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Anni Tarvainen

Systeemiajattelun opetus ja tutkimus

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Systeemiajattelun opetus ja tutkimus

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Sisältö

1 Johdanto

Tämän raportin tavoitteena on selvittää kovan systeemiajattelun opetuksen ja tutkimuksen tämänhetkinen tilanne Suomessa ja maailmalla.

Operaatiotutkimus/operaatioanalyysi (engl. Operational research tai Operations research USA, OR) kehittyi Isossa-Britanniassa ennen toista maailmansotaa. Operaatiotutkimus on työkalu systeemien toiminnan analysointiin ja optimointiin ja se sisältää analyysimenetelmien kehittämistä, arviointia ja käyttöä päätöksenteon ja ongelmanratkaisun parantamiseksi. OR korostaa kokonaisvaltaista systeemistä lähestymistapaa, koska systeemi edellyttää monimutkaisten toiminnallisesti toisiinsa liitettyjen komponenttien yhteistoimintaa. [1]

Systeemisuunnittelun (engl. Systems Engineering, SE) juuret ovat suurissa yhdysvaltalaisissa avaruus- ja puolustusjärjestelmäprojekteissa, joiden toteutus aloitettiin 1940-luvun lopulla. Systeemisuunnittelu on kova systeemimetodi, jonka tavoitteena oli suurien ja kompleksisten projektien sekä johtamisen että insinöörityön hallinta. Systeemisuunnitteluun liitetään usein käsitteet raha, koneet, materiaali, informaatio ja ihmiset, joiden johtamiseksi ja hallinnoimiseksi tarvitaan systeemisuunnittelua. [2]

Systeemianalyysin (engl. Systems Analysis, SA) tausta on Yhdysvaltain ilmavoimissa, joka perusti vuonna 1948 RAND-tutkimuslaitoksen (Research and Development Corporation), josta muodostui systeemianalyysin kehityskeskus. Systeemianalyysi perustuu suurien datamassojen määrälliseen ja analyyttiseen käsittelyyn ja siihen liittyy voimakkaasti taloudellisen valinnan näkökulma. Systeemianalyysi on lähestymistapa kompleksisiin ongelmiin epävarmoissa olosuhteissa, missä prosessissa systemaattisesti tutkitaan eri vaihtoehtojen tavoitteita, kustannuksia, tehokkuutta ja riskejä. [3]

Raportti pohjautuu yliopistojen sekä kansallisten ja kansainvälisten instituutioiden ja järjestöjen internetsivuilla esitettyyn tietoon niiden toiminnasta.

Raportissa listataan ensin Suomessa, Pohjoismaissa ja muualla maailmassa tarjolla olevaa systeemiajattelun opetusta. Listassa on mukana myös opinto-ohjelmia ja kursseja, joiden opetuskieli on muu kuin suomi tai englanti. Tämän jälkeen listataan systeemiajatteluun liittyvää tutkimusta ja tutkimusryhmiä. Raportin lopussa listataan systeemiajatteluun liittyvää kirjallisuutta.

Systeemiajattelun opetuksessa ja tutkimuksessa usein toistuvia aiheita ovat optimointi, tekoäly, koneoppiminen, riski- ja päätösanalyysi, game theory, stokastiikka, matematiikka ja tilastotiede.

Tiedonhaussa käytettyjä hakutermejä:

- operaatioanalyysi
- systeemianalyysi
- operations research
- operational research
- operations and systems research
- system analysis
- systems research
- system and operations research university
- department of operations research
- department of systems analysis
- master of science in operations research
- degree in operations research

- system analysis education
- top universities in operations research
- systeemianalyysin tutkimus
- institute for systems analysis
- institute for operations research
- operations research facility
- systems analysis research
- department of operations research
- department of systems analysis

2 Systeemiajattelun opetus maailmalla

Operaatiotutkimus/-analyysi kehitettiin toisen maailmansodan loppupuolella Yhdysvaltain ilmavoimien ja Kuninkaallisten ilmavoimien ilmapommitustoiminnan optimoimiseksi [4]. Tämän takia operaatioanalyysin opetusta löytyy selvästi eniten Yhdysvalloista ja Iso-Britanniasta. Opetusta löytyy kuitenkin paljon muistakin maista kuten Ruotsista ja Venäjältä.

Suurin osa systeemiajattelun opetuksesta on maisteritasoista, koska aiheen ymmärtäminen vaatii mm. tietojärjestelmien, ohjelmoinnin, fysiikan ja matematiikan tuntemusta. Kandiopintojakin kuitenkin löytyy ja ne sisältävät juuri näitä pohjustavia opintoja.

Seuraavissa luvuissa kunkin listatun opinto-ohjelman/kurssin alla on lyhyt (suurimmassa osassa englanninkielinen) kuvaus opinto-ohjelman/kurssin nettisivulta.

2.1 Suomi

2.1.1 Aalto-yliopisto

Suomessa ainoastaan Aalto-yliopiston vuonna 1984 perustettu *Matematiikan ja systeemianalyysin laitos* tarjoaa tutkinto-opetusta systeemitieteessä.

Kandidaatin tutkintoon kuuluu 65 op:n perusopinnot sekä 75 op:n matematiikan ja systeemitieteen pääaineopinnot. Perusopinnot sisältävät 15 op edestä fysiikan opintoja, 25 op edestä matematiikan opintoja, 10 op edestä tietotekniikan opintoja, 5 op tuotantotalouden opintoja sekä 10 op yleis- ja kieliopintoja sekä monialaisia opintoja.

Maisterin tutkintoon kuuluu pakollisia kursseja (yhteensä 30 op), vähintään yksi seminaari (vaihtoehdot ovat MS-E2177 Seminar on Case Studies in Operations Research, MS-E2191 Graduate Seminar on Operation Research ja MS-E2142 Seminar on Optimization), sekä valinnaisia kursseja 40-42 op:n edestä.

Systeemianalyysin tohtorikoulutusverkostossa Aalto-yliopisto on vastuuyliopisto, jossa tohtorikoulutusverkoston toimintaa koordinoi perustieteiden korkeakoulun Systeemianalyysin laboratorio. Tohtorikoulutusverkostoon kuuluu tutkimusryhmiä Aalto-yliopiston perustieteiden korkeakoulusta sekä kauppakorkeakoulusta, Jyväskylän yliopiston Tietotekniikan laitokselta, Turun yliopiston Matematiikan laitokselta, sekä Åbo Akademi University:stä.

Aalto-yliopiston Matematiikan ja systeemianalyysin laitoksen kursseja löytyy esim. osoitteista https://sal.aalto.fi/fi/opinnot/kurssit/ ja https://sal.aalto.fi/en/teaching/

Aalto-yliopiston Matematiikan ja systeemianalyysin laitos tarjoaa systeemitieteen opetusta myös sivuaineena muille kuin matematiikan ja systeemitieteen kandiopiskelijoille: https://into.aalto.fi/display/ensivuaineet2018/Systeemitieteet

Myös maisteriopiskelijoilla on mahdollisuus opiskella *System and Operation Research* -sivuainetta.

Tietoa käynnissä olevasta opetuksesta: https://math.aalto.fi/en/studies/courses/

Matematiikan ja systeemianalyysin laitoksen tuotoksia:
https://research.aalto.fi/fi/organisations/department-of-mathematics-and-systems-analysis/publications/

2.1.2 Muut suomalaiset yliopistot

Jyväskylän yliopiston tietotekniikan maisteriohjelmasta löytyy *Teknis-matemaattisen mallintamisen ja päätösanalytiikan* opintosuunta
https://opinto-opas.jyu.fi/2021/fi/tutkintoohjelma/tiema2020/
"Teknis-matemaattisen mallintamisen ja päätösanalytiikan opintosuunnan mukaisen maisterin tutkinnon suorittanut henkilö hallitsee laskennallisten tieteiden ja data-analyysin käsitteitä ja menetelmiä, joita käytetään itsenäisen ajattelun, päätöksenteon ja tutkimuksen perustana. Hän tunnistaa matematiikan ja lähitieteenalojen rajapinnoilla esiintyviä laskennallisia kysymyksiä ja tarkastelee niitä ja uutta tietoa kriittisesti. Hänellä on valmiudet toimia laskennallisten menetelmien asiantuntijana tieteellistä tutkimusta tekevässä ryhmässä tai yritysmaailman tuotekehitys-projektissa."

Vaasan yliopistosta löytyy kurssi *ORMS2020 Decision Analysis* (5 op)
https://opas.peppi.uwasa.fi/en/course/ORMS2020/88
"Content: Probability concepts and calculus, decision matrices, decision trees, probability estimates, expected utility hypothesis, criticism of the expected utility hypothesis"

Lappeenrannan-Lahden teknillisestä yliopistosta (LUT) löytyy maisteriohjelma *Data-analytiikka päätöksenteossa*
https://www.lut.fi/fi/opiskelu/tekniikka/data-analytiikka-paatoksenteossa-maisteriohjelma
"Sisältö: Suoritettava tutkinto on Diplomi-insinööri (DI), Master of Science in Technology (M.Sc. Tech.), ylempi korkeakoulututkinto, joka antaa kelpoisuuden tieteellisiin jatko-opintoihin. Opintojen laajuus on 120 op ja ne on mitoitettu kahdeksi lukuvuodeksi.

Ohjelmassa yhdistetään tekniikan, talouden ja johtamisen sekä ohjelmistotekniikan opintoja. Ohjelmasta valmistuneet toimivat yritysten laaja-alaisina toiminnan analysoijina ja kehittäjinä jatkuvasti muuttuvissa ja verkostoituneissa globaaleissa ympäristöissä. Osaaminen rakentuu modernien menetelmien ja työkalujen (esim. SAS JMP, UiPath, Power BI) tehokkaalle käytölle."

2.2 Muut Pohjoismaat

Pohjoismaista selvästi eniten systeemiajattelun opetusta löytyy Ruotsista.

2.2.1 Ruotsi

MSc Applied and Computational Mathematics (Kungliga Tekniska högskolan)
"The master's programme in Applied and Computational Mathematics fosters skilled applied mathematicians, well-prepared for advanced industrial positions or PhD studies. The programme offers four tracks: Computational Mathematics, Financial Mathematics, Optimisation and Systems Theory, and Mathematics of Data Science. Graduates acquire skills in advanced mathematics and computer simulation that are in demand in several important fields."
https://www.kth.se/en/studies/master/applied-and-computational-mathematics

https://www.kth.se/student/kurser/program/TTMAM?l=en

Engineering mathematics and computational science, MSc (Chalmers University)
"Topics covered:
The subjects of mathematical statistics, computational science and engineering mathematical modelling are fundamental areas in the Engineering Mathematics and Computational Science master's programme. The courses included in the programme plan handle topics such as engineering mathematics, applied mathematics, mathematical biology, machine learning, big data science, pure math and mathematical physics."
https://www.chalmers.se/en/education/programmes/masters-info/Pages/Engineering-Mathematics-and-Computational-Science.aspx

Master's Programme: Information Systems (Lund University)
"This programme provides you with the tools and skills to understand the design of information systems that address important organisational and societal challenges. In this programme you will learn how information technologies (IT) and artificial intelligence (AI) can be used to achieve strategic goals, and how to design and develop modern information systems which are flexible to the goals and needs of the organisation. You will gain a deeper understanding of the wider business context of information systems, how digitalisation affects organisations and the relationship between IT, innovation and sustainability."
https://www.lunduniversity.lu.se/lubas/i-uoh-lu-EAGIF

Kurssi: Informatics: Decision Support Systems (Lund University)
"A successful completion of the course enables the participants to recognise that useful decision-support is informed by an understanding of the organisational needs and wants and matching those needs with the technological opportunities inherent in the decision-supporting technologies. Finally, the course will assist the participants to produce a short paper that seeks to develop the ability to recognise and address practical concerns and phenomena relating to decision-making. Regular guest lectures further offer participants with opportunities of insights into solutions and challenges concerning the design of decision-support and Business Intelligence-applications."
https://www.lunduniversity.lu.se/lubas/i-uoh-lu-INFC35

Master's Programme in Decision Analysis and Data Science (Stockholm University)
"In this programme you will learn how to handle decision situations in a systematic way so that preferred consequences are probable.

