uppnå syftet med anställningen. Den sammanlagda anställningstiden får dock omfatta högst åtta år.

Anställningen ingår i tenure track-systemet vid KTH och den biträdande lektorn har möjlighet att efter ansökan prövas för befordran till lektor.

Vi undanber oss all kontakt med bemannings- och rekryteringsföretag samt försäljare av ytterligare jobbannonser.

Anställningsform	Visstidsanställning längre än 6 månader
Anställningens omfattning	Heltid
Tillträde	Enligt överenskommelse
Löneform	Fast lön
Antal lediga befattningar	1
Sysselsättningsgrad	100%

Ort Stockholm
Län Stockholms län
Land Sverige
Ref. nr. **?????**
Kontakt Sandra Di Rocco, professor Tel: 08-790 71 68/ email: dirocco@kth.se, ????, handläggare, frågor ang. ansökan Tel: ???/ email:???.

Publicerat 2018-??-??
Sista ansökningsdag 2018-??-??
Länk till annons http://kth.mynetworkglobal.com/what:job/jobID:???/

WASP - ASSISTANT PROFESSOR OF ALGEBRAIC TOPOLOGY AND MATHEMATICAL STATISTICS IN ARTIFICIAL INTELLIGENCE

KTH proposes an assistant professorship in Algebraic Topology and Mathematical Statistics in Artificial Intelligence. We aim at recruiting a prominent young researcher with a high Mathematical profile and with potential to contribute with breakthrough advances towards the new mathematical research area of Statistical Topological Data Analysis (TDA).

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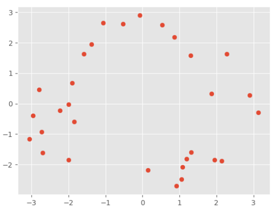
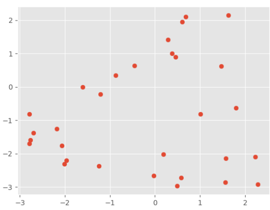
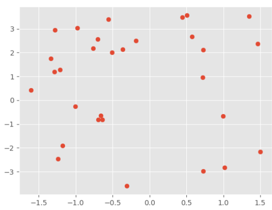
What does it mean to make an intelligent decision from data? Consider for example the following collection of points in the plane:

When do we start to realize that the leftmost are points from a (noisy) sampling on a circle, the middle ones from a triangle, and the third from a rectangle? Why is this ability to infer the underlying 'shape' regarded as a sign of intelligence? Or maybe the truth behind these pictures is the fact that they describe only a one dimensional void?

Unsupervised learning. The above is an example of unsupervised learning, which is the task of inferring a hidden structure from 'unlabeled' data. Since the data is unlabeled, there is no ground truth that can be used when the algorithm is trained against data, which is one way of distinguishing unsupervised learning from supervised learning and reinforcement learning. Unsupervised learning can be a goal in itself (discovering hidden patterns in data) or a means towards an end (feature learning). The latter refers to a set of techniques that allows a system to automatically discover the representations needed for feature detection or classification from raw data. Unsupervised learning is a key element in AI, especially since data associated with many decisions is unsupervised.

In the above example, much of the information content is already captured by identifying the underlying shape and often this is all that is needed for decision making. Intelligent decision making, or Artificial Intelligence (AI), is often identified with the ability to simplify the data while retaining its information content relevant for the decision making. Thus, unsupervised learning is a key enabler for AI and there are several approaches for unsupervised learning, each involving different sub-disciplines of mathematics. Examples are manifold and dictionary learning (sparse signal processing, computational harmonic analysis), topological data analysis (topology, algebraic geometry), and Bayesian networks (mathematical statistics).

The suggested research topic *Algebraic Topology and Mathematical Statistics in AI* seeks to capitalize on possible synergies that come from combining these approaches. The strong and diverse research environments within the Department of Mathematics at KTH is an excellent location for pursuing such a program. The focus is on developing methods applicable to cases where it is difficult, or even impossible, to compare data points directly. Instead, one needs to base the decision making on the underlying geometrical structure in data, where the main information content is available. An example of this situation is in analysis of microarray readings of DNA expression levels. The recorded data depends not only on the device but also on humidity levels when the measurements are recorded as well as other similar environmental factors. Even after normalization, it does not make sense to compare microarray data sets against each other directly. Hence, standard data analytic tools that rely on a metric between measurements will not be suitable for analysis of such data. This is in fact the typical scenario when data is highly heterogeneous and noisy, with big variability, or where some portion of it is missing.

Topological data analysis (TDA). Topology is a sub-discipline of mathematics focusing on various homological invariants and signatures of geometrical objects. Homological invariants are ideal for identifying basic characteristics of geometric objects that do not depend on the accuracy of measurements but rather rely on a notion of proximity and shape. The fundamental problem of using homology in data analysis however is that its outcomes are not suitable for statistical analysis, for example it makes no sense to take the average of homologies of some collection of spaces. That is why so far TDA techniques have been used only as exploratory tools. We believe that this can be changed. As an example, it is quite remarkable that properly defined homology based invariants are sufficient for distinguishing between the three point clouds illustrated above. A crucial step in this analysis is to use homology based invariants that satisfy the law of large numbers. The TDA group at KTH has developed such invariants.

Homological invariants were originally introduced to study topological spaces with controllable cell decompositions, e.g., projective spaces, Grassmann varieties, Lie groups, manifolds etc. Homological invariants of spaces obtained by taking measurements of objects in our environment have fundamentally different characteristics from these classical spaces, e.g., they are typically of very large rank. Consequently, effective use of such homology based invariants from TDA, requires analyzing these invariants with statistical techniques, which in turn requires developing a *new mathematical theory* that combines methods from topology, numerical methods, statistics and probability.

We strongly believe the above can become one of the next standard tools in data analysis and that combining statistics and TDA is presently the most significant research front in TDA and will be so for the forthcoming years. There are already some commercial successes based on these ideas, e.g. AYASDI (USA). However, a lot of fundamental research needs to be done to fully understand potentials and limitations of TDA, and in particular how it is to be combined with statistical analysis.

The above was pointed out already several years ago by Robert J. Adler, a statistician from Technion, who gave a series of talks and wrote several articles aiming at 'convincing statisticians and probabilists that there is an entire new area of applied algebraic topology out there crying out for probabilistic modeling and statistical analysis'. The need for mathematical research aiming at statistics of topological and homological invariants has grown even further since then, mainly due to the growing evidence of the relevance of topological and homological information in a variety of applications, e.g., road network reconstructions, neuroscience, vehicle tracking, object recognition, protein structure analysis, and nano-characterization of materials.

Sweden and KTH can play a significant role in pursuing the above agenda within the WASP program and the department of Mathematics at KTH is in a particularly favorable position to host such an initiative, much thanks to strong scientific excellence in a wide range of fields in the mathematical sciences (mathematical statistics, algebraic topology and geometry, mathematical analysis) along with research groups in TDA, Mathematical Imaging Sciences, and the newly formed Brummer & Partners MathDataLab.

Data integration and statistical learning. The first step in unsupervised learning applied to a dataset $\mathcal{D}$ is to choose a function $m\colon \mathcal{D} \to X$ into a set with a notion of distance (a metric space). Such a mapping allows us to measure distances between data elements in $\mathcal{D}$. Note that elements in $\mathcal{D}$ may be rather complex, e.g., a data element can represent readings from different sensors or information in the form of natural language text. The function m will in principle assign a distance between such complex objects.

An issue that immediately arises when handling *heterogeneous* data is that there is never a good choice for such a function. There might be choices for it if all data were natural language data or readings from the same type of sensors, but for heterogeneous data we quickly run into trouble regarding the choice of m. Even for data of the same type (not heterogeneous), one may face inconsistencies making it meaningless to compare values. These are typically due to high levels of noise, inconsistent data acquisition protocols and/or pre-processing steps. For such cases, m should only be interpreted as a notion of proximity rather than a precise distance. Standard statistical techniques, like manifold learning, do unfortunately require more precise notions of distance if they are to be applicable, making these methods unsuitable for data of the above kind.

Understanding the shape of a data set should on the other hand not require using a precisely defined notion of distance. In fact, it is clear that a robust approach for identifying the shape of a data set should not depend that much on a precise notion of distance.

[4] In its initial form TDA will generate the units to be used in the learning process. The mere integration of data from various sources does not as such generate value. Advanced learning models based on the variables found are needed to enable data-driven optimization. There are typically many models from a diversity of model families that are applied together to solve the broader optimization problems.

The model families of statistical learning theory are, e.g., layered neural networks, radial basis functions, normal, binomial and multinomial mixtures, mixtures of statistical models reduced rank regressions, Boltzmann machines, Bayesian networks, hidden Markov models and stochastic context-free grammars. These families of models are characterized by: (1) constructed of superposition of parametric functions; (2) hierarchical structures; (3) hidden variables; (4) several information processing modules; (5) are constructed to obtain knowledge from random samples; (6) estimate probabilistic grammars. The scientific basis for the TDA/statistics concept is thus the realization that we may use topological data analysis both in the formation of the primary concept of similarity of units and on modeling and statistical learning of those units based on samples of them.

Causal modeling. The subject of data analysis is presently undergoing fundamental changes. The main connecting idea is an attempt to systematically look at causal connections. Causal modeling has over recent years become a major topic, with emphasis on graphical models, networks, Bayesian nets and counter-factual models. Today much more extensive data are collected over time than has previously been the case. New methods for causal analysis can elucidate the effects of changes and developments over time. The new ideas on causality are not a panacea, solving all problems of causality, but they do represent a more systematic approach to this difficult field.

By learning from data one customarily means the process of gaining knowledge about or understanding of the mechanism of the source that generates the data. This can be done by use of models, which serve as the grammar in which the constraints (e.g., independence, cyclic variation, causal influences) predicated to the data can be described.

The challenge of data integration to statistical learning is that the data is coming from too many disparate sources (big variety). Standard statistical methods are concerned in combining information from different data sources and making statistical predictions from the resulting summaries, e.g., Bayesian posterior predictive distributions, to prospective measurements on the same or other units. Such predictions are useful only when the units are judged to be similar or comparable. Such judgments must precede the application of any probability-based modeling. We claim that judgments of this type should be based on data; the question is precisely how data and contextual information are used to make them. Here the role of formal statistical methodology is often minimal, with the difficulty lying in the decision about what in the stream of data is relevant. Here we see the role of TDA as the key to handle the challenge of data integration. Our scientific goal and vision is that the new, hierarchic notions of distance in TDA will be the logic of similarity that gives the concepts of modeling that are more primary than probability.