After the programme you will be familiar with all the stages in decision making from selecting, gathering and processing background information, structuring of the problem and assessing the consequences to making the actual decision based on rational principles."
https://www.su.se/english/search-courses-and-programmes/sbdso-1.413329?semester=HT22&eventcode=43902

Kurssi: Systems Thinking and Modelling (Uppsala Universitet)
"On completion of the course the student shall be able to

- account for the importance of systems thinking as well as explain and independently analyse complex phenomena through systems thinking,
- apply the tools within systems thinking in order to create a holistic understanding of a system /process,
- develop, simulate and analyse basic System Dynamics models and reproduce research results from relevant articles using a software tool,
- assess and execute own analysis of research articles and their results within Systems Dynamics."

https://www.uu.se/en/admissions/master/selma/kursplan/?kKod=1TS305&lasar=&department=1240&gedgsd=

Kurssi: Systems Analysis and Operations Research (Uppsala Universitet)
"Students that pass the course should be able to

- understand and to give a survey of the basic parts of the systems analysis approach, from problem specification, through modelling, validation, problem solving techniques, to result evaluation, presentation of results and implementation
- formulate mathematical models of real-life problems in continuous and discrete time
- simulate continuous time and discrete time systems from their mathematical models using available software, and to analyse the outputs of simulations by relevant statistical methods
- use simulations to analyse system properties with respect to e.g. stability and the effect of feedback
- formulate and solve certain types of optimisation problems using linear programming and dynamic programming
- work with both the primal and dual forms of a linear programming problem, and to extract and use sensitivity information in the simplex tableau"

https://www.uu.se/en/admissions/master/selma/kursplan/?kpid=20799&kKod=1RT316

2.2.2 Norja

Kurssi: Operations Research, Introduction (Norwegian University of Science and Technology)
"The course deals with the use of mathematical models for planning of corporate and governmental activities. Most of the planning problems will consist of an economic objective which we want to maximize under scarce resources. Operations Research consists of: - limiting and defining the current problem, - formulating a mathematical model of the problem, - calculating an optimal solution of the model, -and finally interpreting and implementing the found solution. This course deals with both deterministic and stochastic problems, and they will be analyzed based on the following models and methods: Linear and nonlinear programming, integer programming, network models, simple queuing theory and simulation. We will use spreadsheets to find numerical solutions for some of the analyzed problems."
https://www.ntnu.edu/studies/courses/TI%C3%984120#tab=omEmnet

Kurssi: Logic for Systems Analysis (University of Oslo)
"Course content
This course gives a highlevel introduction to distributed data-systems and shows how logical methods can be used to model and reason about data-types and distributed systems. The course introduces different kinds of classes of distributed systems, like transport-protocols, classical distributed algorithms and security protocols. The course also shows how requirement-specifications can define mathematics, and how to analyse whether a system satisfies a given requirement-specification.

The course uses equational logic and rewriting logic, as well as the analysis-tool Maude, to specify systems in a functional programming-style and to analyse systems."
https://www.uio.no/studier/emner/matnat/ifi/IN2100/index-eng.html#course_content

2.2.3 Tanska

Master's Programme: Mathematical Modelling and Computation; Focus Area: Operations research for decision making (Technical University of Denmark)

"A good Operations Researcher have good skills in mathematics, in particular discrete mathematics. Programming experience is a very valuable skill for an Operations Researcher. Because Linear Programming (LP) is the foundation for most of the OR methods, a good understanding of LP is absolutely essential."
https://www.dtu.dk/english/education/graduate/msc-programmes/mathematical-modelling-and-computation/focus-areas

2.3 Muu Eurooppa

2.3.1 Alankomaat

Master's Programme: Operations Research (Maastricht University)
"Are you self-motivated and enjoy delving deeper into business issues? Do you want to pursue an academic career, or to specialise in research within a business? Do you have a strong academic record and want to challenge yourself even further? Then applying for the two-year master's programme in Business Research, track Operations Research, will give you the edge."
https://www.maastrichtuniversity.nl/education/master/master-business-research-track-operations-research

Master's Programme: Technology and Operations Management (University of Groningen)
"—— You will be introduced to data science, developing competences highly valued by today's and tomorrow's employers like data analysis, visualization, diagnostics, interpretation, and data-driven decision making.

Operations are a core aspect of any business. This programme offers insights from real operational processes and socio-technical systems in areas like logistics, manufacturing, services, energy, healthcare, and governance. You will learn to identify opportunities, analyse, and diagnose operations-related problems, but also to design, develop, and evaluate solutions."
https://www.rug.nl/masters/technology-and-operations-management/

Master's Programme: Econometrics and Operations Research (Vrije Universiteit Amsterdam)
"The track Operations Research focuses on the development and application of quantitative methods for analyzing economic issues. Operations Research connects to many academic disciplines including mathematics, computer science, finance and business studies, and is concerned with optimizing strategic and operational business processes that can be found in, for example, transport networks, stock management, and advanced decision support systems. Specializations within the Operations Research track are Financial Engineering, Operations Research Theory, and Quantitative Logistics."
https://vu.nl/en/education/master/econometrics-and-operations-research/curriculum?year=1st-year&specialization=operations-research-theory

Master's Programme: Analytics and Operations Research in Logistics (Erasmus University Rotterdam)
"This specialisation focuses on areas in transport and logistics requiring strong quantitative skills. It differs from other standard logistics or supply chain management programmes in the sense that you also learn all about the methodology underlying advanced decision support systems. Giving you the edge."
https://www.eur.nl/en/master/analytics-and-operations-research-logistics

2.3.2 Belgia

Research Centre for Operations Research and Statistics (KU Leuven)
"In operations research, a challenging research area is combinatorial optimization. Next to exact methods such as branch-and-bound, branch-and-price, also approximation algorithms are studied. Assignment and scheduling problems, winner determination problems and research on client-oriented vehicle routing problems are some of the subjects under study. Further emphasis is placed on machine scheduling, resource-constrained project planning and on project portfolio management. Deterministic approaches as well as methods taking the uncertainty into account are investigated. Additionally, nonparametric frontier based methods are studied both theoretically and empirically with applications in a variety of economic domains (e.g., finance, microeconomics and macroeconomics)."
https://feb.kuleuven.be/research/decision-sciences-and-information-management/orstat/orstat

2.3.3 Iso-Britannia

Master's Programme: Data and Decision Analytics (University of Southampton)
"Develop the analytic and professional skills for success in the data science on this Data & Decision Analytics MSc. You'll learn advanced level mathematical modelling, statistical analysis, and computation.

This UK master's course will give you the skills and knowledge to make better decisions based on data. There is also a strong focus on real work experience, with opportunities for summer projects in a range of industries."
https://www.southampton.ac.uk/courses/data-decision-analytics-masters-msc

Master's Programme: Operational Research (University of Southampton)
"On this course you'll learn:

- the mathematical, computational and communication skills needed for the practical application of operational research
- an appreciation of related disciplines important in operational research
- how to use operational research tools in a wide range of applications
- research methods and current issues in operational research"

https://www.southampton.ac.uk/courses/operational-research-masters-msc

Research Group: Operational Research (University of Southampton)
"We are a committed and vibrant team of more than 30 academic staff and postgraduate students. We collaborate with more than 150 industrial partners across the world to enable impact arising from our research. In the 2022 QS World University Rankings, Operational Research and Statistics at Southampton was ranked 34th worldwide and 7th in the UK. 99% of Southampton Mathematical Sciences research was deemed to be world leading or internationally excellent (in terms of originality, significance, and rigour) in the 2021 Research Excellence Framework (REF)."
https://www.southampton.ac.uk/maths/research/groups/operational_research.page

MSc Cognitive and Decision Sciences (University College London)
"This program studies the cognitive processes and representations underlying human thought, knowledge and decision-making. It integrates a wide range of disciplines and methodologies, with the core assumption that human cognition and choice are computational processes, implemented in neural hardware. Key topics include: the nature of computational explanation; the general principles of cognition; the scope of rational choice explanation; probabilistic models of the mind; learning and memory; applications to economics and business. The program involves intensive training in

experimental design and methodology, building computational models, and carrying out a substantial piece of original research."
https://www.ucl.ac.uk/pals/study/masters/msc-cognitive-and-decision-sciences

Kurssi: Systems Thinking (University College London)
"This course will help you be able to:

- understand and discuss the properties of systems
- classify systems against a range of criteria
- understand and discuss the principles of systems thinking
- apply a number of techniques to understand systems in a holistic way"

https://www.ucl.ac.uk/short-courses/search-courses/systems-thinking

MSc Analytics: Operational Research and Risk Analysis (Alliance Manchester Business School)
"The aim of the course is to equip students with the concepts, techniques and knowledge required to analyse problems and improve the decision-making processes in industry, business and the public sector.

The course recognises the integration between Decision Sciences, Statistics and Information Technology in an increasingly data-rich society."
https://www.mim-compass.com/universities/alliance-manchester-business-school/msc-analytics-operational-research-and-risk-analysis/

Master's Programme: Operations Research & Analytics (The London School of Economics and Political Science)
"With study in practice and theory, you will gain deep insight into analytics problems. On the practical side, you will learn how to model a range of real-world problems using optimisation, simulation, and statistics, with specialist software taught with accompanying computer lab sessions. On the theoretical side, you will learn to recognise canonical underlying mathematical problems, and how to solve them with state-of-the-art methods."
https://www.lse.ac.uk/study-at-lse/Graduate/degree-programmes-2022/MSc-Operations-Research-and-Analytics

Master's Programme: Operational Research (University of Strathclyde)
"The MSc in Operational Research aims to realise the potential of its graduates, so that you immediately can play an effective role in providing model-based support to managers helping them to make better decisions at an operational/technical level."
https://www.strath.ac.uk/courses/postgraduatetaught/operationalresearchonline/

Bachelor's Programme: Mathematics and Computer Science (Imperial College London)
"With the spread of computing procedures and mathematical ideas into many areas, there is high demand for professionals who are expert in both.

Our Mathematics and Computer Science degrees are mathematical courses orientated towards computing science.

Taught jointly by the Departments of Computing and Mathematics, they provide a firm foundation in mathematics, particularly in pure mathematics, numerical analysis and statistics. They also cover all the essentials of computer science, with an emphasis on developing software, as well as more theoretical topics.

This makes the courses particularly suited to mathematically-able students with interests in both subjects."

https://www.imperial.ac.uk/study/ug/courses/computing-department/mathematics-computer-science/#structure

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This makes the courses particularly suited to mathematically-able students with interests in both subjects."
https://www.imperial.ac.uk/study/ug/courses/computing-department/mathematics-computer-science-meng/

The University of Edinburgh:

Bachelor's Programme: Computer Science and Mathematics
"Mathematics forms the foundation of computer science. With the increasing scale of computing systems, and growing volumes of data, we are developing and using more sophisticated mathematical techniques every day.

This programme aims to give you a thorough understanding of mathematics and computing to allow you to operate at the cutting edge of:

- computer and data science
- machine learning
- artificial intelligence

We offer a wide range of courses delivered by leaders in their field. You will have the flexibility to focus on the areas of computer science and artificial intelligence that interest you most."
https://www.ed.ac.uk/studying/undergraduate/degrees/index.php?action=programme&code=GG14

Master's Programme: Operational Research
"This programme will show you how to use mathematical techniques to tackle real-life problems ranging from scheduling flights and routing mobile phone calls, over optimising power systems and logistic networks, to managing investments and minimising risks.

Operational Research (OR) is an important skill that is in high demand.

Our intensive programme allows you to specialise in an area that best suits your career goals."
https://www.ed.ac.uk/studying/postgraduate/degrees/index.php?r=site/view&edition=2022&id=116

Master's Programme: Operational Research with Computational Optimization
"This programme will show you how to use mathematical techniques to tackle real-life problems ranging from scheduling flights and routing mobile phone calls, over optimising power systems and logistic networks, to managing investments and minimising risks.

Operational Research (OR) is an important skill that is in high demand.

This MSc will give an Operational Research perspective on computational optimization."
https://www.ed.ac.uk/studying/postgraduate/degrees/index.php?r=site/view&edition=2022&id=499

Master's Programme: Operational Research with Data Science
"This programme will show you how to use mathematical techniques to tackle real-life problems ranging from scheduling flights and routing mobile phone calls, over optimising power systems and logistic networks, to managing investments and minimising risks.

Operational Research (OR) is an important skill that is in high demand.

The MSc in Operational Research with Data Science is a new, forward-looking programme that delivers high-quality training in operational research, optimization and statistics.

You will have strong technical skills in these areas and the ability to apply them using appropriate software."
https://www.ed.ac.uk/studying/postgraduate/degrees/index.php?r=site/view&edition=2022&id=915

Master's Programme: Operational Research with Risk
"This programme will show you how to use mathematical techniques to tackle real-life problems ranging from scheduling flights and routing mobile phone calls, over optimising power systems and logistic networks, to managing investments and minimising risks.

Operational Research (OR) is an important skill that is in high demand.

This MSc will give an Operational Research perspective on risk and its management."
https://www.ed.ac.uk/studying/postgraduate/degrees/index.php?r=site/view&edition=2022&id=498

PhD: Optimization and Operational Research
"The work in the Operational Research and Optimization research group is in three main areas: the mathematical and computing aspects of optimization, combinatorial optimization, and energy systems.

The core technology in optimization is the solution of large sparse linear and quadratic problems, and we provide world-class expertise in the two main solution methods for these: the simplex method and the interior point method. In combinatorial optimization, we provide expertise for modelling real-world problems using integer linear programming formulations and for deriving efficient exact and heuristic algorithms to solve them.

Specialist expertise in energy includes optimization of system planning and optimization, security of supply risk analysis, and decision support for public policy. We also have interests in PDE-constrained optimization, global optimization, decomposition methods, parallel computing, industrial applications of optimization and stochastic optimization."
https://www.ed.ac.uk/studying/postgraduate/degrees/index.php?r=site/view&edition=2022&id=514

2.3.4 Italia

Operations Research (Alma Mater Studiorum, Università di Bologna)
"Operations Research (a.k.a. Prescriptive Analytics) is strictly related to Artificial Intelligence and studies mathematical models, efficient algorithms and machine learning techniques to develop decision support systems for optimization problems. The research activities of the OR group at DEI (OR@UniBo) involve both the development of methodological approaches and the design of algorithms that are tailored for specific problems.

The group has a relevant number of collaborations, both at a national and at an international level, involving other universities, research centers, and industries."
https://dei.unibo.it/en/research/research-groups/operations-research

2.3.5 Itävalta

Department of Statistics and Operations Research (Universität Wien)
https://isor.univie.ac.at/
Degree Programmes: https://isor.univie.ac.at/studies/degree-programmes/

2.3.6 Liettua

Department of System Analysis (Vytautas Magnus University)
https://if.vdu.lt/en/about-us/departments/systems-analysis-department/

2.3.7 Puola

Department of Operational Research and Business Intelligence (Wrocław University of Science and Technology)
https://kbo.pwr.edu.pl/en/department/about-us/

2.3.8 Ranska

Computer Science, Decision Making, and Data - Master's Year 1 (Université Paris Dauphine-PSL)
"The Computer Science, Decision Making, and Data track emphasizes the fundamental aspects of computer science, as well as discrete mathematics, data science, operational research, and decision support. This 1st-year program is for students who want to pursue one of the following 2nd-year Master's tracks: Modeling, Optimization, Decision Making, and Organization (MODO) or Artificial Intelligence and Data Science (IASD)."
https://dauphine.psl.eu/en/training/masters-degrees/computer-science/m1-i2d

Modeling, Optimization, Decision and Organization (MODO) - Master's Year 2 (Université Paris Dauphine-PSL)
"This program aims to provide students with robust training focused on decision support and operational research. Emphasis is placed on mastering concepts and tools broadly related to operational research and decision support, and on associated computing techniques, as well as on methodological aspects and the conditions for incorporating methods and tools within organizations."
https://dauphine.psl.eu/en/training/masters-degrees/computer-science/m2-modo

2.3.9 Saksa

Master's Program: Mathematics in Operations Research (Technical University of Munich)

"The Mathematics in Operations Research master's program is tailored to students who are interested in a demanding vocational education and training, with emphases on mathematical optimization and the other subdisciplines of applied mathematics.

The theory and application of nonlinear and discrete optimization are central to the course of studies, as are lectures in numerical analysis, stochastic processes or applied analysis.

The course content is complemented by a minor that can be chosen from the areas of economics, computer science or business informatics. Interdisciplinary knowledge of methods and cross-disciplinary soft skills round out the course of studies."
https://www.tum.de/en/studies/degree-programs/detail/mathematics-in-operations-research-master-of-science-msc

Master's Program: Data Analytics and Decision Science (RWTH Aachen University)
"Become tomorrow's technological expert by enrolling in our master program which combines the fields of Data Analytics and Decision Science. Learn how to develop state-of-the-art predictive models (Predictive Analytics) and use the predictions to optimize business objectives (Prescriptive Analytics using Operations Research techniques)."
https://www.rwth-aachen.de/go/id/puiq?lidx=1#aaaaaaaaaaapuit

2.3.10 Sveitsi

Institute for Operations Research (ETH Zürich)
"The Institute for Operations Research represents the fields of Mathematical Optimization and Mathematics of Operations Research with their multitude of facets.

It furthermore serves as a bridge, offering support to all departments of ETH regarding problems in optimization: from mathematical modeling, through their analysis, and computational approaches for their resolution. The institute also has extensive experience with successful industrial cooperations."
https://math.ethz.ch/ifor/the-institute.html
Education: https://math.ethz.ch/ifor/education.html

2.3.11 Tšekki

Department of Systems Analysis (Prague University of Economics and Business)
https://ksa.vse.cz/english/

2.3.12 Ukraina

Department of systems analysis and information-analytical technologies (Kharkiv Polytechnic Institute)
"The department of systems analysis and information-analytical technologies conducts integrated training of bachelors and masters by an information technology, applied mathematical methods, control theory and the making decision.

The high level of a fundamental education and computer training at the department of systems analysis and information-analytical technologies, which corresponds the highest international standards, allows graduates to adapt in almost any area of scientific, technical and social activities very well.

The graduates of the our department are able to design, create and develop the computer systems for the analysis, forecasting and management of processes in technical, environmental, economic and social complex systems."
https://www.kpi.kharkov.ua/eng/department/department-of-systems-analysis-and-information-analytical-technologies/

Bachelor's Degree Program: System Analysis (Cybernetics Faculty of Taras Shevchenko National University of Kyiv)
Kuvausta ei saatavissa englanniksi.
http://csc.knu.ua/en/curriculum

Master's Degree Program: Decision-making systems and methods (Cybernetics Faculty of Taras Shevchenko National University of Kyiv)
Kuvausta ei saatavissa englanniksi.
http://csc.knu.ua/en/curriculum

Master's Degree Program: Intelligent Systems (Cybernetics Faculty of Taras Shevchenko National University of Kyiv)
Kuvausta ei saatavissa englanniksi.
http://csc.knu.ua/en/curriculum

Doctor of Philosophy Degree Program: System Analysis (Cybernetics Faculty of Taras Shevchenko National University of Kyiv)
Kuvausta ei saatavissa englanniksi.
http://csc.knu.ua/en/curriculum

2.4 USA

Yhdysvalloista löytyi todella paljon systeemiajatteluun liittyvää opetusta, joten tässä listassa ei varmasti ole kaikkea Yhdysvalloissa tarjolla olevaa opetusta.

MIT Operations Research Center: Master's in Operational Research
"MIT's Operations Research Center (ORC) is the world's premier graduate program in operations research (OR).

Since our founding more than 60 years ago, we have received numerous distinguished awards and fellowships for our academic achievements. We have written the definitive textbooks in OR and analytics. We have presided over the professional organizations in the field. But most importantly, we have made significant contributions to our global society in the areas of health care, transportation, manufacturing, and services, among many others—and we will continue to do so for years to come.

It's no wonder, then, that our prestigious program attracts the best students and faculty, who share their passion for discovery in our challenging yet uniquely supportive environment.

The MIT ORC provides an innovative, interdisciplinary education with a focus on collaborative investigation—in fact, here, research starts on day one. We aim to connect data to decisions in order to solve problems effectively and impact the world positively.

We offer the following programs:

- doctoral degree (PhD) in operations research
- master's degree (SM) in operations research
- master's degree (MBAn) in business analytics"

https://orc.mit.edu/about-orc

Management Science and Engineering (Stanford University)

"——

2. Operations and Analytics

The Operations and Analytics track prepares students in the fundamentals and applications that are critical to careers in fields ranging from operations management in the service, healthcare, production, manufacturing, computer, telecommunications, and banking industries, to modern Silicon Valley information technology and data analytics. The program emphasizes a balance between the technical rigor of methodologies with lasting value and insightful modern applications and design challenges in a variety of established and emerging industries and operations environments. It offers a portfolio of courses in probabilistic modeling, optimization, simulation, algorithms, data science, networks, markets, and their corresponding applications.

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5. Decision Analysis and Risk Analysis

Students who specialize in Decision and Risk Analysis are prepared for careers including management consulting, policy analysis, and risk management, applying engineering systems analysis to tackle complex economic and technical management problems in the private and public sectors. They acquire the skills to identify and develop opportunities in uncertain situations while recognizing and hedging the downside risks. Specialized course work includes the mathematical foundations for modeling in dynamic uncertain environments to value and manage uncertain opportunities and risks, applications to public policy, and an opportunity to work on a client project under faculty guidance."

https://bulletin.stanford.edu/departments/MGMTSCI/overview
https://msande.stanford.edu/academics-admissions/graduate/ms-program/ms-degree#specialty

Bachelor's Program: Decision Science (Radford University)

"Explore artificial intelligence/machine learning with a focus on business to bridge the gap between data and the people who make decisions.

Topics include decision analysis, risk analysis, decision support systems, information assurance management and computer science."

https://www.radford.edu/content/csat/home/computing/programs/information-science/decision-science.html

Master of Science Applied Statistics and Decision Analysis (Western Illinois University)

"Building on the recommendations of the American Statistical Association (ASA)'s professional panel of experts, graduates of the M.S. in Applied Statistics and Decision Analytics program will be able to:

- Apply advanced statistical methodologies; derive and understand basic theory underlying these methodologies; and formulate and model practical problems for solutions using these methodologies
- Produce relevant computer output using necessary and sufficient programming skills and standard statistical software (e.g., SAS, R, STATA, etc.) and interpret the results appropriately
- Communicate statistical concepts and analytical results clearly and appropriately to others
- Identify areas where ethical issues may arise in statistics"

http://www.wiu.edu/cbt/eds/graduate-appliedstats.php

Master's Program: Computational Decision Science and Operations Research (Illinois Tech)
"Courses in applied mathematics, computer science, business, and engineering maximize your ability to help organizations improve decision-making. Learn cutting-edge, sophisticated approaches—advanced analytics methods, algorithms, and machine learning—to meet the growing need for computationally sophisticated decision scientists and operations research professionals."
https://www.iit.edu/academics/programs/computational-decision-science-and-operations-research-ms

MS in Operations Research (Columbia University in the City of New York)
"The Master of Science in Operations Research (MSOR) is a 30-credit STEM program for students to concentrate in areas such as mathematical programming, stochastic models, and simulation, through domain specific courses in logistics, supply chain management, revenue management, financial engineering, risk management, entrepreneurship, and general management."
https://www.ieor.columbia.edu/masters/operations-research

Master's Program: Operations Research (Florida Tech)
"Operations research analysts work with an organization to help improve its overall business operations. They create mathematical models to examine data that helps a business improve its efficiency, asset management, policies, and operational decision-making.

Florida Tech's master's in operations research degree is one of the few in the nation. With a strong emphasis on mathematics and stochastic theory, this interdisciplinary field overlaps mathematics with other disciplines such as industrial design and operations management. Students tailor their degree to their particular interests and career path."
https://www.fit.edu/programs/operations-research-ms/

Master in Operations Research and Information Engineering (Cornell Tech)
"Businesses in the digital age are awash in data and hungry for skilled analysts and information scientists who can use that data to make insightful, real-time business decisions. Cornell Tech's Master's in Operations Research and Information Engineering (ORIE) will provide you with the mathematical modeling, large-scale computation and data analytics skills you need to turn heaps of data into effective business decisions."
https://tech.cornell.edu/programs/masters-programs/master-in-operations-research-and-information-engineering/

Master's Program: Operations Research (Northeastern University)
"This program seeks to train students in the basic techniques and theory of operations research and their applications to real-world problems. Graduates should have developed their analytical skills to attack complex, large-scale optimization problems of both a deterministic and stochastic nature."
https://www.northeastern.edu/graduate/program/master-of-science-in-operations-research-5283/

Master's Program: Operations Research (University of Washington)
"Operations research is concerned with system modeling and optimal decision making in a deterministic or stochastic setting, as frequently arise in the context of resource management, portfolio selection, logistics planning, vehicle routing, scheduling, and inventory control. This Option provides a firm foundation in the mathematical tools of operations research, particularly optimization and stochastic modeling."
https://acms.washington.edu/content/operations-research

Master of Science in Operations Research Engineering (University of Southern California)

"The Master of Science in Operations Research Engineering program (available both on-campus and online via DEN@Viterbi) is conferred upon candidates who hold bachelor's degrees in engineering, mathematics, science or related fields who successfully complete an integrated program (with departmental approval in advance) of not less than 30 units.

The MS in Operations Research Engineering trains students in solving business problems with computers and mathematics."
https://online.usc.edu/programs/operations-research-ms/

Master of Science in Information Systems and Operations Management (Warrington College of Business)
"The Master of Science in Information Systems and Operations Management program at the University of Florida prepares students to thrive in the age of analytics, artificial intelligence (AI) and machine learning. Technology advancements have put our students in position to discover effective methods and innovative strategies that help companies take the next big step.