Correlations and multi parameter TDA. In applications it is crucial and critical to understand relations between different parameters, for instance how readings of various sensors correlate to each other. Developing mathematics relevant to encoding and understanding such correlations is therefore essential and needed. Traditionally one only looks for functional correlations. This is related to a so called 1 parameter persistent analysis in TDA. Looking just for functional correlations is however not enough to understand more involved relations between different parameters. There is some evidence indicating that TDA's multi parameter homological invariants may provide tools to address some aspects of this problem. By varying the parameters the homological invariants form modules over the polynomial ring in several variables (each variable corresponds to a different parameter). Understanding such modules, obtained from data sets, is the objective of so called multi parameters persistence. Most of the efforts to understand the multi parameters persistence so far has been about adopting methods of commutative algebra and algebraic geometry. In our view this approach is one of the reasons underlying the progress in the subject. The moduli of multi-graded modules with a fixed Hilbert polynomial or dimension table is a very complicated algebraic variety, moreover current computational commutative algebra methods can only handle modules with very low rank, while most of the modules coming form data sets have large ranks. Furthermore, classical commutative algebra invariants such as rank, Betti diagrams, Hilbert polynomials etc. are not stable in a sense that small changes in data sets can lead to very big changes of the invariants of the corresponding modules. For data analysis purposes we need to develop an entirely new set of stable invariants of such modules. The first such invariant, not obtained simply by restricting to 1-parameter submodules, has been constructed by the TDA group at KTH. The key guiding principle in its construction was not the algebra, but the need for statistical analysis of the outcome. We believe this need for statistical modeling and analysis can lead to further progress in multi parameter persistence.

Autonomous systems acting in collaboration with humans. Making decisions based on measurements and observations is essential for building autonomous systems. For such systems to interact with humans we need to be able to simulate and predict outcomes of human decisions. The flood of information, and not the lack thereof, is often the key prohibitive factor to make an adequate decision. Humans are remarkable at focusing on essential characteristics of the data relevant to the problem and ignoring irrelevant information. These are simply the flood processes which we need to be able to simulate. There is growing evidence that some of these processes (for example shape recognition) can be simulated well with help of topological invariants. The ability of making statistical decisions and predictions based on these invariants is therefore crucial. Bridging TDA and mathematical statistics is currently one of the key research fronts in TDA. We believe that there is a realistic hope to make a progress towards reaching this goal within the next 5 years.

Software as the main enabler in autonomous systems. The Homological invariants of spaces which TDA aims to understand are typically very large. To analyze these examples, test hypothesis, and look for patterns it is necessary to use computer analysis and adequate software. An integral part of this proposal is to develop relevant algorithms and turn them into software which can be used to experiment enabling us to improve both the theory and its implementation.

Putting Sweden in the center of TDA research. There is a growing interest in the subject of TDA. Funding for related projects has been growing outside of Sweden, for example: (1) at EPFL (Lausanne) a Laboratory for Topology and Neuroscience has been formed; (2) although currently there is no Horizon 2020 calls in mathematics, a consultation is under way to change this in the future, where 5 new math related subjects are considered and among them TDA is mentioned explicitly; (3) Fujitsu Laboratories announced a plan to make time-series data classification technology based on deep machine learning and TDA to be the core in its systematic approach to artificial intelligence; (4) A Center for Topological Data Analysis has been formed spanning across 3 UK universities (Liverpool, Oxford, Swansea). This development happens since many believe it is the right time to invest in TDA as there is enough basic ideas and illustrative examples present to transform the subject into a powerful data analytic method in the near future. This transformation however can not happen without investment into mathematical foundations for TDA which would lead to these methods being implemented, tested and integrated into a decision making process. This task requires a close collaboration between topologists, statisticians, computer scientists, experts on data generation/collection, and data/problem owners. KTH mathematics together with WASP are in a particularly favorable position to make such a collaboration happen and be successful. Sweden has an opportunity to become one of the key centers for the development and implementation of TDA, an opportunity that should not be missed.

3. A description of how to advertise the position

3.1. **Advertisment.** The position will be advertised nationally and internationally, on the KTH website, and the main international communities: `mathjobs.org`, the American Mathematical Society (AMS), European Mathematical Society (EMS), the Institute for Mathematical Statistics (IMSTAT) and subjects related networks.

3.2. **Timeline.** The anticipated timeline for the hiring process is as follows:

09/2018 Announcement of the position
11/2018 Application deadline
01/2019 External review
02/2019 Interviews
03/2019 Hiring
08/2019 Candidate starts at KTH

The above schedule would require the documents for the proposed position to be forwarded from the department to be handled at KTH either before the summer of 2018 or immediately after the summer. We would aim towards having interviews held in February, as this would coincide timewise with offers made by leading US universities.

3.3. **Qualifications and potential candidates.** We are primarily seeking a candidate with excellent potential for a prominent future academic career in Algebraic Topology and Mathematical Statistics. The candidate is expected to have a strong background (including a PhD) in mathematics or applied mathematics, closely related to one or several of the topics mentioned in the research proposal. The qualifications of the candidate must be supported by publications in top-level journals, and demonstrated research interest in artificial intelligence or machine learning. The candidate is expected to have international experience (PhD or Postdoc) and a broad, documented, international research network. The candidate is likely to be a late career Postdoc or early career assistant professor. Here is list of potential candidates (in alphabetical order):

Magnus Bakke Botnan (T U Munchen), Michael Catanzaro (University of Florida), Michael Lesnick (Princeton Neuroscience Institute), Martina Scolamiero (EPFL in Lausanne), Sara Kalisnik Verovsek (Standford, Leipzig).

3.4. **Evaluation process.** The candidates will be thoroughly examined and ranked by external reviewers. The combined competence of the external reviewers is expected to include:

- Algebraic topology and its applications in data analysis
- Mathematical statistics and stochastic processes related to geometrical and spatial information.

Suggestions for external reviewers: Robert J. Adler (Technion), Frédéric Chazal (INRIA, France), Herbert Edelsbrunner (Institute of Science and Technology Austria), Robert Ghrist (University of Pensilvenia), Ulrike Tillmann (Oxford), Yasuaki Hiraoka (Yasuaki Hiraoka Lab, Tohoku U. Japan).

4. The academic environment relevant for the position

4.1. **Research environment.** The following faculty at the Department of Mathematics of KTH have the most relevant expertise for this proposal:

- The Algebraic topology and Homotopy theory: Tilman Bauer, Wojciech Chacholski.
- The Computational and applied algebraic geometry: Wojciech Chacholski and Sandra Di Rocco.
- The TDA and Computational methods for topological invariants: Wojciech Chacholski.
- The Computational methods and Generative models: Henrik Hult.
- The Bayesian networks, Hidden Markov models, and Computational methods: Timo Koski.
- The Inverse problems, mathematical analysis, and Generative models: Ozan Öktem.

There is a wide spectrum of world class research groups and researchers represented at the Department of Mathematics of KTH that would provide support and stimulating environment for the proposed WASP assistant professor. Examples are the division of Mathematical Statistics, Combinatorics group, Random matrices group, Algebra and Geometry group, Brummer & Partners MathDataLab, and Mathematical Imaging Sciences group.

Most of the above mentioned divisions and groups are well established with a long tradition of scientific excellence. In contrast the *Algebraic Topology* group was formed only eight years ago. During this period however the group has seen a rapid expansion. There are now two permanent members (Tilman Bauer and Wojciech Chacholski). The group has attracted Göran Gustafsson Foundation, VR and Knut and Alice Wallenberg Foundation grants as well as EU funding. Algebraic topology has seen a similar expansion at Stockholm University. Together we have formed the *Stockholm Topology Center* to provide an umbrella for close collaboration. Most of our research activities such as seminars, visitors programs, conferences etc. are done jointly. In particular we have hosted the Young Topologists Meeting, a large meeting of 200 young researchers in algebraic topology. This meeting used to alternate between Copenhagen and Lausanne, but Stockholm is now a regular host to these conferences, which are the world's most important events for algebraic topologists at the beginning of their career. Stockholm, and in particular KTH, has become an important place on the algebraic topology map.

The TDA group at KTH has been formed 6 years ago. It currently consists of 3 PhD students, 1 post doc and the head of the group Wojciech Chachólski. Two students associated with the group obtained PhD degrees and they both work in research related to data analysis and/or TDA. Wojciech Chachólski has also supervised numerous master thesis related to TDA some of them co-advised with faculty from the mathematical statistics, robotics, and computer science departments. The group has an active collaboration with Karolinska Institute, particularly with the Genetic Epidemiology of Multiple Sclerosis group. Wojciech Chachólski is a partner in the MS consortium (see https://www.multiplems.eu) supported by the Horizon 2020 Framework Programme for Research and Innovation.

The Mathematical Imaging Sciences group within KTH was formed in 2014 by a large SSF-grant in applied mathematics. It encompasses about 10 people at any given time, among which 4–5 are faculty. Focus for the research is on regularization methods for ill-posed inverse problems arising in imaging, and much of the groups effort targets challenging problems in medical and biomedical imaging. Since the last two years, the group is pioneering the development of a new class of reconstruction methods that combine techniques from supervised machine learning with regularization theory and microlocal analysis. More precisely, one designs a deep neural network architecture for reconstruction that embeds a physics based simulator for the measured data.

Within the Division of Mathematical Statistics, Timo Koski is currently supervising two PhD students in causal statistical inference and in population biology. Moreover, he is leading a number of strategic collaborations in different research themes including causal inference with Karolinska Institutet, Multiple Sclerosis group and Institute of Environmental Medicine, population biology with Prof. Erik Aurell, theoretical Biophysics, KTH, Mats Gyllenberg, University of Helsinki and Prof. Göran Högnäs at Åbo Akademi University. In statistical learning theory he collaborates with Prof. Jukka Corander (University of Oslo) and with his group at Helsinki university. In Bayesian networks there is collaboration with Dr. John Noble, Mathematical statistics, University of Warsaw.

The Department of Mathematics at KTH is a host to the *Brummer & Partners MathDataLab*, a hub for mathematical research in analysis of complex data. Its activities focus on organizing conferences, workshops, seminars, and supporting top junior researchers, for instance by offering competitive postdoc positions. The lab aims at stimulating collaboration between existing faculty and surrounding institutions and facilitating the education of a new generation of mathematicians focused on foundations and implementations of novel methods for data analysis. Per-Gunnar Martinsson (Oxford) and Konstantin Mischaikow (Rutgers) are two international experts in the mathematics of data science who are on the scientific steering committee of the MathDataLab and have become affiliated professors at KTH. Konstantin Mischaikow is a world expert on TDA who was one of the pioneers of the subject. We believe the proposed WASP assistant professor will greatly benefit from the unique research environment provided by the MathDataLab.