The program gives students access to cutting edge methods in analytics that line up with what employers around the world are looking for today. You'll learn how to collect data, but more importantly, you'll know how to analyze it and help companies make critical decisions."
https://warrington.ufl.edu/master-of-science-in-information-systems-and-operations-management/

Operations Research Minor (University at Buffalo, The State University of New York)
"The abundance of data has created the need for data science that allows models to run off vast amounts of available data and thereby optimize performance of the system. The field of operations research is central to data sciences. It is an analytical field that is concerned with modeling and optimization of systems. Having the depth of coursework associated with this minor, as well as a formal credential in this area, will enhance our graduates' knowledge of operations research and their ability to obtain employment in related fields."
https://catalog.buffalo.edu/academicprograms/operations_research_minor.html

Operations Research, MS (George Mason University)
"The program prepares students for research and professional practice associated with the formulation, analysis, and computer implementation of mathematical models of operational systems. Features of the program include mathematical programming, queueing and network theories, computer simulation and modeling, applied and computational probability, and the application of these to realistic problems. Students are expected to become proficient in these areas, as well as in supporting areas of information technology necessary to implement OR analysis approaches."
https://volgenau.gmu.edu/program/operations-research-ms

Systems Engineering and Operations Research, PhD (George Mason University)
"Mason's doctoral program in systems engineering and operations research offers a unique integration of systems engineering and operations research. This integration gives students a strong analytical and computational capability and an overarching systems perspective that is well-grounded in application. The program prepares students for leadership positions in research and development in government, industry, research organization, and academia."
https://volgenau.gmu.edu/program/systems-engineering-and-operations-research-phd

Department of Operations and Information Systems (University of Utah)
"The Department of Operations & Information Systems understands it's one thing to create complex information systems and processes, and it's another to know how to manage them in a way that makes a business more efficient, effective, and competitive. Employees with these skills are

considered invaluable assets to any company. In addition, careers in information systems and operations can be the most financially rewarding in the marketplace."
https://eccles.utah.edu/faculty/department-operations-management-information-systems/

Stony Brook University, New York:

Master's Program: Operations Research
"Operations Research is the branch of applied mathematics concerned with applying analytical methods to help make better management decisions. Operations research is also known as management science and industrial engineering. Operations researchers build mathematical models and apply optimization, simulation, and other mathematical tools to analyze complex situations. Operations Research is used in a wide range of industries, from telecommunication to health care to financial services."
https://www.stonybrook.edu/commcms/ams/graduate/or/

PhD: Operations Research
"Doctoral study consists of the following four stages. There are no specific course requirements for the Ph.D. in Applied Mathematics and Statistics.

1. Mastery of core knowledge in preparation for study in one of the five disciplinary areas. Mastery is demonstrated by passing the Common Qualifying exam, which is normally taken at the start of the second semester.
2. Mastery of the theory and techniques of one of the five disciplinary areas. Mastery is demonstrated by passing an Area Qualifying exam, which is normally taken at the start of the fourth semester. At the same time, a thesis advisor is selected.
3. Development of a thesis topic. Completion of this step is marked by passing the preliminary examination and advancing to candidacy.
4. Completion of dissertation research. Completion is marked by a successful dissertation defense."

https://www.stonybrook.edu/commcms/ams/graduate/_resources/phdrequirements.php

Advanced Graduate Certificate: Operations Research
"The Advanced Graduate Certificate in Operations Research provides students with the fundamental applied mathematics tools for developing protocols for the efficient management of private companies, government agencies and non-profit organizations. In today's global marketplace, organizations need to be efficient to survive. The Operations Research program will provide formal training in methods of optimization, modeling and statistics used in operations research. The objective of this program is to help individuals assist organizations to make efficient use of their resources so as to maximize efficiency and minimize net cost. Graduates of this program may be able to advance in management and organizational planning positions within their current employment or obtain new employment. It is recommended that applicants to the program hold a bachelor's degree in mathematics, engineering or computer science."
https://www.stonybrook.edu/spd/graduate/operations

Research: Operations Research
"The Operations Research area has two themes of primary focus: computational geometry, and stochastic optimization. The computational geometry group consists of Esther Arkin and Joe Mitchell along with adjunct faculty Michael Bender, Jie Gao, and Steve Skiena in Computer Science. The stochastic optimization group consists of Eugene Feinberg, Jiaqiao Hu, and Professor Zhenhua Liu, along with adjunct professors Ji Liu and Thomas Robertazzi in Electrical and Computer Engineering."
https://www.stonybrook.edu/commcms/ams/research/opresearch.php

Columbia University in the City of New York:

Bachelor's Program: Operations Research (BSOR)
"Operations Research is an applied science, and is concerned with quantitative decision problems, generally involving the allocation and control of limited resources. At the undergraduate level, it offers foundational courses in probability, statistics, applied mathematics, simulation, optimization, with professionally oriented operations research courses. The curriculum is well suited for students with an aptitude for mathematics applications. It prepares graduates for professional employment as operations research analysts, e.g., with professional services, financial services, and big technology organizations. We also cultivate students for continued graduate studies in operations research, business, medicine, law, or other disciplines."
https://www.ieor.columbia.edu/undergraduate/operations-research

MS in Operations Research (MSOR)
"The Master of Science in Operations Research (MSOR) is a 30-credit STEM program for students to concentrate in areas such as mathematical programming, stochastic models, and simulation, through domain specific courses in logistics, supply chain management, revenue management, financial engineering, risk management, entrepreneurship, and general management."
https://www.ieor.columbia.edu/masters/operations-research

PhD: Industrial Engineering and Operations Research
"The IEOR PhD program is designed for students with an interest in pursuing advanced studies in Industrial Engineering and Operations Research. Prospective applicants come from a diverse set of backgrounds including Math, Applied Math, Statistics, Computer Science, Electrical Engineering and Operations Research. Graduates from the program have gone on to careers in academia, research, and industry. Visit our alumni page to learn more about the exciting opportunities our alumni are pursuing."
https://phd.ieor.columbia.edu/admissions

Online Master's Program: Operations Research (NC State University)
"The Master of Operations Research (MOR) online program is designed to meet the needs of professionals by deepening their mathematical modeling abilities while broadening key analytical and problem-solving skills. An Operations Research degree provides graduates a wide range of relevant skills to succeed in today's technical and data-intensive work environments. The program delivers the knowledge and experience required by working professionals currently not served by the full-time resident MOR program. The individuals best served by this online program are professionals in the local, national and global community who are looking to advance their education, but, due to family or employment commitments, are unable to participate in a full-time resident program. The online program provides schedule flexibility and remote access so students can earn a MOR from a nationally recognized program in two to three years."
https://online-distance.ncsu.edu/program/operations-research/

Online Master's Program: Operations Research (Georgia Tech)
"Focus: advancing study and research emphasizing topics such as deterministic optimization, probabilistic models and their applications, simulation, and mathematical statistics."
https://www.gatech.edu/academics/degrees/masters/operations-research-online-degree-ms

Kursseja: Operations Research (University of Illinois Urbana-Champaign, The Grainger College of Engineering)

"Operations Research (OR) is a discipline that deals with the development and application of advanced analytical methodologies to provide decision support to complex decision-making problems in business, industry, government, and other enterprises. OR encompasses a wide range of problem-solving techniques and methods such as mathematical optimization, queuing theory, Markov decision processes, simulation, economic methods, data analysis, statistics, neural networks, expert systems, and decision analysis. Its application scope has been broadened significantly over time. The major application areas of modern OR include but are not limited to supply chain management, marketing and revenue management, manufacturing, financial engineering, tele-communication networks, healthcare management, transportation networks, energy and the environment, service systems, web commerce, military defense, and homeland security."
https://ise.illinois.edu/research/operations-research

Kursseja: Industrial Engineering and Operations Research (UC Berkeley)
"Introductory course on the theory and applications of decision analysis. Elective course that provides a systematic evaluation of decision-making problems under uncertainty. Emphasis on the formulation, analysis, and use of decision-making techniques in engineering, operations research and systems analysis. Includes formulation of risk problems and probabilistic risk assessments. Graphical methods and computer software using event trees, decision trees, and influence diagrams that focus on model design."
http://guide.berkeley.edu/courses/ind_eng/

Kursseja: Management Systems & Operations Research (Ohio State University College of Engineering)
"The ISE track in Management Systems will be of interest to students who would like to apply their ISE and Operations Research knowledge and skills to careers paths in areas such as healthcare, energy systems, financial management, manufacturing and production systems, insurance, and transportation. This track includes a focus on logistics, supply chain management, optimization, simulation, lean sigma, logistics and supply chain management, as well as management systems engineering and the design of quality and productivity improvement programs."
https://ise.osu.edu/management-systems-operations-research

2.5 Venäjä

Venäläisistä yliopistoista löytyi yllättävän paljon systeemiajattelun opetusta. Pääsy joidenkin yliopistojen sivuille oli kuitenkin estetty, joten kaikkea opetusta ei ollut edes mahdollista löytää.

Bachelor's Programme: Computing and Data Science (HSE University)
"Structurally, the program consists of several main components - a professional cycle (also called “major”), project and research work, an additional profile of the student’s choice (“minor”), humanitarian subjects, and English.

The first two years students study a set of basic disciplines in mathematics and programming. The list of mathematical disciplines includes all the key sections for a computer scientist. The programs of disciplines are compiled taking into account the specifics of computer science, which is reflected in the choice of examples, the depth of consideration of various topics, etc. At the second stage of the program, the student must become a specialist in the chosen field of computer science (obtain a "specialization"), complete a completed scientific research or, as part of a team, develop a complex software project, undergo an internship."
https://www.hse.ru/en/ba/compds/documents

Bachelor's Programme: Applied Mathematics and Information Science (HSE University, Moskova)
"This programme aims at training researchers, engineers, and developers who are highly skilled in theoretical and applied computer science. It incorporates the best practices of the leading computer science faculties at such institutions as EPFL, Stanford University, and Yandex School of Data Analysis, which offers one of the best computer science programmes in Russia."
https://www.hse.ru/en/ba/ami/about

Bachelor's Programme: Applied Mathematics and Information Science (HSE University, Pietari)
"This programme is offered by HSE University in St. Petersburg in collaboration with JetBrains, the strategic partner of the program. This programme prepares highly qualified specialists in the field of software development, programming languages, data analysis, and machine learning. Thanks to its combination of the fundamental and applied aspects of computer science, graduates can either continue their studies in Master's programmes at leading universities around the world, or find work in leading Russian (Yandex, JetBrains, Acronis, DELL EMC, etc.) and global (Google, Facebook, etc.) IT firms."
https://spb.hse.ru/en/ba/appmath/

Bachelor's Programme: Applied Mathematics and Information Science (HSE University, Nizhny Novgorod)
"This programme successfully combines fundamental training in mathematics and computer sciences with applications in economics and business. Students actively participate in world-class research at the scientific laboratories, TAPRADESS and LATNA. Graduates will be able to apply their knowledge in working for research centers, government bodies, educational institutions and commercial organizations."
https://nnov.hse.ru/en/ba/ami/

Bachelor's Programme: Data Science and Business Analytics (HSE University)
"The aim of this programme is to train analysts and data scientists who are experienced in modern methods of machine learning, software development, working with big data and developing analytical models for business. The programme is based on the successful experience of HSE University's Bachelor's programme in Applied Mathematics and Informatics and the longstanding work of the London School of Economics and Political Science (University of London).

Graduates of the programme will receive: Bachelor of Science in Applied Mathematics and Informatics, HSE University"
https://www.hse.ru/en/ba/data/

St Petersburg University:

Bachelor's Programme: Applied Computer Technologies
"

- The programme is implemented with the participation of academic staff with high-performance publication activity. It makes it possible to involve students in solving crucial research and practical tasks.
- The programme is based on the fundamental and applied achievements of Russian university education and the traditions of the applied mathematics school of St Petersburg University.
- Graduates receive an education that makes it possible for them to: solve current issues of designing and managing various technical objects, technological processes, social and economic systems, and information systems; carry out practical activities and apply various

mathematical methods and computer technologies; and have the ability to master and develop new technologies."

https://english.spbu.ru/admission/programms/undergraduate/applied-computer-technologies

Bachelor's Programme: Applied Mathematics, Fundamental Informatics and Programming

"

- The bachelor's programme 'Applied Mathematics, Fundamental Informatics and Programming' trains students for professional activities in fields that combine knowledge of mathematics and computer science. Fundamental theoretical knowledge and practical skills acquired by students in the learning process make it possible for graduates to successfully analyse, simulate and predict various processes and phenomena of public life. They can also develop tools and software products which solve set tasks.
- The programme trains students to perform practical activities and apply methods of applied mathematics and computer technology. They will create, analyse and use mathematical models of processes and objects for solving problems of science, technology, economics and management.
- The programme is interdisciplinary and continues the best traditions of the St Petersburg Mathematical School. An in-depth analysis of various problems in engineering, physics, economics, ecology and medicine is carried out along with the development of a strong mathematical approach to solving applied problems;
- Students can have practical training at the IT clinic."

https://english.spbu.ru/admission/programms/undergraduate/applied-mathematics-fundamental-informatics-and-programming

Master's Programme: Operations Research and Systems Analysis

"

- The master's programme 'Operations Research and Systems Analysis' trains highly qualified specialists for a future career in industry, science and education. The content of the programme consists of both classical disciplines and courses based on modern scientific advances
- The master's programme covers a wide range of disciplines in: operations research; mathematical game theory; systems analysis; artificial intelligence; machine learning; and neural networks
- The programme is aimed at university graduates with a bachelor's or specialist's degree who wish to continue their education in applied mathematics and informatics. The academic programme is taught in Russian"

https://english.spbu.ru/admission/programms/graduate/operations-research-and-systems-analysis

Master's Programme: Applied Informatics Technologies. Information Expert Systems

"

- The academic programme "Applied Informatics Technologies. Information Expert Systems" is designed to train master's students who will be engaged in practical activities in the field of: the theory and methods of digital synthesis and signal processing; physical and mathematical models of processes in matter; and applied diagnostic tasks
- Such tasks can most effectively be solved by creating information expert systems to collect, process, analyse and examine information and control processes of different physical nature. Special attention is paid to the computer implementation of the resulting solutions through high-performance computing
- The programme "Applied Information Technology. Information Expert Systems" provides a wealth of fundamental and specific knowledge in a variety of fields of applied mathematics and informatics. Graduates of the programme are capable of applying their knowledge and

skills in many areas of fundamentals science and state-of-the-art technology, including: solid state physics; surface and interface physics; biophysics; physical optics; materials science; and micro- and nanoelectronics"

https://english.spbu.ru/admission/programms/graduate/applied-informatics-technologies-information-expert-systems

Master's Programme: Game Theory and Operations Research

"MSc Game Theory and Operations Research provides you with the skills needed to use applied mathematics to problems faced by companies, governments, and other institutions. The graduates will learn to construct and investigate mathematical models of real-life problems using optimization, simulation, and statistics, with specialist software taught during computer lab sessions.