4.2. **Educational environment.** The educational programs directed by the Department of Mathematics provide a natural environment to disseminate progress of the acquired knowledge within the proposed research area. Moreover, the programs provide a source for Master's students that can participate in research activities as well as a base for recruitment of doctoral students.

The Department of Mathematics at KTH is responsible for two Master's programs and two doctoral programs. The Master's program in mathematics is joint with Stockholm University and attracts 15-20 students annually, whereas the program in applied and computational mathematics is mainly run by the Divisions of Mathematical Statistics, Numerical Analysis and Optimization and Systems Theory and attracts about 80 students annually.

Presently the education towards probabilistic artificial intelligence lies mostly within the specialization in Statistical Learning and Data Analytics, where related courses include modern methods of statistical learning, topological data analysis, computational methods in mathematical statistics and statistical machine learning. There is an ongoing development to replace this specialization with a broader specialization called Mathematics in Data Science, aiming for a broader mathematical knowledge of the techniques behind complex data analysis and artificial intelligence. The new specialization will, in addition, offer courses in high-dimensional optimization, numerical multi-scale methods, probabilistic networks, etc. The new specialization is planned to start in the academic year 2019/20.

The Department of Mathematics has significant experience is supervision of Master's theses within the two Master's programs and, in recent years, the interest in topics related to artificial intelligence and machine learning has increased significantly. In the last three years, 2015-2017, the department has supervised about 250 Master's theses, of which roughly 40 are related to artificial intelligence and machine learning. With the new specialization in Mathematics of Data Science, those numbers are expected to increase in the coming years.

The Department of Mathematics provides two doctoral programs, in mathematics and in applied and computational mathematics, with about 30 doctoral students in each program. The doctoral programs offer third-cycle courses in probability, combinatorics, Bayesian networks, Markov processes, etc that link well to the proposed research area. The candidate will thus benefit from the presence of two strong doctoral programs in which there is significant interest in probabilistic artificial intelligence.

During the last decade, new data analytic tools have emerged with increasingly spectacular usages. As an example, TDA which is based on Algebraic Topology is applied to problems in road network reconstructions, neuroscience, vehicle tracking, object recognition, protein structure analysis, and nano-characterization of materials. However, addressing increasingly complex tasks, such as design of autonomous systems capable of interacting with humans, will require combing various techniques from mathematical statistics, topology and geometry. Clearly, this is required for unsupervised learning and data integration, but it will also be an important part of supervised learning.

One key issue is therefore to use TDA invariants not only for data exploration, but also for decision making. This requires *developing homology based invariants suitable for statistical analysis*, a topic that is currently one of the most significant research fronts in TDA. Two such invariants are presently available: persistence landscapes and signatures. The signatures have been developed by the TDA group at KTH. The signatures indicate that there is a realistic chance to develop robust homology based invariants suitable for decision making. Such a development will transform TDA from an exploratory method into a powerful data analytic method. Another key issue is lack of master courses on this subject at Swedish Universities, the first master course in TDA at KTH is given this academic year and will be a part of the standard curriculum of the Mathematics in Data Science specialization at KTH.

A final line of development concerns the role of homology based invariants in supervised learning. The central topic would be to develop generative models from mathematical statistics that account for a priori topological invariants, such as homology based invariants dictated by TDA. More precisely, a long-term vision is to design generative adversarial network architectures that allows us to randomly sample points from a probability measure that respects geometric and topological properties prescribed by TDA based invariants. Combined with embedding physics based simulators for how the supervised data is generated yields a very powerful tool that utilizes various different kinds of a priori knowledge for supervised learning. A concrete example of this is the recently developed novel deep CNN (Convolution Neural Network) architecture for sparse view tomographic reconstruction, which outperforms existing approaches in its computational speed as well as reconstruction quality. The proposed deep residual learning is based on the assumption that streaking artefacts from sparse view tomographic reconstruction have simpler topological structure, so learning streaking artefacts is easier than learning the original artefact-free images. One can thus use persistent homology to show that the residual manifold is much simpler than the original one and use this as part of the CNN architecture.

We therefore believe it is the right time to invest in mathematical research bridging Algebraic Topology and Mathematical Statistics. Our vision is that within 5–7 years TDA techniques will become standard methods that are tested and used within broad Swedish academic environment (robotics departments for example). Within 10–12 years these techniques will penetrate to Swedish companies specializing in data analysis services. The proposed WASP assistant professorship can make a significant difference in realizing this vision.

Table 1 includes a description of the cost of the actual position and its start package during the first 5 years. The department will cover the part of the overhead cost which is not financed by the WASP initiative.

Table 1. financial plan for position year 1-5

	Year 1	Year 2	Year 3	Year 4	Year 5
Teaching 25% GRU	350 tkr	350 tkr	350 tkr	350 tkr	350 tkr
Research 75% WASP	950 tkr	950 tkr	950 tkr	950 tkr	950 tkr
Ph.D student WASP	800 tkr	800 tkr	800 tkr	800 tkr	800 tkr
Drift	150 tkr	150 tkr	150 tkr	150 tkr	150 tkr
Postdoc WASP	1 Mkr	1 Mkr	1 Mkr	1 Mkr	1 Mkr

The existing research grants in the area have been already mentioned in section 4. TDA is one of the focus themes of the Brummer & Partners MathDataLab initiative. One of the incoming Postdocs is an expert on TDA and will be working with statistical learning. Brummer & Partners contributes with 15.5 Mkr in 5 years towards the Lab activities and the department is cosponsoring the Postdoc program. We expect a flourishing of research activities and research grants in Data analysis within the next 5 years.

The research group in Imaging and Statistics is currently supported by a generous SSF grant. The department is committed to strengthening this research area by announcing an associate professorship this spring, including a strategical research package for the first two years.

Biträdande lektor i matematik med inriktning mot sannolikhetsteori och kombinatorik inom artificiell intelligens

Kungliga Tekniska högskolan, Skolan för teknikvetenskap

KTH är ett av Europas ledande tekniska universitet och en viktig arena för kunskapsutveckling. Som Sveriges största universitet för teknisk forskning och utbildning samlar vi studenter, forskare och fakultet från hela världen. Vår forskning och utbildning omfattar såväl naturvetenskap som alla grenar inom teknik samt arkitektur, industriell ekonomi, samhällsplanering, teknisk historia och filosofi.

Skolan för teknikvetenskap bedriver frontlinjeforskning inom ett brett fält, från forskning inom grundläggande ämnen som fysik och matematik, till teknisk mekanik med tillämpningar inom bland annat flygteknik och fordonsteknik. Skolan driver och utvecklar civilingenjörsutbildningarna Teknisk Fysik och Farkostteknik, liksom utbildningsprogrammet Öppen ingång och ett flertal masterprogram.

Centret Wallenberg AI, Autonomous Systems, and Software Program (WASP) lanserar ett program för att utveckla matematiken inom AI, med målet att främja kompetensen inom AI i Sverige. Anställningen erbjuder en unik karriärmöjlighet, där innehavaren ska ha möjlighet att identifiera och utveckla forskningsområden, samt upprätta en långsiktig forskningsagenda som bidrar till KTHs och WASPs stora utmaningar inom matematik för AI.
Med anställningen följer forskningsresurser som innefattar finansiering för 5 post-doc år och en doktorand, samt projektrelaterade kostnader motsvarande 60 tkr/år.

Ämnesområde

Matematik med inriktning mot sannolikhetsteori och kombinatorik inom artificiell intelligens

Ämnesbeskrivning

Ämnesområdet omfattar grundläggande sannolikhetsteori och kombinatorik inklusive kombinatorisk optimering, som antas kunna öka förståelsen för eller komma till användning vid studier av artificiell intelligens. Exempel på sådan matematik är kausal inferens, kombinatoriska studier av riktade grafmodeller, probabilistiska studier av system med latenta variabler och andra multiskalmodeller; samt optimeringslära relaterat till sådana modeller.

Arbetsuppgifter

I tjänsten ingår forskning, undervisning, handledning och viss administration. Även undervisning med upp till 30% av arbetstiden ingår i tjänsten.
Anställningen ingår i en WASP-satsning gällande matematik inom artificiell intelligens och den biträdande lektorn blir ansvarig för en liten forskargrupp med minst en postdoktor och en doktorand.

Kandidaten förväntas bidra till verksamheten inom WASP-programmet och dess nationella aktiviteter samt inom matematikinstitutionen inklusive Brummer & Partners MathDataLab. Engagemang för den nya specialiseringen mot matematisk datavetenskap inom masterprogrammet i beräkningsmatematik och tillämpad matematik förväntas också.

Den biträdande lektorn kommer att ges möjlighet att vidareutveckla sin självständighet som forskare och få meriter som kan ge behörighet för en annan läraranställning där högre krav på behörighet är ställda (se 4 kap. 12 a § högskoleförordningen).
Den biträdande lektorn kommer att kunna ansöka om befordran till lektor i enlighet med 4 kap. 12 c § högskoleförordningen.

Behörighet

Behörig att anställas som biträdande lektor är den som har avlagt doktorsexamen i matematik eller tillämpad matematik eller har motsvarande vetenskaplig kompetens. Främst bör den komma i fråga som har avlagt doktorsexamen eller har nått motsvarande kompetens högst fem år innan tiden för ansökan av anställningen som biträdande lektor har gått ut. Även den som har avlagt doktorsexamen eller har uppnått motsvarande kompetens tidigare kan dock komma i fråga om det finns särskilda skäl. Med särskilda skäl avses ledighet på grund av sjukdom, föräldraledighet eller andra liknande omständigheter.

Bedömningsgrunder

Som bedömningsgrunder vid anställning som biträdande lektor vid KTH gäller de bedömningsgrunder som anges i avsnitt 1.3. i KTH:s anställningsordning i förhållande till fastställd anställningsprofil.

Det är av *högsta betydelse* att den sökande har

- vetenskaplig skicklighet visad genom vetenskaplig publicering inom ämnesområdet.
- potential till meritering för högre läraranställning. Häri inbegrips potential till självständig utveckling som forskare och lärare inom aktuellt ämnesområde samt förmåga till etablering, förnyelse och utveckling av ämnesområdet.
- Internationell forskningserfarenhet och potential att stärka forskningsområdet inom Sverige.