The two-year Master's degree programme in Game Theory and Operations Research prepares a student for a career in industry, science and education. The programme facilitates learning in modern concepts, techniques and methods in operations research and leads the student to different functional areas of operations research to apply it in a future career.

This is the first programme focused on areas of game theory and operations research in St Petersburg University, which is designed to study in English.

The courses are composed to develop – the analytical, problem-solving and decision-making abilities, the awareness of the socio-economic environment, and the enhancement of knowledge in new areas of mathematics. Possible areas of research applications are different fields of technological research and development, economic activities, particularly in diverse trade negotiations, foreign and domestic investment, multinational pollution planning, market development, joint venture, resource extraction, competitive marketing, regional cooperation, etc.

The Master's degree programme is designed for students who have relevant Bachelor degrees and wish to continue their education in the field of applied mathematics, game theory and operation research."

https://english.spbu.ru/admission/programms/graduate/game-theory-and-operations-research

Master's Programme: Methods of Applied Mathematics and Computer Science in Control Problems

"

- The fundamental training is in line with the traditions of the St Petersburg school of mathematics. This makes it possible for graduates to apply reasonably methods of applied mathematics and computer technology for creating, analysing and using mathematical models of controlled processes and dynamic objects. The models can solve problems of science, technology, biology, economics and management.
- Work on high-performance computing (computing clusters) opens up the opportunity for students to take an active part in the development of the national IT education system.
- Internship are held at leading national enterprises and research institutes of the Russian Academy of Sciences such as: V. Efremov Institute of Electrophysical Apparatus; the Krylov State Research Centre; Avrora Scientific and Production Association; Concern Central Scientific Research Institute Elektropribor; Impulse Scientific and Production Association; the JSC Klimov; and others.
- Mathematical modelling to build and analyse controlled and uncontrolled dynamic systems is currently an actively developing field of applied mathematics and computer science. This opens up unlimited opportunities for students and graduates to take part in research. They can present their results in top-ranked Russian and foreign academic journals and at international conferences.

- Academic contacts and joint research involve the exchange of specialists and students with Heidelberg University, Jilin University, and Czech Technical University in Prague."

https://english.spbu.ru/admission/programms/graduate/methods-applied-mathematics-and-computer-science-control-problems

Master's Program: Applied Computer Science — Applied Computer Science in Economy (Kazan Federal University)
"Within the specialty 09.03.03 Applied Computer Science, profile: “Applied Computer Science in Economics” trains specialists in creating, modifying and maintaining information systems that automate organizational management tasks and business processes in organizations of various forms of ownership in order to improve the efficiency of organizations."
https://eng.kpfu.ru/bachelor-specialist-programs/engineering-and-technology-bachelor-programs/

Bachelor's Program: Systems Analysis and Management (Ural Federal University)
https://programs.edu.urfu.ru/en/10128/

Master's Program: Systems Engineering (Ural Federal University)
https://programs.edu.urfu.ru/en/10136/

2.6 Aasia

Monien Aasiassa sijaitsevien yliopistojen nettisivujen kanssa vastaan tuli kielimuuri, sillä monen yliopiston pääsivut olivat osin tai täysin englanniksi, mutta laitosten/tiedekuntien eivät.

2.6.1 Etelä-Korea

Kurssi: Operations Research 1 (Seoul National University)
"The purpose for taking is to improve the ability of thinking quantitatively and systematically, and the ability of dealing with problems in management, information, communication, and engineering systems. The contents of this course include linear programming, goal programming, integer programming, nonlinear programming, dynamic programming."
https://en.snu.ac.kr/academics/curriculum

Kurssi: Operations Research 2 (Seoul National University)
"The purpose for taking is to improve the ability of thinking quantitatively and systematically, and the ability of dealing with problems in management, information, communication, and engineering systems. The contents of this course include transportation problems, game theory, network theory, CPM, PERT, queueing theory, equipment replace model, and simulation."
https://en.snu.ac.kr/academics/curriculum

2.6.2 Intia

Department of Operational Research (University of Delhi)
http://www.du.ac.in/index.php?page=department-of-operational-research

2.6.3 Israel

Operations Research and Optimization (Israel Institute of Technology)
"The master's program in Operations Research and Optimization is a challenging program covering a broad spectrum of mathematical theory (such as combinatorial and continuous optimization, stochastic processes, and game theory), as well as exposure to a wide range of practical applications."
https://web.iem.technion.ac.il/site/programm/operations-research-and-optimization/

2.6.4 Japani

Mathematical Informatics (The University of Tokyo)
"Our basic objective is the formulation and analysis of adequate mathematical models for the description and solution of practical engineering and related problems based on the understanding of their underlying informational structure, with the ultimate aim of contributing to the development of human society."
https://www.i.u-tokyo.ac.jp/edu/course/mi/index_e.shtml

2.6.5 Kiina

Institute of Operations Research & Statistics (Tsinghua University)
"After ten year's development, the Institute has made significant achievements in academic research, academic program development, and academic exchange. The research we conduct cover many areas in operations research and statistics. From the theoretical aspect, we explore fields like global optimization, discrete optimization, stochastic optimization, decision theory and data mining. For applications, we have done research in Logistics and Supply Chain Management, Behavior and Service Operations Management, Transportation Management."
https://www.ie.tsinghua.edu.cn/eng/Research/Institute_of_Operations_Research___Statistics.htm

2.6.6 Malesia

Decision Science MCs, PhD (Universiti Utara Malaysia)
"—— Thus, this program aims to produce students who possess knowledge and skills for scientific decision making; possess sufficient knowledge in integrating other fields such as economy, management, humanities, and fundamental knowledge of quantitative sciences; and apply the knowledge through practical and other problem-solving activities. The program encourages a multi-disciplinary approach in enhancing and enriching the personal development through operational research, decision support systems, simulation techniques, heuristic techniques, computer programming, and research methodology. ——"
https://www.uum.edu.my/index.php/admissions-uum/postgraduate/decision-science

2.6.7 Singapore

Bachelor of Science in Business Analytics (National University of Singapore)
"The Bachelor of Science (Business Analytics) degree programme is an inter-disciplinary under-graduate degree programme offered by the School of Computing with participation from the Business School, Faculty of Engineering, Faculty of Science, and Faculty of Arts and Social Sciences. This is a four-year direct honours programme which offers a common two-year broad-based inter-disciplinary curriculum where all students will read modules in Mathematics, Statistics, Economics, Accounting, Marketing, Decision Science, Industrial and Systems Engineering, Computer Science and Information Systems. Students in their third and fourth years of study may choose elective modules from two lists of either functional or methodological elective modules. Functional elective modules

span business functions or sectors of marketing, retailing, logistics, healthcare, etc. Methodological elective modules include those related to big data techniques, statistics, text mining, data mining, social network analysis, econometrics, forecasting, operations research, etc. In sum, these elective modules span the most exciting and challenging areas of business analytics practice in the industry today."
https://www.comp.nus.edu.sg/programmes/ug/ba/curr/

Graduate Diploma in Systems Analysis (National University of Singapore)
"The Graduate Diploma in Systems Analysis programme (GDipSA) is designed for non-IT graduates intending to craft a new career path in the IT industry. IT graduates and professionals who wish to advance their careers in their current field and recognise the need to equip themselves with the latest IT knowledge and skills to stay relevant may apply as well."
https://www.iss.nus.edu.sg/graduate-programmes/programme/detail/graduate-diploma-in-systems-analysis

Institute of Operations Research and Analytics (National University of Singapore)
"IORA was established in 2016 as a centre of excellence to integrate Operations Research with Data Analytics. The institute aims to develop world-class research programmes to modernize the practice of Operations Research in this new data-intensive environment; and to nurture a new generation of PhD students, well versed in the tools and theories in the integration of Data Analytics into Operations Research."
https://nusgs.nus.edu.sg/programmes-iora/

2.7 Afrikka

2.7.1 Egypti

Operations Research and Decision Support DS Department (Cairo University)
"It includes the following scientific domains:-
Bases and concepts of the systems science – researches of operations and the decision support methodology – modeling and simulation – simulating computer languages – computer applications and simulation of administration and economy – linear and non-linear programming – Multi-goals programming – Dynamic and random programming – smart a accounts networks theory and planning project – theory of queues - systems of observing production and stock – methods and tools of decision support- systems of decision support – administrating data for decision support – systems of cognitive decision support – technology of decision support – statistical analysis of decision support – systems of geographical information for decision support – strategic administration – administration of integrated quality – games and crisis administration various applicable models of production services economics and administration."
http://fci.cu.edu.eg/Operations_Research_and_Decision_Support__DS_Department_

2.7.2 Etelä-Afrikka

Bachelor of Science Honours in Operations Research (University of South Africa)
"The purpose of this qualification is to equip qualifying learners with a range of technical, scientific and research skills in Operations Research and to enable them to pursue a career in industry and commerce. Learners will be able to demonstrate the following upon completion of the qualification: Critical and creative thinking and a comprehensive and systematic knowledge basis, having a

coherent and critical understanding of the principles, theories and research methods of Operations Research. - Application of appropriate Operations Research skills and techniques to complex and real-world problems and the ability to operate effectively in complicated but sometimes ill-defined contexts. - Planning and conducting of research in the field of Operations Research, including the gathering, analysing, synthesising and interpretation of information correctly by utilising the relevant theoretical research principles and reflecting on the research undertaken. - Thinking and reflecting contextually on learning from individual experience and academic disciplines in relation to scientific, technological and economic realities, locally and globally. - Demonstrating efficient and effective information retrieval and processing skills and the ability to present and communicate academic work effectively. - Manage learning tasks in an autonomous, professional and ethical manner displaying a high level of intellectual independence."
https://www.unisa.ac.za/sites/corporate/default/Register-to-study-through-Unisa/Undergraduate-&-honours-qualifications/Find-your-qualification-&-choose-your-modules/All-qualifications/Bachelor-of-Science-Honours-in-Operations-Research-(90078)

Operations Research: Undergraduate (Stellenbosch University)
"The slogan of operations research is “The Science of Better”. An operations researcher follows a scientific approach to suggest methods of improving real-life problems such as the above, and uses techniques that typically overlap with mathematics, statistics and computer science to calculate best or optimal solutions. OR is a powerful tool in the hands of decision-makers and managers, since it allows them to make high-quality decisions that are scientifically justified. Such decisions may be found in, for example, factories, businesses, banks, mining, the construction industry, agriculture, ecology and consulting environments."
http://www.sun.ac.za/english/faculty/economy/logistics/Pages/Undergraduate%20programmes/Operations_Research_Undergraduate.aspx

Master's Program: Computational and Applied Mathematics (University of The Witwatersrand)
"The MSc by Coursework and Research Report in Computational and Applied Mathematics offers a curriculum tailored towards maximising candidates' employability and success in future research. Many industrial sectors and occupations are heavily reliant on the ability to interpret problems and creatively meaningful solutions and analysis thereof. Industrial settings include but are not limited to, banking, quantitative finance, algorithmic trading, operations research, supply chain and mining.