Det är av *näst högsta betydelse* att den sökande har

- intresse för och insikter rörande pedagogisk utveckling inom ämnesområdet.
- postdoktorsvistelse i annan forskningsmiljö än det lärosäte den sökande disputerat vid.

Det är *även av betydelse* att den sökande har

- intresse för och insikter rörande ledarskap i akademin, samverkan med det omgivande samhället, samt medvetenhet om mångfalds- och likabehandlingsfrågor med särskilt fokus på jämställdhet.
- graden av administrativ skicklighet och annan skicklighet.

Särskilda bedömningsgrunder för befordran till lektor

Vid prövning av ansökan om befordran till lektor kommer den sökandes förmåga att självständigt initiera och driva forskning av hög vetenskaplig kvalitet, publicerad i internationella tidskrifter och konferensvolymer samt sökandes förmåga att erhålla finansiering av forskningsverksamhet att bedömas. Av högsta betydelse är den sökandes förmåga att självständigt etablera nya samarbeten och forskningsinriktningar. Av högsta betydelse är även att den sökande har visat skicklighet i undervisning samt handledning. Av högsta betydelse är även den sökandes förmåga att undervisa på svenska.

Fackliga representanter

Du hittar kontaktuppgifter till fackliga representanter på KTH:s webbsida.

Ansökan

Utforma din ansökan enligt KTH:s cv-mall för anställning av lärare. Du som sökande har huvudansvaret för att ansökan är komplett utifrån annonsen och cv-mallen. Ansökan ska vara KTH tillhanda senast sista
ansökningsdagen och du ansöker via KTH:s rekryteringsverktyg.

Övrigt

Tidsbegränsat till: Anställningen är tillsvidare, dock längst sex år, och kan förnyas om det på grund av lärarens sjukfrånvaro, föräldraledighet eller andra särskilda skäl krävs ytterligare tid för att uppnå syftet med anställningen. Den sammanlagda anställningstiden får dock omfatta högst åtta år.

Anställningen ingår i tenure track-systemet vid KTH och den biträdande lektorn har möjlighet att efter ansökan prövas för befordran till lektor.

Vi undanber oss all kontakt med bemannings- och rekryteringsföretag samt försäljare av ytterligare jobbannonser.

Anställningsform Visstidsanställning längre än 6 månader
Anställningens omfattning Heltid
Tillträde Enligt överenskommelse
Löneform Fast lön
Antal lediga befattningar 1
Sysselsättningsgrad 100%
Ort Stockholm
Län Stockholms län
Land Sverige
Ref. nr. **?????**
Kontakt Sandra Di Rocco, professor Tel: 08-790 71 68/ email: dirocco@kth.se, ???, handläggare, frågor ang. ansökan Tel: ???/ email:???

Publicerat 2018-??-??
Sista ansökningsdag 2018-??-??
Länk till annons http://kth.mynetworkglobal.com/what:job/jobID:???/

Anställningsprofil för biträdande lektor i matematik

Ämnesområde
Matematik med inriktning mot sannolikhetsteori och kombinatorik inom artificiell intelligens

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Kandidaten förväntas bidra till verksamheten inom WASP-programmet och dess nationella aktiviteter samt inom matematikinstitutionen inklusive Brummer & Partners MathDataLab. Engagemang för den nya specialiseringen mot matematisk datavetenskap inom masterprogrammet i beräkningsmatematik och tillämpad matematik förväntas också.

Den biträdande lektorn kommer att ges möjlighet att vidareutveckla sin självständighet som forskare och få meriter som kan ge behörighet för en annan läraranställning där högre krav på behörighet är ställda (se 4 kap. 12 a § högskoleförordningen).
Den biträdande lektorn kommer att kunna ansöka om befordran till lektor i enlighet med 4 kap. 12 c § högskoleförordningen.

Behörighet
Behörig att anställas som biträdande lektor är den som har avlagt doktorsexamen i matematik eller tillämpad matematik eller har motsvarande vetenskaplig kompetens. Främst bör den komma i fråga som har avlagt doktorsexamen eller har nått motsvarande kompetens högst fem år innan tiden för ansökan av anställningen som biträdande lektor har gått ut. Även den som har avlagt doktorsexamen eller har uppnått motsvarande kompetens tidigare kan dock komma i fråga om det finns särskilda skäl. Med särskilda skäl avses ledighet på grund av sjukdom, föräldraledighet eller andra liknande omständigheter.

Bedömningsgrunder

Som bedömningsgrunder vid anställning som biträdande lektor vid KTH gäller de bedömningsgrunder som anges i avsnitt 1.3. i KTH:s anställningsordning i förhållande till fastställd anställningsprofil.

Det är av *högsta betydelse* att den sökande har

- vetenskaplig skicklighet visad genom vetenskaplig publicering inom ämnesområdet.
- potential till meritering för högre läraranställning. Häri inbegrips potential till självständig utveckling som forskare och lärare inom aktuellt ämnesområde samt förmåga till etablering, förnyelse och utveckling av ämnesområdet.
- Internationell forskningserfarenhet och potential att stärka forskningsområdet inom Sverige.

Det är av *näst högsta betydelse* att den sökande har

- intresse för och insikter rörande pedagogisk utveckling inom ämnesområdet.
- postdoktorsvistelse i annan forskningsmiljö än det lärosäte den sökande disputerat vid.

Det är *även av betydelse* att den sökande har

- intresse för och insikter rörande ledarskap i akademin, samverkan med det omgivande samhället, samt medvetenhet om mångfalds- och likabehandlingsfrågor med särskilt fokus på jämställdhet.
- graden av administrativ skicklighet och annan skicklighet.

Särskilda bedömningsgrunder för befordran till lektor

Vid prövning av ansökan om befordran till lektor kommer den sökandes förmåga att självständigt initiera och driva forskning av hög vetenskaplig kvalitet, publicerad i internationella tidskrifter och konferensvolymer samt sökandes förmåga att erhålla finansiering av forskningsverksamhet att bedömas. Av högsta betydelse är den sökandes förmåga att självständigt etablera nya samarbeten och forskningsinriktningar. Av högsta betydelse är även att den sökande har visat skicklighet i undervisning samt handledning. Av högsta betydelse är även den sökandes förmåga att undervisa på svenska.

WASP - ASSISTANT PROFESSOR OF PROBABILITY AND COMBINATORICS IN ARTIFICIAL INTELLIGENCE

KTH proposes an assistant professorship in Probability and Combinatorics in Artificial Intelligence. We aim at recruiting a prominent young researcher with a high mathematical profile and with potential to contribute with breakthrough advances towards the mathematical research areas of Probability and Combinatorics.

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1. Probability and Combinatorics in Artificial Intelligence

Intelligence is a quality that enables an entity to function appropriately and with foresight in its environment (Nils. J. Nilsson). *Artificial intelligence* (AI) analyzes the computational foundations and mechanisms of intelligence and the architectures underlying thought and intelligent behavior. The "AI" nomenclature, and possibly even the initiation of the modern field, can be traced back to *A proposal for the Dartmouth Summer Project on Artificial Intelligence*, written by McCarthy, J., Minsky, M.L., Rochester, N., Shannon, C.E.. In this document, the main goal of AI was to discover how to make machines solve the kinds of problems reserved for humans. Key to how humans solve problems is our ability to rapidly learn from experience. Consequently, a core challenge of the WASP program is to develop software capable of learning through experience. This challenge is the focus of key subfields of AI including *probabilistic and decision-theoretic reasoning, statistical inference, optimization* and *machine learning.*

Recently, these subfields of AI have seen remarkable breakthroughs, many of which are due to thoughtful combinations of fundamental ideas from *probability* and *combinatorics.* Algorithms in AI embrace both of these perspectives. They associate a system of interest with a combinatorial object, such as a network, and then use observational data to infer desired probabilities based on the network structure. For example, the combinatorial object of a *neural network* can be used within *generative models* to make inferences about latent variables based on observed data. Similarly, algorithms for learning *Bayesian networks* rely on combinatorial characterizations of conditional probabilities. Due to the size of the problems, combinatorial optimization is often essential in making such inferences. Consequently, there is a need for research groups that work to develop and combine contemporary theory in both probability and combinatorics with an eye towards applications in AI, specifically within machine learning and statistical inference. Below we highlight some of the core research topics to be considered: namely *causal inference with probabilistic graphical models* and *learning in the presence of latent variables.* We seek a young mathematician of highest standard that will contribute to the fundamentals of the mathematics behind one or more of these topics.

Causal Inference. A fundamental problem within AI is to efficiently learn the structure of complex cause-and-effect systems. This is formalized as the problem of learning *probabilistic graphical models*, which constitutes a powerful coalescence between probability and graph theory. Graphical models use graphs with various edge types (directed, bidirected, etc.) to encode conditional independence (CI) relations amongst random variables, with nodes corresponding to random variables and the edges encoding dependencies. Equipped with a well-chosen graphical model, an AI can perform inference and improve its conditional interactions. However, the structure of this graph must first be *learned* from data. Consequently, the *main problem of causal inference*, i.e., learning an unknown graphical model from data, has become central to machine learning. This problem is a *graph learning problem*, and benefits from the field of graph theory in combinatorics. Causal inference has also seen a recent influx of contemporary combinatorics, with algorithms using objects like *generalized permutohedra*, *imset polytopes* and other polytopes.