The research report component of the programme requires you to conduct research under the guidance of a supervisor. The topic that you will focus on will be formulated by you and your supervisor, focussing on cutting edge problems in the field of computational and applied mathematics."
https://www.wits.ac.za/course-finder/postgraduate/science/msc-computational-and-applied-mathematics/

Kurssi: Operations Research 780 (University of Pretoria)
"Building on undergraduate modules in Operations Research, the module aims to extend the mathematical programming and optimisation capabilities by introducing uncertainty. Many decision makers are confronted with complex environments in which data is not known with certainty, or in which the decision constraints are uncertain. For cases where one knows the shape, or can assume that the uncertainty follows a known probabilistic distribution, stochastic programming can be used. In the module both chance-constrained programming and fixed recourse are introduced. Fuzzy optimisation is introduced for cases where the shape and/or distribution of the uncertainty are not known. The module also addresses the uncertainty when a decision maker is confronted with multiple, competing objectives."
https://www.up.ac.za/yearbooks/2022/EBIT-faculty/PG-modules/view/BOZ%20780

2.8 Oseania

2.8.1 Australia

Bachelor of Mathematics (Operations Research) (Queensland University of Technology)
"The operations research major encompasses the study of quantitative techniques relevant to decision-making in its broadest sense. You will employ a problem-solving approach, using advanced analytical methods such as operations research, financial mathematics, stochastic and mathematical modelling, and mathematical optimisation. You will also use a variety of software and improve your information technology skills. Because of its emphasis on human-technology interaction and its focus on practical applications, operations research overlaps with other disciplines, notably industrial engineering and operations management, economics and finance, so it is a multi-disciplinary field"
https://www.qut.edu.au/courses/bachelor-of-mathematics-operations-research

Operations Research (University of Queensland)
"Operations research (OR) is the mathematical study of resource allocation problems, decisions, games, uncertainty, scheduling and optimization.

The various sub-disciplines of OR yield both analytic and computational tools that allow for mathematical modelling and efficient problem solving."
https://smp.uq.edu.au/research/operations-research

Master of Statistics and Operations Research (RMIT Australia)
"The Master of Statistics and Operations Research will develop your knowledge of statistical and operations research methodologies.

You'll combine a theoretical foundation with practical applications of current techniques employed by practising engineers, scientists and other professionals in industry, research, consulting, teaching and business."
https://www.rmit.edu.au/study-with-us/levels-of-study/postgraduate-study/masters-by-coursework/master-of-statistics-and-operations-research-mc004

Kurssi: Advanced Decision Analysis (University of New South Wales)
"Course outline:

Module 1: This three-day course addresses problems that can be addressed through Decision Analysis tools. The course addresses the concepts of analysis and introduces few basic decision analysis tools such as heuristic decision making, payoff matrices, single and multiple criteria decision analysis involving uncertainty and risk, AHP, SMART, Monte-Carlo simulation, and resource allocation and negotiation models.

Module 2: This two-day module builds upon the course "Basic Decision Analysis". The course addresses the concepts of decision-making using decision models, decision trees, probability theory, Bayesian analysis, utility functions, software approaches to decision analysis and scenario planning using decision analysis."
https://www.unsw.adfa.edu.au/professional-education-courses/advanced-decision-analysis

2.8.2 Uusi-Seelanti

Master of Operations Research & Analytics (University of Auckland)
"In an age of rapid technological development, Operations Research and Analytics is an essential field. Offered by the Faculty of Engineering, this interdisciplinary programme is open to students with undergraduate backgrounds in arts, commerce, engineering or science."
https://www.auckland.ac.nz/en/study/study-options/find-a-study-option/master-of-operations-research-and-analytics-moran.html

Postgraduate study in Operations Research (University of Auckland)
"You will familiarise yourself with theory and methodology in your postgraduate programme. Topics such as optimisation under uncertainty, and network design and simulation are common.

The broad, interdisciplinary nature of operations research makes it a field with extensive variety – it is utilised in many industries, with many opportunities arising continuously for new applications. As a postgraduate student, your main challenge may involve finding new areas or aspects for you to contribute to.

Some of the projects we have undertaken include:

- Delivery and policy analysis for the healthcare industry
- Optimising transportation systems, including airlines and yachts
- Route simulation and optimisation for emergency vehicles
- Electricity and telecommunications network design"

https://www.auckland.ac.nz/en/study/study-options/find-a-study-option/operations-research/postgraduate.html

3 Systeemianalyysin tutkimus maailmalla

Systeemi- ja operaatioanalyysin tutkimusta ei löytynyt läheskään yhtä paljon kuin niiden opetusta. Varmasti osa tutkimusta tekevistä yliopistoista puuttuu tästä raportista, sillä osalla yliopistoista tutkimuksesta kertovat sivut vain listasivat julkaistuja artikkeleita ja tutkimustuloksia, joiden joukosta oli vaikeaa löytää mitään tiettyä aihetta käymättä jokaista artikkelia läpi yksitellen.

3.1 Suomi

Suomessa systeemi- ja operaatioanalyysia tutkitaan lähinnä Aalto-yliopiston Systeemianalyysin laboratoriossa. Tutkimusaloihin kuuluu *Dynamic games, large scale systems and optimization*, *Decision making, systems thinking and decision support*, *Energy resources, and environment* sekä *Mathematical programming and industrial applications*. Aikaisempiin tutkimusaloihin kuuluu *Biological systems analysis*.
Systeemianalyysin laboratorion nettisivut: https://sal.aalto.fi/fi/tutkimus/

Jyväskylän yliopisto
Monitavoiteoptimoinnin tutkimusryhmä

Jyväskylän yliopiston IT-tiedekunnassa toimii professori Kaisa Miettisen johdolla Monitavoite-optimoinnin (Multiobjective Optimization) tutkimusryhmä. Ryhmän tutkimus keskittyy ristiriitaisten tavoitteiden ei-lineaariseen optimointiin mm.

- menetelmien kehittämisessä
- teoreettisissa kysymyksissä
- ohjelmistokehityksessä
- todellisissa simulaatioon perustuvissa ja datapohjaisissa ongelmissa

http://www.mit.jyu.fi/optgroup/index.html

DEMO

Jyväskylän yliopiston yksi tutkimusala on *Decision Analytics unitizing Causal Models and Multi-objective Optimization* (DEMO). Sen tavoitteena on luoda keinoja hyödyntää dataa parhaalla mahdollisella tavalla ja tukea datapohjaista päätöksentekoa. DEMO-projektia johtaa professori Kaisa Miettinen.

https://www.jyu.fi/it/en/research/research-projects/academy-of-finland/demo

Matematiikan ja tilastotieteen laitos

Jyväskylän yliopiston matematiikan ja tilastotieteen laitoksella on tutkimusta systeemi- ja operaatio-analyysiin läheisesti liittyvistä aiheista, kuten *Parametrittomat ja robustit menetelmät*, *Laskennallinen tilastotiede ja simulointeihin perustuvat menetelmät* ja *Todennäköisyysteoria* (stokastiikka).

https://www.jyu.fi/science/fi/maths/tutkimus/tilastotiede
https://www.jyu.fi/science/en/maths/research/stochastics

FORS – Suomen Operaatiotutkimusseura ry

Suomen Operaatiotutkimusseura ry (Finnish Operations Research Society, FORS) syntyi maaliskuussa 1973, jolloin noin 60 operaatiotutkimuksesta kiinnostunutta liike-elämän, julkisen hallinnon ja korkeakoululaitoksen edustajaa päätti seuran perustamisesta.

Seuran tarkoituksena on kehittää ja edistää operaatiotutkimusta ja sen soveltamista sekä toimia siitä kiinnostuneiden henkilöiden yhdyssiteenä. Seuraan voi liittyä kuka tahansa operaatiotutkimuksesta kiinnostunut henkilö. Seura järjestää vuosittain kaksi seminaaria sekä ekskursioita operaatio-tutkimusta soveltaviin yrityksiin. Näistä sekä seuran muista ajankohtaisista tapahtumista tiedotetaan tämän sivuston lisäksi seuran jäsenlehdessä INFORS:issa.

Suomen Operaatiotutkimusseura on siis tutkimusseura, ei tutkimuslaitos.
http://www.operaatiotutkimus.fi/

3.2 Muut Pohjoismaat

3.2.1 Ruotsi

Kungliga Tekniska Högskolan

Optimization and Systems Theory

Matematiikan laitoksella on *Division of Optimization and Systems Theory*, jossa tutkitaan mm. useita matemaattiseen systeemiteoriaan liittyviä aiheita, painottaen stokastisia järjestelmiä, seulontaa, tunnistamista ja robustia ja epälineaarista hallintaa; optimointia painottaen erityisesti laajan skaalan

epälineaarista ohjelmointia ja erilaisia sovelluksia. Esimerkkejä sovelluksista ovat sädehoito, solubiologia, robotiikka ja vuoronnus.
https://www.kth.se/math/optsys/our-research-1.907592
Research in Decision and Control Systems
Sähkötekniikan ja tietojenkäsittelytieteen laitoksella on tutkimusta aiheesta *Decision and Control Systems*. Tutkimukseen sisältyvät aiheet ovat *Control of Transport Systems*, *Machine Learning*, *Networked Control and Robotics*, *Optimization and Control*, *Process Modelling and Control*, *Secure Control Systems* ja *System Identification*.
https://www.kth.se/is/dcs/research

Chalmers University: Data Science and AI
Suurin osa tutkimuksesta Datatieteen ja tekoälyn yksikössä tehdään yhteistyössä akateemisten ja alan toimijoiden kanssa. Tämä tutkimus yhdistetään koneoppimisen ja liittyvien aiheiden perustutkimuksen kanssa:

- algorithm theory (design, complexity, randomness)
- optimization and operations research (scheduling, routing)
- theoretical ML research (learning, decision-making)
- health informatics, bioinformatics and computational biology
- natural language processing (text analysis, representation learning, multimodality)
- autonomous vehicles
- mathematical modelling and problem solving

https://www.chalmers.se/en/departments/cse/research/dsai/Pages/default.aspx

Stockholm University
Optimization and Systems Theory
Optimoinnin ja systeemiteorian yksikössä tehty tutkimus ulottuu laajalle, ja kattaa teorian ja sovellukset. Se käsittelee useita matemaattisen systeemiteorian aiheita, painottaen erityisesti stokastisia järjestelmiä, suodatusta, tunnistusta sekä robustia ja epälineaarista hallintaa; matemaattista ohjelmointia, laajan skaalan epälineaarista ohjelmointia, rakenteellista ohjelmointia ja useita sovelluksia. Tutkimus toimii luonteeltaan siltana matematiikan laitoksen ja monien soveltavien tieteenalojen välillä.
https://www.math-stockholm.se/en/forsk/optsyst-1.75265
Computer and Systems Sciences
Tietojenkäsittely- ja systeemitiede on monitieteinen tutkimusala, jolla on vankka pohja yhteiskuntatieteissä. Työmme kehittyy uuden teknologian ympärille, mutta teknologia ei sinänsä ole keskiössä. Sen sijaan tutkimme, kuinka ICT:tä voidaan käyttää tehokkaasti ja eettisesti yhteiskunnallisen edistyksen mahdollistamiseksi.
https://www.su.se/english/research/research-subjects/computer-and-systems-sciences
Risk and Decision Analysis
Riski- ja päätösanalyysin tutkimushankkeissa vertaillaan objektiivisuutta ja sosiaalisia vivahteita riskianalyysissä, sekä etsitään menettelytapoja energia-alan hiilidioksidipäästöjen vähentämiseksi.
https://www.su.se/english/research/research-subjects/computer-and-systems-sciences/risk-and-decision-analysis

Uppsala Universitet: Systems and Control

Uppsalan yliopistossa tutkitaan dynaamisia systeemejä ja niiden toimintaa. Tutkimusta sovelletaan monella alalla, kuten biolääketieteessä, langattomassa kommunikaatiossa, navigoinnissa ja jäteveden käsittelyssä.
http://www.it.uu.se/research/systems_and_control?lang=en#__utma=1.215846185.1655203777.1656418902.1657020156.7&__utmb=1.3.10.1657020156&__utmc=1&__utmx=-&__utmz=1.1655712843.4.3.utmcsr=google|utmccn=(organic)|utmcmd=organic|utmctr=(not%20provided)&__utmv=-&__utmk=202965265

3.2.2 Tanska

Technical University of Denmark: Operations Research
Operaatioanalyysin osastolla on kokonaisvaltainen lähestymistapa operaatioanalyysiin: se kattaa kaikki operaatioanalyysin vaiheet ongelman analysoinnista mallin rakentamiseen ja uusien ratkaisumenetelmien kehittämiseen ja lopulta saatujen tulosten tulkintaan.

Osasto on aktiivisesti mukana monilla sovellusaloilla, kuten taloussuunnittelu, henkilöstösuunnittelu, ympäristöllisesti kestävän liikenteen suunnittelu, terveydenhuollon toiminta ja energiajärjestelmien suunnittelu. Osasto on rakentanut vahvat joukkoliikenteen tutkimusperinteet. Merenkulullisessa logistiikassa osasto on tunnustettu kansainvälisesti johtavaksi.
https://www.ms.man.dtu.dk/english/Research/Operations-Research

3.3 Muu Eurooppa

3.3.1 Alankomaat

University of Groningen: Data Science & Systems Complexity
Datatieteen ja systeemikompleksisuuden (DSSC, Data Science & Systems Complexity) tavoite on ymmärtää ja suunnitella monimutkaisia järjestelmiä ja prosesseja Big Datan avulla. Erityisesti se tutkii, mukauttaa ja jalostaa malleja tieteelliseen tutkimukseen ja luonnonilmiöiden ymmärtämiseksi. Lisäksi se kehittää tekniikoita monimutkaisten järjestelmien ymmärtämiseksi ja hallitsemiseksi. DSSC myös kehittää työkaluja ja menetelmiä, jotka helpottavat Big Dataa käsittelevän edistyneen ja monimutkaisen instrumentoinnin kehittämistä. DSSC liittyy mm. luonnontieteisiin, tekniikkaan ja älykkääseen teollisuuteen sekä terveydenhuoltoon.
https://www.rug.nl/research/fse/themes/dssc/about-dssc/

Utrecht University
Tutkimuksesta:

- Sopivat hakumenetelmät ja tiedonlouhinta ja -haku
- Graafialgoritmit, kiinteiden parametrien ohjattavuus ja network science
- Optimointi, logistiikka ja vuoronnus
- Dataintensiiviset järjestelmät, datan valmistelu ja kuratointi
- Todennäköisyyspohjainen päättely ja verkostot
- Laskenta grafiikkaa, GIS:ää, liikesuunnittelua ja joukkomallinnusta varten
- Monimutkaisten järjestelmien käyttäytymis-, siirtymä- ja kestävyysominaisuudet

https://www.uu.nl/en/research/algorithms

3.3.2 Belgia

KU Leuven: Research Centre for Operations Research and Statistics
Operaatioanalyysissä haastava tutkimusalue on kombinatorinen optimointi. Tarkkojen menetelmien, kuten branch-and-bound ja branch-and-price ohella tutkitaan myös approksimaatioalgoritmeja. Tutkittavia aiheita ovat esimerkiksi tehtävä- ja vuoronnusongelmat ja asiakaslähtöiset ajoneuvojen reititysongelmat. Tutkimuksessa tarkastellaan deterministisiä lähestymistapoja sekä epävarmuuden huomioon ottavia menetelmiä. Lisäksi ei-parametrisia rajapohjaisia menetelmiä tutkitaan sekä teoreettisesti että empiirisesti erilaisilla talouden aloilla (esim. rahoitus, mikrotalous ja makrotalous).

Tilastollisen tutkimuksen aiheet kattavat joukon haastavia tutkimusaiheita. Tällä hetkellä tutkitaan aiheita suuren ulottuvuuden datan saatavuuteen liittyen, sekä aiheita, jotka liittyvät puutteellisen datan analysointiin. Tuloksia voidaan käyttää aikasarja-analyysissä, mm. lääketieteellisen datan graafisessa mallintamisessa ja esim. työttömyystutkimuksesta saadun ajallisen keston datan analysoinnissa.
https://feb.kuleuven.be/research/decision-sciences-and-information-management/orstat/orstat

3.3.3 Iso-Britannia

Cardiff University: Operational Research Group
Tutkimusryhmällä on vaikuttavan paljon kokemusta sekä aiheen teoreettisista perusteista että uusista sovelluksista, mukaan lukien terveydenhuollon, kansanterveyden ja epidemiologian, rahoituksen, kuljetuksen, aikataulutuksen, ympäristöasioiden, valmistuksen, tietoturvan ja ympäristöystävällisen logistiikan monimutkaisista ongelmista.
Tämänhetkisen ryhmän tutkimuksen pääaiheet ovat:

- Suunnittelu ja optimointi
- Jonotusjärjestelmät
- Terveydenhuollon mallintaminen
- Ympäristön mallintaminen
- Rahoitus ja riskit

https://www.cardiff.ac.uk/research/explore/research-units/operational-research

London Metropolitan University: Intelligent Systems Research Centre
Muutama esimerkki laitoksen tutkimuksista:

- Big Data -tutkimus
- Bioinformatiikan tutkimus: tekoälyn ja koneoppimisen sovellukset biologiaan ja lääke-tieteeseen
- IT- ja kyberturvallisuustutkimus, kuten steganografia, kryptografia, identiteetin selvittäminen, joukkolähdetieto, mobiililaitteiden tietoturva, pilvitietoturva, verkkopalvelin-hyökkäykset, läpäisytestaus, verkkokauppojen turvallisuus ja käytänteet, GDPR, krypto-valuutat, dark net, social graph ja paljon muuta
- Tekoäly- ja koneoppimistekniikoiden sovellus robotiikassa
- Kehittynyt verkkoteknologia ja sen sovellukset
- Neurolingvistinen ohjelmointi ja luonnollinen kielen prosessointi
- Tekoäly- ja koneoppimistekniikoiden sovellus avustettuun asumiseen
- Iso-Britannian jokien hydrodynaamisen virtauksen mallintaminen
- Henkilöllisyyden selvittäminen dataan pohjautuvassa valvonnassa

https://www.londonmet.ac.uk/research/centres-groups-and-units/intelligent-systems-research-centre/

University of Southampton

CORMSIS Centre for Operational Research, Management Sciences and Information Systems

Tutkimusmenetelmät ulottuvat matemaattisista operaatioanalyysin tekniikoista kvalitatiivisiin tutkimusmenetelmiin, jotka kattavat analytiikan, koneoppimisen, järjestelmäajattelun (system thinking) ja matemaattisen optimoinnin. Kaikessa tutkimuksessa painotetaan vahvasti käytännön sovelluksia.

Menetelmiä:

- Ennustava ja ohjaava analytiikka
- Jatkuva optimointi
- Diskreetti optimointi
- Riski ja epävarmuus
- Simulaatio

Sovellusalueet:

- Luottopisteytys
- Leikkaus ja pakkaus
- Digitaalinen talous
- Energia
- Tekniikka
- Rahoitus
- Game Theory
- Terveydenhuolto
- Tulonhallinta
- Vuoronnus
- Urheilu
- Toimitusketjun hallinta
- Kuljetus ja logistiikka
- Verkko- ja markkinointianalyysi

https://www.southampton.ac.uk/cormsis/about/index.page

Research Group: Operational Research

https://www.southampton.ac.uk/maths/research/groups/operational_research.page

York Cross-disciplinary Centre for System Analysis (YCCSA)

York Cross-disciplinary Centre for System Analysis on laaja ja aktiivinen yhteisö Yorkin yliopiston laitosten (ja sen ulkopuolisten) välillä. Sen ensisijainen tavoite on kehittää uusia matemaattisia ja laskennallisia menetelmiä ja työkaluja monimutkaisten teknisten, fyysisten ja biologisten systeemien analysoimiseen ja mallintamiseen.

https://www.york.ac.uk/yccsa/

The Operational Research Society

The Operational Research Society perustettiin 1950-luvulla alun perin tarkoituksenaan koota mahdollisimman paljon operaatioanalyysiin liittyvää tietoa operaatioanalyysin parissa työskenteleville.

https://www.theorsociety.com/

3.3.4 Italia

Università di Bologna: Operations Research
Tutkimusryhmän työ sisältää sekä lähestymismetodien kehittelyä että algoritmien kehittämistä tiettyjen ongelmien ratkaisuun. Tutkimusryhmä tekee yhteistyötä sekä paikallisten että ulkomaisten yliopistojen, tutkimuskeskusten ja teollisuuden kanssa.
https://dei.unibo.it/en/research/research-groups/operations-research

3.3.5 Itävalta

Universität Wien: Department of Statistics and Operations Research
Operaatioanalyysi käsittelee monitieteellistä ongelmanratkaisua (päätösanalyysi) muun muassa taloustieteissä, tekniikassa, tietotekniikassa ja terveystieteessä. Tutkimuksessa käytetään matematiikan, tilatotieteen ja tietojenkäsittelytieteen kvantitatiivisia nykyaikaisia menetelmiä, mukaan lukien optimointi (lineaarinen, epälineaarinen, kombinatorinen ja stokastinen ohjelmointi, mukaan lukien metaheuristiikka), päätös- ja peliteoria, simulointi ja tilastoanalyysi.
https://isor.univie.ac.at/research/working-groups/

International Institute for Applied Systems Analysis (IIASA)
IIASA:n Advancing Systems Analysis -projektin päätavoitteet ovat:

1. Kehittää lähestymistapoja ja työkaluja, joilla analysoidaan yhä systeemisempiä sosiaalis-ekologisia riskejä ja tuetaan päätöksiä, joilla pyritään parantamaan sietokykyä ja helpottamaan kestävyyden siirtymiä ja muutoksia.
2. Edistää ketterän on-demand-systeemianalyysin kapasiteettia, jota tukee joukko sopivan monimutkaisia mallinnuskehyksiä.
3. Mobilisoida useita tietolähteitä ja datatieteen voimaa diagnosoimaan ja tunnistamaan ratkaisuja haavoittuvuuksien ja riskien vähentämiseksi.
4. Edistää toteuttamiskelpoisia ja tehokkaita tapoja kommunikoida poliittisten päättäjien, yksityisen sektorin ja kansalaisten kanssa.
5. Vahvistaa luottamusta ja yhteistä ymmärrystä systeemianalyysimenetelmiin ja -työkaluihin erityisesti avoimen tieteen avulla.

https://iiasa.ac.at/
https://www.ukri.org/what-we-offer/browse-our-areas-of-investment-and-support/international-institute-for-applied-systems-analysis/

3.3.6 Liettua

Vytautas Magnus University: Department of System Analysis
Ensisijaiset tutkimusaiheet:

- Tekoälyn soveltaminen puhe- ja kieliteknologioihin
- Biosignaalianalyysi ja oppimismekanismien mallintaminen biojärjestelmissä
- Digitalisaation ja älykkäät ympäristöt
- Virtuaaliympäristöjärjestelmien mallintaminen

https://if.vdu.lt/en/about-us/departments/systems-analysis-department/

3.3.7 Saksa

Hamburg University of Technology: Operations Research and Information Systems
Tutkimuksen painopisteenä on kvantitatiivisten mallien kehittäminen ja algoritmien käyttö liiketoiminnan ja johtamisen suunnitteluongelmien ratkaisemisessa, sekä päätöksenteossa. Erityisiä kiinnostuksen kohteita ovat logistiikan alan ongelmat, kuten:

- Ympäristöllisesti kestävän logistiikan suunnitteluongelmien ratkaiseminen kvantitatiivisilla menetelmillä
- Suunnittelumetodien käyttö katastrofilogistiikassa
- Menestystekijät ja strategian optimointi sähköisessä logistiikassa
- Klassinen sijaintisuunnittelu ja paikannussuunnittelu kilpailussa
- Verkoston optimointi
- Tuotannon suunnittelu
- Tulojen hallinta konttilogistiikassa
- Toimitusketjun hallinta
- Reittisuunnittelu sekä yhdistetyt sijainti- ja reittisuunnitteluongelmat
- Kuljetussuunnittelu

https://www.tuhh.de/oris/en/home.html

Hasso-Plattner-Institut: System Analysis and Modeling
Käynnissä olevia projekteja:

- ICT COST Action: Multi-Paradigm Modelling for Cyber-Physical Systems
- SOAMED: Service-oriented Architectures for the Integration of Software-based Processes, exemplified by Health Care Systems and Medical Technology
- QUANTUM: Quantitative analysis of service-oriented real-time systems with structure dynamics

https://hpi.de/en/giese/research.html

Leuphana University of Lüneburg: Information Systems, especially Operations Research
Olemme kiinnostuneita kvantitatiivisten ja datapohjaisten operaatioanalyysin menetelmien soveltamisesta käytännön ongelmiin esimerkiksi logistiikassa, kuljetuksessa, urheilussa ja palvelujen hallinnassa. Tutkimuksessamme käyttämämme metodit ovat matemaattinen mallintaminen, simulointi, metaheuristiikka/matemaattinen heuristiikka, jonoteoria, stokastinen optimointi, datan louhinta ja data-analyysi koneoppimismetodeja hyödyntäen. Tutkimuksemme tavoite on kuroa umpeen käytännön ja teorian välinen kuilu; eli soveltaa uusimpia teoreettisia tuloksia tärkeisiin, käytäntöön suuntautuneisiin ongelmiin, mutta myös saada inspiraatiota todellisista ongelmista ja siten laajentaa teoriaa.
https://www.leuphana.de/en/institutes/iis/information-systems-especially-operations-research.html

Systems Analysis Research Network
Systems Analysis -tutkimusverkosto perustettiin vuonna 2015 antamaan neuvoa liittovaltion talous- ja energiaministeriölle sekä tutkimuksen ja energia-alan sidosryhmille digitaalisen tiedonkäsittelyn, tietoinfrastruktuurien ja lisensoinnin rahoitusstrategioista. Tavoitteena on tehdä näillä alueilla käytettävistä mallinnustyökaluista läpinäkyvämpiä ja helpommin vertailtavia tieteellisen laadunvalvonnan avulla.
https://www.forschungsnetzwerke-energie.de/system-analysis

3.3.8 Sveitsi

ETH Zürich: Institute for Operations Research
Neljä operaatioanalyysiin liittyvää tutkimusryhmää: Bandeira Group, Sudakov Group, Weismantel Group ja Zenklusen Group
https://math.ethz.ch/ifor/research.html

3.3.9 Ukraina

Department of System Analysis and Decision Making Theory (National University of Kyiv)
Systeemianalyysin ja päätöksenteon laitos perustettiin vuonna 1988 ja tutkijoita ja tutkimusavustajia on tällä hetkellä 10. Tutkijoiden kiinnostuksenkohteita ovat mm.