The fundamental graphical model is known as a *Bayesian network*, or *DAG model.* A *directed acyclic graph* (DAG) is a graph $\mathcal{G} = ([p], A)$ with node set $[p] := \{1, \ldots, p\}$ and a collection A of *arrows* $i \to j$ between nodes such that following any path in the direction of the arrows can never return you to a previously visited node. A Bayesian network (DAG model) assigns a random variable X_i to each node $i \in [p]$. It then uses the arrows of $\mathcal{G}$ to encode conditional dependencies between the variables and the absence of edges to encode the collection of conditional independencies: $\mathcal{C}(\mathcal{G}) := \{X_i \perp\!\!\!\perp X_{ND(i)} \mid X_{Pa(i)} : i \in [p]\}$, where $X_{ND(i)}$ and $X_{Pa(i)}$ respectively denote the collections of random variables corresponding to the non-descendants of

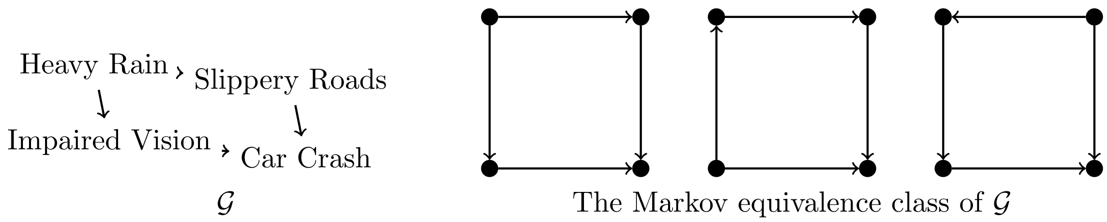

FIGURE 1. A Bayesian network $\mathcal{G}$ encoding the causal relations of four events and the three DAGs in its Markov Equivalence Class (MEC).

i and parents of i in $\mathcal{G}$. If the CI relations $\mathcal{C}(\mathcal{G})$ hold in the joint distribution $f_{\mathbf{X}}$ of the random variables $X_1, \ldots, X_p$ then the distribution factors as a product of conditional densities, in which each variable is considered relative to its direct causes: $f_{\mathbf{X}} = \prod_{i \in [p]} f_{X_i \mid X_{Pa(i)}}$. Conversely, a distribution defined as a product of any such local conditional densities entails the CI relations $\mathcal{C}(\mathcal{G})$. This factorization allows us to infer marginal and conditional probabilities using prior knowledge by way of Bayes' Rule, a process called *inference* in machine learning.

Since a Bayesian network completely encodes the variables and their relationships, inference can be done efficiently as long as we know the DAG $\mathcal{G}$. Thus, in simple cases an expert can define the DAG $\mathcal{G}$ and proceed. However, in most systems encountered by automated (or autonomous) systems, the DAG $\mathcal{G}$ is much too complex to be identified by a human. Therefore, one of the main challenges facing the AI community is a *combinatorial* problem; namely, find efficient ways to learn the structure of the DAG $\mathcal{G}$ based on data.

Stated in its simplest form the goal of this learning problem is to identify the underlying DAG $\mathcal{G}$ based on a collection $\mathcal{C}$ of CI relations obtained from observational data. However, this problem is not well-defined since multiple DAGs turn out to encode the same set of CI relations; see for example Figure 1. Instead, the goal is to learn the *Markov equivalence class (MEC)* of the graph, which can be combinatorially represented by a special type of *partially directed graph*. Unfortunately, both DAGs and their MECs grow in number at a super-exponential rate, ruling out the possibility of considering each DAG or MEC independently. Consequently, researchers have constructed a variety of algorithms that aim to efficiently and accurately learn the unknown MEC. Each such algorithm invokes a variety of combinatorial aspects of the MEC that draws on ideas already well-developed in graph theory, such as the shape and/or number of chordal subgraphs, or permutations that correspond to linear extensions of the DAGs within the MEC. Recent algorithms have even exhibited promising results by invoking newly popularized combinatorial structures such as the polytopes known as *generalized permutohedra*.

Beyond the basics, there exist a wide variety of important questions whose answers will inherently be both probabilistic and combinatorial in nature. For instance, algorithms that use additional *interventional data* are being developed to better learn *which member* of the MEC is the true DAG. However, such provably reliable algorithms only accommodate small graphs, and thus need to be scaled up to accommodate more realistic scenarios. In this respect we envisage that combinatorial optimization, most likely new combinatorial optimization methods of stochastic nature, will be central for efficiently solving large-scale graph learning problems. At the same time, the combinatorial structure of Markov equivalence for more general graphical models using additional edge types is not yet well-understood. Such combinatorial results could greatly improve methods that aim to learn causal structures in the presence of *latent variables*.

Latent variable models in artificial intelligence. Data are fundamental in all AI and machine learning systems. In most situations where an AI is learning from experience, it is, in principle, making inferences about latent variables on the basis of observed data. The latent variables may represent images or signals that are visible to the automatic learner only in a perturbed or transformed state, or they may represent features or abstractions of the observed data. In the probabilistic approach to AI, the learner's prior assumption on the relation between the latent and observed data is described by a probabilistic model. Such a model can be described in a multi-layer or combinatorial, typically graphical, framework, where higher layers correspond to higher levels of abstractions. Operating with the model and observed data, learning amounts to transforming prior understanding - as represented by the model - of the task into posterior knowledge of the latent variables generating the received observations. The complexity of the underlying probabilistic model may vary, sometimes being quite simple. However, diverse and increasingly challenging learning tasks now involve dynamical phenomena, and thus require models comprising sequences of distributions evolving recursively in time.

A simple, but powerful, latent variable model is the *hidden Markov model*, which is a dynamic latent variable model on two levels. Here, an unobserved Markov chain, representing the latent variable, is only partially observed. Conditional upon the states, the observations are mutually independent and such that the conditional distribution of each observation depends on the corresponding state only. The use of unobservable states makes hidden Markov models one of the most successful statistical learning ideas of the last forty years, and this generic model class handles a variety of real-world time series. A key goal of the proposed research area is to extend the ideas underlying hidden Markov models to more general latent variable models.

Generative models. Within the artificial intelligence community, generative models are being developed with the aim to produce samples of complex data structures that resemble real data. In statistical terms a generative model is a mechanism that produces samples from a, often high dimensional, parametric distribution. Generative models are used for producing artificial samples of images, natural language, voice and sound, video, times series, financial data, etc. Probabilistic models have been developed for many complex phenomena and sampling from such models is used abundantly in Monte Carlo methods across a wide range of disciplines. When the underlying data generating mechanism is largely unknown, as is the case in e.g. natural images, the particular features of the data cannot easily be characterized and built into the model at the outset, and instead they must be learned from the observed samples. In such instances latent variable models are primary candidates for modeling. The latent variables represent higher level features or abstractions of the data and the observed data is described as a deterministic or random function of these features. The functions involved can, for example, be approximated using techniques from deep neural networks. The latent variable representation is key to the popular generative models used today, e.g. variational auto-encoders and generative adversarial networks (GAN). The future development of such models lie in the design of the latent variable structure. For instance, by introducing general Markov transitions between the different levels of abstractions and development of more efficient inference procedures.

Generative models play a key role in the development of AI systems when there is a lack of easily accessible data. For example, when developing AI systems for *cancer treatment*, where patient data may be scarce and highly regulated, a generative model can produce artificial data, that resembles real data, on which the decision system can be trained and evaluated. In this way, decision systems can be developed in an artificial environment for use in the real world.

Stochastic computational methods. To facilitate learning of complex data the training mechanism needs to be sufficiently fast. The training of probabilistic models requires the evaluation of the likelihood, which, for latent variable models, is given as an expectation of the conditional likelihood over the latent variables. In high-dimensional settings, sampling from the prior distribution typically gives very small likelihood, because it is unlikely to draw a latent variable that fits with the observed data. Importance sampling is a generic method for improving sampling efficiency of rare events, by sampling from a sampling distribution under which the event of interest is no longer rare. In recent years the development of efficient importance sampling algorithms have taken significant steps forward through the development of sequential Monte Carlo methods, Markov chain Monte Carlo methods (MCMC) and by considering asymptotic properties, based on large deviations theory, of the underlying stochastic models.

The sequential Monte Carlo methods (SMC) form a class of genetic-type algorithms approximating online (i.e., at constant computational and storage requirements) sequences of probability distributions, with unknown partition function, by sequences of empirical measures associated with samples of random draws with associated importance weights. The great generality and flexibility of the SMC methodology has together with the dramatic increase of computational power over recent years lead to a rapidly and steadily increasing interest in these methods during the last decades. Today sequential Monte Carlo methods are successfully applied within a wide range of applications, including, e.g., computer vision, machine learning, automatic control, signal processing, optimization, robotics, econometrics, and finance. A future grand challenge lies in developing the sequential Monte Carlo methods to high-dimensional settings to cope with the problems and complex data arising in artificial intelligence.

Markov chain Monte Carlo (MCMC) is a well established method for sampling from posterior distributions in Bayesian decision making and is equally popular in statistical physics for sampling Gibbs distributions. In the context of high-dimensional models encountered in artificial intelligence and machine learning standard implementation of MCMC may be slow because the energy landscape that defines the probability distribution is complex, with many local minima. Alternative designs, based on defining extended ensembles can facilitate faster convergence necessary for practical use in high-dimensional settings. Efficient designs can be mathematically analyzed within large deviations theory, which aims at characterizing the asymptotic properties of the resulting estimators. Recent progress of large deviations theory has led to the development of new efficient algorithms for complex computations in chemical and statistical physics, and the development of such mathematical techniques is likely to have a significant future impact on the computational methods used in artificial intelligence.

Optimization and inverse problems. The relation between latent abstract representations of knowledge and the observed data can, for instance, be described by a function that links the latent variables to observations and vice versa. Such a function can encode information of the relation between the latent variables and the observations, or, it can be largely unknown and parametrized by, e.g., a deep neural network. When learning the parameters of the latent model, one uses advanced optimization techniques to reconstruct the latent state, based on observations. In the context of small noise there is a close connection to inverse problems where the latent variable represents, say, the true image, but the observations are transformed versions of the true image.

In physics-based inverse problems there is an underlying function, or simulator, that explicitly models how the latent variables give rise to data. Such problems arise in applications in physics and engineering that are essential in medicine, material sciences, chemistry, and more. Here, it is often necessary to account for a priori information about latent variables, needed to stabilize an unstable (ill-posed) reconstruction procedure. An entirely data driven approach that disregards available knowledge regarding the simulator is unfeasible due to lack of sufficient training data and the computational burden resulting from a rich parametrization required to learn the simulator. Hence, there is a need for combining data driven and model based approaches.

2. Discussion the links to the grand challenges of AI

The central goal in artificial intelligence is to develop software systems capable of autonomous interactions with humans. Fundamental to such software systems are widely-applicable algorithms that learn through experience. Learning involves abstract representations of data, often in the form of latent variables.

Autonomous systems for human and superhuman learning and reasoning. Building autonomous systems for human or superhuman learning of complex patterns relies on effective representation of abstract features of data. There is deep interest and future opportunity ahead with developing software systems for unsupervised learning methods that can learn without predefined labels and can use high-dimensional and large scale data sets such as large images, videos, and multiple data modalities. A key aspect is the representation of complex patterns in the form of generative models, that automatically can learn patterns from data in an unsupervised setting and generalize these patterns by reproducing similar data. Much of machine learning has been focused on learning associations in preference to causality. Causal knowledge is a critical aspect of scientific discovery and engineering. A longstanding challenge is to identify causality in an automated manner. Latent variable models in general, and directed acyclic graphs in particular has the potential to address this issue.

Software systems for autonomous learning and interaction. There is deep interest and future opportunity ahead with developing software systems for unsupervised learning methods that can learn without predefined labels and can use high-dimensional and large scale data sets such as large images, videos, and multiple data modalities. The proposed research area addresses such issues in several ways by studying computational methods needed for developing affective software systems.

Reaching the frontier of mathematics for artificial intelligence. The study of probabilistic and combinatorial methods in artificial intelligence is embraced by a wide variety of research communities. For example, the 2017 *Conference on Uncertainty in Artificial Intelligence* hosted a Special Workshop on Causality that included talks by philosophers, physicists, combinatorialists, AI researchers, and statisticians. The 2018 conference on *Stochastic Processes and their Application* includes invited sessions on probabilistic methods in machine learning and the *2018 IMS Annual Meeting on Probability and Statistics* hosts several invited session on causal inference, graphical models, and related topics.

Strong programs in statistics and machine learning such as those of Caroline Uhler at MIT, Peter Bühlmann at ETH, Judea Pearl at UCLA, Milan Studený in Prague and Steffen Lauritzen at University of Copenhagen have made the problem of causal inference central to their research. It is also the focus of research groups in philosophy such as that of Peter Spirtes at Carnegie Mellon. The relevance of successful development of generative models is highlighted by, e.g., Google Deepmind's WaveNet technology currently used for generating voice for the Google assistant, and the development of deep generative models is receiving much attention at the leading artificial intelligence and machine learning conferences such as NIPS, IJCAI, ICML, and ICLR.

The department of mathematics at KTH is in a unique position to become a leading institution on research on probabilistic and combinatorial methods in artificial intelligence. The department hosts leading researchers in all relevant supporting areas such as combinatorics, discrete probability, causal inference, Bayesian statistics, stochastic computational methods, large deviations, inverse problems and optimization. The department also has well established collaborations with industry and data providers in this area.

3. Advertisement of the position and hiring process

3.1. **Advertisement.** The position will be advertised nationally and internationally, on the KTH website, and the main international communities: `mathjobs.org`, the American Mathematical Society (AMS), the European Mathematical Society (EMS), the Institute for Mathematical Statistics (IMSTAT) and subjects related networks.

3.2. **Timeline.** The anticipated timeline for the hiring process is as follows:

09/2018 Announcement of the position
11/2018 Application deadline
01/2019 External review
02/2019 Interviews
03/2019 Hiring
08/2019 Candidate starts at KTH

3.3. **Qualifications and potential candidates.** We are primarily seeking a candidate with excellent potential for a prominent future academic career in probabilistic artificial intelligence. The candidate is expected to have a strong background (including a PhD) in mathematics or applied mathematics, closely related to one or several of the topics mentioned in the research proposal. The qualifications of the candidate must be supported by publications in top-level journals, and demonstrated research interest in artificial intelligence or machine learning. The candidate is expected to have international experience (PhD or Postdoc) and a broad, documented, international research network. The candidate is likely to be a late career Postdoc or early career assistant professor. Here is list of potential candidates (in alphabetical order):

> Sebastian Banert (KTH), Daniel Irving Bernstein (MIT), Jonas Peters (U. Copenhagen), Preetam Nandy (U. Penn), Pierre Nyquist (T U Eindhoven), Liam Solus (KTH), Yuhao Wang (KTH), Caroline Uhler (MIT), Johan Westerborn (Uppsala), Hiva Ghanbari (Lehigh), Sabyasachi Chatterjee (U. Illinois).

3.4. **Evaluation process.** The candidates will be thoroughly examined and ranked by external reviewers. The combined competence of the external reviewers is expected to include:

- Graphical models/Bayesian networks
- Probabilistic methods in machine learning
- Large scale stochastic optimization

Suggestions for external reviewers: Francis Bach (INRIA), Peter Bühlmann (ETH), Michael Jordan (UC Berkeley), Steffen Lauritzen (U. Copenhagen), Eric Moulines (Ecole Polytechnique), Sofia Olhede (University College London), Katya Scheinberg (Lehigh), Milan Studený (Academy of Sciences of the Czech Republic).

4. Academic environment

4.1. **Research environment.** The Department of Mathematics at KTH offers an active and engaged environment for pursuing research on probability and combinatorics in artificial intelligence. There are world-class research groups with interest and documented excellence in the proposed research area including, probability, combinatorics, mathematical statistics and optimization and systems theory. The research area outlined in this proposal is supported by the expertise of several professors and researchers:

- Latent variable models, Bayesian networks, Hidden Markov models: Timo Koski, Jimmy Olsson
- Random graphs and combinatorics: Petter Brändén and Svante Linusson

- Generative models: Henrik Hult, Ozan Öktem
- Computational methods: Henrik Hult, Timo Koski, Jimmy Olsson, Boualem Djehiche, Anders Szepessy,
- Inverse problems: Johan Karlsson, Anders Szepessy, Ozan Öktem
- Large scale nonlinear optimization: Anders Forsgren

The excellence of the research environment in the area of this proposal is demonstrated through publications in top journals such as Annals of Mathematics, Annals of Probability, Annals of Statistics, Annals of Applied Probability, Inventiones, Journal of the AMS, Comm. Pure Appl. Math., etc. Researchers in the relevant research groups have also received numerous prizes and awards for their research, including

- *Wallenberg Scholar*: Kurt Johansson (2010).
- *Wallenberg Academy Fellows*: Petter Brändén (2013), Fredrik Viklund (2014), Karim Adiprasito (2017).
- *Wallenbergpriset i matematik*: Petter Brändén (2008), Fredrik Viklund (2014), Maurice Duits (2017).
- *Göran Gustafssons prize to young researchers*: Petter Brändén (2012), Henrik Hult (2011).
- *ERC Starting Grant*: Karim Adiprasito (2016).

4.2. **Industry research collaborations.** The Department of Mathematics has several ongoing industry collaborations on topics related to artificial intelligence and machine learning, which creates an attractive environment for a future assistant professor. The collaborative projects cover a broad range of application areas, from medical imaging and radiotherapy to scheduling and finance. Companies involved in such collaborations include: SEB, Elekta, Raysearch Laboratories, Philips, Brummer & Partners, etc.

4.3. **Brummer & Partners MathDataLab.** The Department of Mathematics at KTH is host to the Brummer & Partners MathDataLab. This is a newly minted lab with financing for (at least) the next five years. Its aim is to be a hub for mathematical research in analysis of complex data by conducting research, organise conferences, workshops and seminars, and related research activities. The MathDataLab supports top talent among junior researchers, for instance by offering competitive Postdoc positions, and aims to stimulate collaboration between existing faculty and surrounding institutions. The MathDataLab is currently hiring three two-year Postdocs starting in summer 2018. A further aim of the MathDataLab is to inspire and facilitate the education of a new generation of mathematicians focused on foundations and implementations of novel methods for data analysis.

Per-Gunnar Martinsson (Oxford) and Konstantin Mischaikow (Rutgers) are two international experts in the mathematics of data science who are on the scientific steering committee of the MathDataLab and have become affiliated professors at KTH.

The MathDataLab provides a unique environment for mathematical research into the foundations of AI and we expect that the proposed assistant professor will benefit greatly from the presence of the MathDataLab at KTH.

4.4. **Educational environment.** The educational programs directed by the Department of Mathematics provide a natural environment to disseminate progress of the acquired knowledge within the proposed research area. Moreover, the programs provide a source for Master's students that can participate in research activities as well as a base for recruitment of doctoral students.

The Department of Mathematics at KTH is responsible for two Master's programs and two doctoral programs. The Master's program in mathematics is joint with Stockholm University and attracts 15-20 students annually, whereas the program in applied and computational mathematics is mainly run by the Divisions of Mathematical Statistics, Numerical Analysis and Optimization and Systems Theory and attracts about 80 students annually.

Presently the education towards probabilistic artificial intelligence lies mostly within the specialization in Statistical Learning and Data Analytics, where related courses include modern methods of statistical learning, topological data analysis, computational methods in mathematical statistics and statistical machine learning. There is an ongoing development to replace this specialization with a broader specialization called Mathematics in Data Science, aiming for a broader mathematical knowledge of the techniques behind complex data analysis and artificial intelligence. The new specialization will, in addition, offer courses in high-dimensional optimization, numerical multi-scale methods, probabilistic networks, etc. The new specialization is planned to start in the academic year 2019/20.

The Department of Mathematics has significant experience is supervision of Master's theses within the two Master's programs and, in recent years, the interest in topics related to artificial intelligence and machine learning has increased significantly. In the last three years, 2015-2017, the department has supervised about 250 Master's theses, of which roughly 40 are related to artificial intelligence and machine learning. With the new specialization in Mathematics of Data Science, those numbers are expected to increase in the coming years.

The Department of Mathematics provides two doctoral programs, in mathematics and in applied and computational mathematics, with about 30 doctoral students in each program. The doctoral programs offer third-cycle courses in probability, combinatorics, Bayesian networks, Markov processes, etc that link well to the proposed research area. The candidate will thus benefit from the presence of two strong doctoral programs in which there is significant interest in probabilistic artificial intelligence.

5. Vision for the Development of the Research Area

A central goal in artificial intelligence is to develop software systems capable of autonomous interactions with humans. Fundamental to such software systems are widely-applicable algorithms that learn through experience. The following three challenges are cornerstone pursuits of the proposed research area, and each must be addressed in order to reach this goal.

(1) Develop efficient and reliable methods for learning in the presence of latent variables,
(2) Develop efficient and reliable techniques for learning causal relationships, and
(3) Develop *scalable* algorithms; i.e., algorithms useful for learning in the high-dimensional setting, or simply in the presence of a large number of variables and/or large data sets.

In recent decades, subfields of AI such as machine learning and statistical inference have taken the first major steps towards achieving these goals, and many of these achievements are due to effective combinations of probabilistic and combinatorial models. We now outline how the pursuit of each of these three goals will shape the development of the proposed research area.

Efficient and reliable learning in the presence of latent variables is among the most important challenges facing the AI community. An AI system conducting autonomous interactions with humans will naturally need to estimate probabilities conditional on both observed and latent variables. The design and training of latent variable models for AI relies on combinations of ideas from several fields, and it is currently unclear which combination of ideas will lead to the next big breakthrough. Will asymptotic analysis in large deviations theory lead to the development of sufficiently fast stochastic computational methods? Can generative models benefit from previously unused, or currently unknown, combinatorial methods for describing and analyzing hierarchical structures? Can innovative combinatorial descriptions of various latent variable models be used to reduce the complexity of learning a latent structure?

Of similar importance is the need for AI systems that can efficiently and reliably learn causal relationships. The framework of *probabilistic graphical models* presents a combinatorial approach to the efficient recovery of Bayesian networks up to their defining set of conditional probabilities when there are no latent confounders present. However, much work is needed to (1) extend the methods for Bayesian networks to more realistic models that include latent confounders, and (2) learn the *exact* causal structure when possible. New methods, for example in biology, are now able to produce large *interventional* data sets which allow for determining a causal structure beyond its Markov equivalence class. Can the current combinatorial and probabilistic modeling techniques be extended to accommodate these new, large data sets?

To truly meet the grand challenges facing the artificial intelligence community efficient and reliable algorithms, that are *scalable* to meet the needs of an autonomous AI system, must be developed. Consequently, the latent variable and causal inference algorithms discussed above must be able to accommodate (1) large numbers of variables, (2) large data sets, and (3) high-dimensional data. Research in stochastic computational methods aims to address these types of complex data through the development of *sequential Monte Carlo methods* applicable in high-dimensional settings. Similarly, new combinatorial methodology in causal inference that involve greedy simplex-type algorithms is being developed that allows for learning causal structures in the presence of both observational and interventional data. The scalability of such algorithms is currently a key questions for research focused on applications of AI to biological research.

These three goals have already served to shape the development of modern artificial intelligence research, and the research area highlighted in this proposal captures the cornerstone methodology that has resulted in the impressive breakthroughs seen in the last decades. Thoughtful combinations of probabilistic and combinatorial methods has been foundational to many of these results, and most certainly will continue to guide their future development.

6. Financial plan

Table 1 includes a description of the cost of the actual position and its start package during the first 5 years. The department will cover the part of the overhead cost which is not financed by the WASP initiative.

Table 1. financial plan for position year 1-5

	Year 1	Year 2	Year 3	Year 4	Year 5
Teaching 25% GRU	350 tkr	350 tkr	350 tkr	350 tkr	350 tkr
Research 75% WASP	950 tkr	950 tkr	950 tkr	950 tkr	950 tkr
Ph.D student WASP	800 tkr	800 tkr	800 tkr	800 tkr	800 tkr
Drift	150 tkr	150 tkr	150 tkr	150 tkr	150 tkr
Postdoc WASP	1 Mkr	1 Mkr	1 Mkr	1 Mkr	1 Mkr

The existing research grants in the area have been already mentioned in Section 4.1. Combinatorics and Probability as well as Optimization are central for the Brummer & Partners MathDataLab initiative. All the incoming Brummer & Partners Postdocs (2 already accepted and one is under negotiation) and some part of the existing research groups in combinatorics and mathematical statistics are key actors in the proposed research area. Brummer & Partners contributes with 15.5 Mkr in 5 years towards the Lab activities and the department is co-sponsoring the Postdoc program. We expect a flourishing of research activities and research grants in Data analysis within the next 5 years.

The research group in Combinatorics has had great success in attracting external funding. Karim Adiprasito, who was recently hired as associate professor and will start his position in January 2019, will strengthen the group's high level profile even more. He is an ERC consolidator grant receiver and one of the 2017 Wallenberg Academy Fellows.

The Division of Mathematical Statistics is a rapidly expanding group. We are currently recruiting two associate professors (interviews on March 23, 2018) and expect to appoint specialists in areas related to this proposal. These positions come with a strategic research package for the first two years of appointment.

Mathematics for WASP Grand Challenges
Call for proposals

1 Background

The expansion of Artificial Intelligence (AI), in the broad sense, is one of the most exciting developments of the 21st century. This progress opens up many possibilities but also poses grand challenges. The center Wallenberg AI, Autonomous Systems, and Software Program (WASP) is launching a program to develop the mathematical side of this area. The program will be conducted in close cooperation with leading Swedish universities with an aim to promote the competence of Sweden as a nation within the area of AI.

2 Aims and call

The purpose of the program is to develop strong and active research groups in areas connected to the WASP research agenda within areas of mathematics relevant to artificial intelligence. The call focuses on the recruitment of assistant professors and the creation of research groups.

The call is by invitation only and is targeted towards the mathematics departments of Chalmers/Gothenburg University, Linköping University, Lund University, Royal Institute of Technology, Stockholm University, Umeå University, and Uppsala University. Each invited department may submit at most two applications. An application is submitted by the head of department and should contain information about the items below. The required format is a single pdf document for which the maximum[1] lengths[2] of each section are indicated below.

- The research area in which the position as assistant professor is to be announced. 4 pages.
- A discussion on how this area links with the grand challenges of WASP. 1 page.
- A description of how to advertise the position and of the process of locating suitable candidates. This includes a time-line of the appointment process.

[1] This is a strict maximum and this amount of space should only be used if needed. On average the expectation is that around half the allowed space is sufficient.

[2] On A4-paper with standard margins and 11 point font.

The announcement must be broad and international. A list of potential candidates is helpful but not required. 2 pages.

- The academic environment relevant for the position. 2 pages.
- A vision for the development of the research area associated with the announced position covering a period of ten years. 1 page.
- A financial plan for the research group in which the position is allocated. 1 page.

All submitted documents should be in English.

3 Evaluation process and criteria

All proposals will be evaluated by an international committee. Evaluation criteria include.

- The quality of the academic environment of the research group.
- The commitment of the host department, in short and longer term perspectives.
- The relevance of the proposed research area to the mathematical principles behind AI.
- The intrinsic mathematical interest of the proposed research area.

Based on the international evaluation, some applications will be selected. To achieve nationwide coordination some adjustments of selected applications can be proposed by the national steering committee for WASP/AI/mathematics. After this finalization the positions are advertised and candidates evaluated by the normal procedures of the respective universities. The top ranked candidate is submitted to the WASP board for final approval.

4 Research areas

The program supports mathematics relevant to AI, where this concept is interpreted in the broad sense. The call is oriented towards long term relevance and foundations as opposed to immediate applications. As stated above the application is required to discuss the connections of the proposed research project to the grand challenges of the area.

5 Level of support

The expected size of a grant is to cover the salary costs for a period of 5 years for an assistant professor, one post-doc and one graduate student. Salary costs are calculated with an "LKP" level of 50 % and may include indirect costs to a maximum of 17.5%. The grant is also expected to include costs related to the project, such as travel expenses, up to a yearly level of 60000 SEK.

A candidate may, at the time of appointment, initiate a discussion with WASP to, under similar financial terms, modify the structure of the research group and the budget, to better suit the research agenda.

6 Additional details

When a proposed position is chosen to be advertised it is expected that the appointment will be funded. The final decision of funding is taken by the WASP board once a candidate has been selected by the university. The parameters of this decision are the quality of the candidate and the potential of the candidate to strengthen this research area in Sweden.

The questions of gender balance and diversity are of central importance and the search for candidates should take extra care to identify a wide selection of candidates. For a position which has two excellent candidates of which at least one is of under-represented gender the possibility of hiring two candidates will be discussed with the hosting university.

The application should be received by March 8, 2018 and should be sent to position@wasp-sweden.org. The applications should be submitted by the head of the department in which the position as assistant professor will be placed. The announcement of selected proposals will be done no later than June 1, 2018.

Any questions in connection with this call should be directed to Johan Håstad, by email to johanh@kth.se or by calling 070-565 5211.

From: Sandra Di Rocco dirocco@kth.se
Subject: Fwd: WASP-finansierade biträdande lektorat - mer info behövs till skolans strategiska råd
Date: 21 May 2018 at 15:32
To: Anna Delin annadel@kth.se

SD

Hej!

Se nedan (andra brevet från Johan), svaret från Johan.
Jag befogar också tidigare mail där det står att KTH fick två tjänster.

Mvh
Sandra

> Begin forwarded message:
>
> **From:** Johan Håstad <johanh@kth.se>
> **Subject: Biträdande lektorat WASP/AI/Matematik**
> **Date:** 23 April 2018 at 08:58:28 CEST
> **To:** Sandra Di Rocco <dirocco@kth.se>, me <johanh@kth.se>
>
> Kära Sandra,
>
> Vår internationella kommitte har nu utvärderat de förslag som kommit in på biträdande lektorat inom WASP/AI/Matematik. Det glädjer mig att meddela att vi går vidare med båda ers förslag
>
> Algebraic Topology and Mathematical Statistics in AI
>
> och
>
> Probability and Combinatorics in AI.
>
> Nästa steg är att skriva en formell tjänsteutlysning som vi kan presentera i mer eller mindre slutlig form för WASPs styrelse vid deras möte 24 maj (utskick av material inför det mötet sker 17 maj).
>
> Kan du skriva en första version av denna utlysning och skicka till mig så fort som möjligt och absolut senast 4 maj? Jag behöver versioner både på svenska och engelska då internationella kommitten har lovat att hjälpa till även i detta steg. Den internationalla kommitten betonar särskilt värdet av en bred utlysning för att kunna attrahera många sökande. Även programgruppen för matematik inom WASP kommer delta i det fortsatta arbetet att skapa en optimal utlysning.
>
> I diskussioner har vi även kommit fram till att det kan vara effektivt att samordna utlysningsprocessen av de fem eller sex tjänster som kommer utlysas i detta steg. Tanken är att gå ut med gemensam information i tidningar såväl som elektroniskt som pekar på utlysningarna vid repektive lärosäte. Vi funderar i så fall på en utlysning i början av september och sista ansökningsdag i slutet av september. Exakt koordinerar är inte nödvändig bara att annonsen kan gå ut när alla tjänster är aktuella, dvs utlysta och rimligt med tid kvar på ansökningstiden. Vi räknar dock inte med någon synkronisering av de olika tjänsternaefter ansökan. Tror ni att denna process skulle fungera för er?
>
> Jag vill passa på att påminna att, som beskrivet i utlysningstexten, slutgiltigt finansieringsbeslut tas av WASPs styrelse först när det finns en konkret kandidat till tjänsten men det finns medel reserverade för samtliga utlysta tjänster.
>
> Slutligen vore jag tacksam att du kvitterar att du fått denna information genom att svara på denna epost.
>
> Vänliga hälsningar,
>
> Johan Håstad
> WASP/AI/Matematik

——————————————————
Sandra Di Rocco
professor, Head of Mathematics Department

KTH Royal Institute of Technology
https://www.kth.se/profile/dirocco

> Begin forwarded message:
>
> **From:** Johan Håstad <johanh@kth.se>

Subject: **Re: Fwd: WASP-finansierade biträdande lektorat - mer info behövs till skolans strategiska råd**
Date: 21 May 2018 at 15:22:42 CEST
To: Sandra Di Rocco <dirocco@kth.se>

WASPs styrelse kommer förhoppningsvis besluta om att den stödjer nästa steg på torsdag.

Beslut om slutgiltig finansiering tas inte förrän det finns en kandidat, KAW ger bara ut pengar till individer.

Jag ser det som en formalitet, blir det en kandidat som KTH vill anställa ser jag ingen fara att WASP inte finansierar. Förutom att det inte finns något skäl att säga nej skulle det ge väldigt mycket bad-will.

Dock det enda beslut som kommer finnas är styrelseprotkollet från torsdag.

Frågan hur vi gör detta. Vi kan säkert få styrelsen att förklara punkten som omedelbart justerad men vilket papper vi kan få på detta är inte så uppenbar.

Johan

On 2018-05-21 14:28, Sandra Di Rocco wrote:

> Hej Johan,
> fick detta från vår vice-dekanus. För att kunna ha en chans att FR tar tjänsterna i augusti så måste de passera skolans strategiska rådet, som har sitt sista möte den 27/5.
> Finns det något beslut om finansiering jag kan skicka med?
> mvh
> Sandra
> ——————————————————
> *Sandra Di Rocco*
> professor, Head of Mathematics Department
> *KTH Royal Institute of Technology*
> https://www.kth.se/profile/dirocco
>
> > Begin forwarded message:
> >
> > *From: *Anna <annadel@kth.se <mailto:annadel@kth.se>>
> > *Subject: **WASP-finansierade biträdande lektorat - mer info behövs till skolans strategiska råd*
> > *Date: *21 May 2018 at 14:22:07 CEST
> > *To: *Sandra di Rocco <dirocco@kth.se <mailto:dirocco@kth.se>>
> >
> > Hej igen Sandra,
> >
> > har du kopia på något beslut från WASP att och hur dessa tjänster (TDAStatistics och ProbComb) finansieras?
> > Strategiska rådet bör ha tillgång till det som del av underlaget, så att de ser hur finansieringen ser ut.
> >
> > Vänliga Hälsningar,
> >
> > Anna

BESLUT	Datum:	Diarienummer:	KS-kod
	2018-03-28	S-2018-0425	2.2

Beslutat av Leif Kari, skolchef SCI	Expeditionsdatum 2018-03-28
Föredragande Lisa Johnsson, HR-ansvarig SCI	För åtgärd Arbetsgruppens medlemmar bestående av Lisa Prahl Wittberg, Fredrik Lundell, Jenny Jerrelind, Gunnar Tibert, Annika Borgenstam, Artem Kulachenko, Anna-Karin Burström, Erik Edstam (skyddsombud och representant för arbetstagarorganisation), Anna Wahl, Adam Sandström (THS), Anna Delin och Leif Kari (ordförande)
Övriga närvarande	För kännedom Samtliga medarbetare inom mekanikområdet på SCI, administrativ chef SCI, prefekterna SCI, rektor, vicerektor för forskning, dekanus, prodekanus, förvaltningschef, samtliga skolchefer, THS och arbetstagarorganisationer vid KTH

Tillsättning av och uppgifter för arbetsgrupp inom mekanikområdet på skolan för teknikvetenskap

Beslut

En arbetsgrupp utses med medlemmar bestående av Lisa Prahl Wittberg, Fredrik Lundell, Jenny Jerrelind, Gunnar Tibert, Annika Borgenstam (prefekt för institutionen för materialvetenskap vid skolan för industriell teknik och management), Artem Kulachenko, Anna-Karin Burström (gruppchef för administrationen inom mekanikområdet på SCI), Erik Edstam (skyddsombud och representant för arbetstagarorganisation, utsedd av arbetstagarorganisationerna vid KTH), Anna Wahl (vicerektor med ansvar för jämställdhet och värdegrund, professor i genus, organisation och ledning), Adam Sandström (studeranderepresentant utsedd av THS), Anna Delin och Leif Kari (ordförande). Arbetsgruppens uppgift är att ta fram förslag på framtida organisation av mekanikverksamheten vid skolan för teknikvetenskap för implementering 1 januari 2019. Utgångspunkten är att eftersträva en ämnesmässig samhörighet utan organisatoriska hinder och därigenom möjliggöra skapandet av en konsistent, framtida utbildnings- och forskningsstrategi i nära samarbete med varandra. Vidare ska arbetsgruppen föreslå styr- och finansieringsprinciper för infrastrukturen inom mekanikområdet, speciellt forskningslaboratorierna inom Odqvistlaboratoriet, för att säkerställa ett långsiktigt hållbart, ändamålsenligt och effektivt utnyttjande av dessa. En annan viktig utgångspunkt är att den nya organisationen ska åstadkommas genom konkreta förändringar av organisationsstrukturen och organisationskulturen, för ökad jämställdhet, förbättrad arbetsmiljö och säkrad generationsväxling inom mekanikområdet vid skolan för teknikvetenskap, där ledning och medarbetare på alla nivåer delar samma värdegrund och eftersträvar ett inkluderande förhållningssätt. Personella och ekonomiska konsekvenser ska belysas inklusive möjliga och eftersträvansvärda, framtida förändringar i programutbudet på grundnivå, avancerad nivå och forskarnivå inom mekanikområdet till följd av den nya organisationsstrukturen och intentionerna med den. Arbetet kommuniceras kontinuerligt med nuvarande prefekter för de tre institutionerna.

Ett första utkast på ny organisation ska avrapporteras senast 21 juni.

Bakgrund

Skolan för teknikvetenskap bedriver forskning och utbildning i bred bemärkelse inom fysik-, matematik- och mekanikområdena. Institutionerna för farkost och flyg, hållfasthetslära och mekanik ansvarar för mekanikområdet. Deras forskning och utbildning har blivit utvärderade både externt och internt ett flertal gånger under de senaste åren inkluderande Research Assessment Exercise (RAE) 2008, Education Assessment Exercise (EAE) 2011, RAE 2012, Vetenskapsrådets utvärdering av all forskning inom teknisk mekanik i Sverige (VR) 2012-13 och Universitetskanslerämbetets utvärdering av ingenjörs- och teknikutbildningar (UKÄ) 2012-13. Resultaten visar entydigt att både forskningen och utbildningen håller hög kvalitet och att det även finns stor potential till förbättringar. Bland annat visar VR 2012-13 att forskningen är inom intervallet excellent till enastående, RAE 2012 att forskningsmiljön bidrar i huvudsak till att producera forskning från internationellt erkänd till världsledande kvalitet, att forskningsmiljön bidrar i huvudsak till från betydande och enastående påverkan och engagemang i samhället till världsledande kvalitet och UKÄ 2012-13 att utbildningen håller hög kvalitet. Utvärderingarna visar även att organisationsstrukturen inom mekanikområdena skapar ologiska splittringar mellan olika ämnen och att dessa organisationsgränser är ett hinder för samarbete och i fall då samarbetet fungerar beror detta i första hand på bra personliga relationer (EAE 2011), att rekommendationen är att mekanikområdet inom skolan för teknikvetenskap bör ägna särskild uppmärksamhet åt skapandet av en konsistent, framtida forskningsstrategi i nära samarbete med varandra (RAE 2012) – splittringen är även uppenbar i VR:s utvärdering 2012-13 där de utvärderade, specifika ämnesområdena spände över flera organisationsgränser på skolan för teknikvetenskap, att andelen kvinnliga studenter inom flera utbildningsprogram och andelen kvinnliga lärare på skolan för teknikvetenskap är generellt lägre än för övriga KTH (EAE 2011) och att en jämnare könsbalans inom mekanikområdet inom skolan för teknikvetenskap är viktigt och att detta kommer att kräva mer aktiva åtgärder (RAE 2012). Det har heller inte skett tillräcklig fakultetsförnyelse inom vissa delar av mekanikområdet. Det finns således stor potential till förbättringar och det är nu hög tid att ta forskningen och utbildningen inom mekanikområdet på skolan för teknikvetenskap till en ännu högre nivå.

En utgångspunkt är Odqvistlaboratoriet för experimentell mekanik som spänner över alla tre institutionerna inom mekanikområdet på skolan för teknikvetenskap. Det bildades 2010 och har erhållit medel från både rektor (10MSEK) och Knut och Alice Wallenberg (KAW) Stiftelserna (23.6MSEK) för att utveckla och bygga teknologiplattformar för att stärka och utöka den experimentella forskningsverksamheten. Odqvistlaboratoriet som endast täcker den experimentella forskningsdelen av mekanikområdet på skolan för teknikvetenskap, saknar arbetsgivaransvar och drivs därmed mer som ett projekt än som en organisatorisk enhet, samt är starkt beroende av de tre institutionsledningarna. Detta har exempelvis inneburit att medel för ny mätutrustning från KAW Stiftelserna i realiteten först splittrats mellan de tillhörande laboratorierna vid de tre institutionerna och att (sub)optimeringen skett vid de tillhörande laboratorierna. Detta innebär att de verkliga strategiska besluten fortfarande sker på institutionsnivå, att verklig gemensam infrastruktur fortfarande saknas över institutionsgränserna med CICEROLaboratoriet (del av nuvarande Competence Center for Gas Exchange - CCGEx) som ett lyckat motexempel, att medarbetarna fortfarande internt identifierar sig själva och sina verksamheter med institutionerna och tillhörande laboratorierna samt att Odqvistlaboratoriet som organisatorisk enhet fortfarande endast har betydelse externt, speciellt vid ansökningar av forskningsmedel och vid forskningsutvärderingar. Ett slående exempel på den organisatoriska låsningen är att det fortfarande finns fyra självständiga mekaniska verkstäder inom Odqvistlaboratoriet trots att det gått hela åtta år sedan dess bildande.

En arbetsgrupp utses med uppgift att ta fram förslag på framtida organisation av mekanikverksamheten vid skolan för teknikvetenskap. Utgångspunkten är att eftersträva en ämnesmässig samhörighet utan organisatoriska hinder och därigenom möjliggöra skapandet av en konsistent, framtida utbildnings- och forskningsstrategi i nära samarbete med varandra.

Vid protokollet

Lisa Johnsson, HR-ansvarig SCI