- päätöksenteko epävarmoissa olosuhteissa ja ristiriitatilanteissa
- erilaiset systeemianalyysiprosessien menetelmät
- dynaamisten järjestelmien stabiiliuden tutkimus
- järjestelmäoptimointi
- vesiympäristöjen ilmansaasteiden leviämisen mallintaminen

http://csc.knu.ua/en/department/sadmt

3.4 Pohjois-Amerikka

3.4.1 USA

MIT: Operations Research Center
Viimeaikaisia tutkimusaiheita ovat mm.

- Approksimaatioalgoritmit
- Diskreetti, jatkuva, konveksi, robusti ja stokastinen optimointi
- Maa- ja lentoliikenne
- Terveydenhuolto
- Terveydenhuoltoanalyysi
- Koneoppiminen ja sen rajapinta optimointiin
- Online-algoritmit
- Personoitu lääketiede
- Hinnoittelu ja tulonhallinta
- Sosiaaliset verkostot
- Stokastinen mallintaminen
- Toimitusketjun hallinta

https://orc.mit.edu/

Northwestern University: Systems Analysis Research Group
Operaatioanalyysin tutkimusryhmässä käytetään teknistaloudellista elinkaari- ja materiaalivirta-analyysiä uusien teknologioiden kustannuskilpailukyvyn ja kestävyyden arvioimiseksi, mukaan lukien sivutuotteet, kiertovalmistusjärjestelmät, vähähiiliset polttoaineet ja ravinteiden talteenotto- ja suolanpoistojärjestelmät. Tutkimusryhmä tekee yhteistyötä muiden Northwesternin ryhmien kanssa ympäri maata ja kansainvälisesti saavuttaakseen järjestelmätason näkökulmia.

https://sites.northwestern.edu/dunnlab/

Ohio State University: Operations Research & Analytics
Menetelmiä:

- Data-analyysi
- Datapohjaiset menetelmät
- Päätösanalyysi
- Taloudelliset menetelmät
- Optimointi
- Jonoteoria
- Simulointi
- Tilastotiede
- Stokastiset prosessit

Sovelluksia:

- Kyberturvallisuus
- Energiajärjestelmät
- Tuotanto ja aikataulutus
- Kestävyys
- Toimitusketjun analysointi
- Kuljetusjärjestelmät
- Vesivarojen hallinta

https://ise.osu.edu/faculty-research/operations-research-analytics

Rutgers Business School: Rutgers Center for Operations Research
Keskus keskittyy operaatioanalyysin teorian ja sovellusten kehittämiseen yhteistyössä hallituksen ja teollisuuden kanssa. Se kehittää edistyneitä analyyttisia monimutkaisten järjestelmien optimointi-menetelmiä ohjaamaan päätöksentekoa useilla eri aloilla.
https://www.business.rutgers.edu/operations-research-center
http://rutcor.rutgers.edu/index.html

Stanford University: Operations Research and Decision and Risk Analysis
Operaatioanalyysin tiedekunta on johdonmukaisesti edistänyt sekä metodologista innovaatiota että näiden metodologisten innovaatioiden toteuttamista soveltavilla aloilla. Merkittäviä sovellusalueita ovat: kouluvalinta; munuaissiirtojen suunnittelu; hinnoittelu- ja yhteensopivuusalgoritmien suunnittelu online-alustoille; terveydenhuollon toimintojen hallinta; laskennalliset menetelmät sosiaalista valintaa ja kollektiivista päätöksentekoa varten; epidemioiden analysointi ja valvonta; ja rakennusten energiatehokas hallinta.
https://msande.stanford.edu/research-impact/research-areas

Stony Brook University
Operaatioanalyysi-alueella on kaksi ensisijaista painopistettä: laskennallinen geometria ja stokastinen optimointi. Laskennallisen geometrian ryhmään kuuluvat Esther Arkin ja Joe Mitchell sekä tietojenkäsittelytieteen apulaishenkilöstö Michael Bender, Jie Gao ja Steve Skiena. Stokastisen ohjelmoinnin ryhmään kuuluvat Eugene Feinberg, Jiaqiao Hu ja professori Zhenhua Liu sekä sähkö- ja tietokonetekniikan apulaisprofessorit Ji Liu ja Thomas Robertazzi.
https://www.stonybrook.edu/commcms/ams/research/opresearch.php

Texas A&M University: Operations Research Faculty
Operaatioanalyysin tutkimus keskittyy optimointiin, stokastisiin prosesseihin, soveltavaan todennäköisyyslaskentaan ja riskianalyysiin. Tällä hetkellä tutkijoita on 9.
https://engineering.tamu.edu/industrial/research/operations-research.html

University of Illinois Urbana-Champaign, The Grainger College of Engineering
Operations Research
Operaatioanalyysi kattaa laajan valikoiman ongelmanratkaisutekniikoita ja -menetelmiä, kuten matemaattinen optimointi, jonoteoria, Markovin päätösprosessit, simulointi, taloudelliset menetelmät, data-analyysi, tilastot, hermoverkot, asiantuntijajärjestelmät ja päätösanalyysi. Sen soveltamisala on laajentunut merkittävästi ajan myötä. Modernin operaatioanalyysin tärkeimpiä sovellusalueita ovat muun muassa toimitusketjun hallinta, markkinointi ja tulonhallinta, valmistus, rahoitussuunnittelu, tietoliikenneverkot, terveydenhuollon hallinta, kuljetusverkot, energia ja ympäristö, palvelujärjestelmät, verkkokauppa, sotilaallinen puolustus ja kotimaan turvallisuus.
https://ise.illinois.edu/research/operations-research
Decision and Control Systems
Ohjausjärjestelmien ala (control systems) sisältää dynaamisten järjestelmien tunnistamisen, mallintamisen, analyysin ja ohjauksen. Sen sovellukset vaihtelevat robottikäsivarsien ohjaamisesta telekirurgiaan, taloudellisten markkinoiden mallintamiseen ja hallintaan; Lämpötilan säätelystä kodeissa ja toimistorakennuksissa miehittämättömien ajoneuvojen, rakettien ja robottien hallintaan. Säätöjen analysointi ja toteutus saattavat vaatia suurta matemaattista hienostuneisuutta. Monet tunnetut optimoinnin tekniikat, kuten dynaaminen ohjelmointi, perustuvat ohjausteoriaan. Ohjaus-järjestelmien ala tarjoaa ennennäkemättömän valikoiman mahdollisuuksia teoreettiseen työhön, sovelluksiin ja niiden välimuotoihin.
https://ise.illinois.edu/research

University of Maryland: The Institute for Systems Research: Operations Research, Decision Making
Institute for Systems Research (ISR) on tunnustettu johtaja päätöksenteossa ja operaatioanalyysissä. Tiedekunta ja sen opiskelijat ovat luoneet mm. mallipohjaisen lähestymistavan integroidun tuote-prosessin suunnitteluun ja useita malleja päätöksentekoon, mukaan lukien massarokotusklinikoihin ja muihin kansanterveystarpeisiin. Merkittävintä on ehkä se, että ISR-tutkijat ovat osana NEXTOR-konsortiota yli 20 vuoden ajan tehneet toimintatutkimusta Federal Aviation Administrationille ilma-liikenteen hallinnan, ilmailutalouden ja -politiikan sekä suorituskyvyn arvioinnin ja mittareiden alalla.
https://isr.umd.edu/research/operations-research-manufacturing

University of Wisconsin-Madison: Operations Research, Optimization and Analytics
Tässä tutkimuksessa toteutettuja teorioita ja työkaluja voidaan käyttää kehitysmahdollisuuksien tunnistamiseen useilla sovellusalueilla:

- Tuotanto
- Logistiikka, kuljetus ja toimitusketju
- Terveydenhuollon järjestelmät
- Energiajärjestelmät
- Ilmastonmuutos ja kestävyys
- Kriittisen infrastruktuurin suojaus ja turvallisuus
- Yleisen turvallisuuden ja hätätilanteiden hallinta

https://engineering.wisc.edu/departments/industrial-systems-engineering/research/operations-research-optimization-and-analytics/

Virginia Tech: Operations Research and Analytics
Tutkimusryhmä tutkii operaatioanalyysin teoreettisia näkökohtia, kuten matemaattista ohjelmointia, simulointia (esim. diskreetit tapahtumat, Monte Carlo, järjestelmädynamiikka) ja stokastisia prosesseja, tilastoja ja todennäköisyyksiä, jonoverkkoja, järjestelmätiedettä, verkon optimointia, päätöksen tekoa, koneoppimista ja muita. Nämä työkalut on kehitetty käsittelemään mm. terveydenhuollon ja lääketieteen, julkisen politiikan, tuotannon, televiestinnän, toimitusketjun ja logistiikan ja älykkään infrastruktuurin ongelmia, ja ovat välttämättömiä nykypäivän monimutkaisten järjestelmien ja organisaatioiden ymmärtämiseksi ja hallitsemiseksi.
https://www.ise.vt.edu/research/operations-research-analytics.html

Institute for Complex Additive Systems Analysis (ICASA)
ICASA:n perustutkimuksen painopiste on ymmärtää tehokkaan suunnittelun lisävaikutuksia – tai tahattomia seurauksia – toisistaan riippuvaisissa järjestelmäjärjestelmissä. Tutkimusta tehdään neljällä strategisella alueella:

- Perustutkimuksen suorittaminen monimutkaisista summautuvista järjestelmistä
- Tutkimuksen soveltaminen todellisiin ongelmiin yksityisellä ja julkisella sektorilla
- Keskeisten mahdollistavien teknologioiden kehittäminen tutkimustulosten soveltamisessa
- Opetus- ja koulutusohjelmien perustaminen vastaamaan asiakkaidemme ainutlaatuisia tarpeita

https://www.nmt.edu/research/organizations/icasa.php

United States Military Academy: Operations Research Center
Tällä hetkellä käynnissä olevia projekteja:

- Operational Activity Analysis for AFRICOM
- Applying Natural Language Processing to Maintenance Data for DoD CPO
- A cost analysis of the Army's Ground Mobility Fleet for the ASA(ALT)
- An Operational Impact Study of the Next Generation Automatic Test System (NGATS) fielding for PD TMDE
- Simulating a Maintenance Free Operating Period (MFOP) in Army Aircraft for FVL CFT
- Strategic Messaging Assessment for INDOPACOM
- Active Component/Reserve Component Optimal Mix Study for DASD Force Readiness
- Full Mobilization Simulation Development for DASD Force Readiness
- Big Data Analysis of Army UH60 GCCS-A Data for the ASA(ALT)

https://www.westpoint.edu/centers-and-research/operations-research-center/research

3.4.2 Kanada

Simon Fraser University: Centre for Operations Research and Decision Sciences (CORDS)
Centre for Operations Research and Decision Sciences (CORDS) sijaitsee Simon Fraser Universityssä Surreyssä. Keskus keskittyy liiketalouden, tietojenkäsittelytieteen, matematiikan, SIAT:n ja tilasto-tieteen opettajien kanssa operaatioanalyysin, optimaalisen päätöksenteon tieteen, tutkimiseen. Jäsenet tekevät sekä perus- että soveltavaa tutkimusta ja tekevät yhteistyötä teollisuuden kanssa konsultoimalla ja luomalla opiskelijoille harjoituspaikkoja.
https://www.sfu.ca/math/research/cords.html

Université de Montréal: Department of Computer Science and Operations Research

Asiantuntijoiden kiinnostuksen kohteita:

- Algoritmit
- Game Theory
- Kombinatorinen optimointi
- Operaatioanalyysi
- Laskennallinen kompleksisuusteoria
- Logistiikka
- Kuljetusjärjestelmien optimointi
- Kuljetusverkostot
- Itseajavat ajoneuvot
- Suuren skaalan suunnitteluongelmat
- Koneoppiminen
- Tekoäly
- Big Data
- Hintaoptimointi

https://diro.umontreal.ca/english/research/research-interests/experts/ex/Operations%20research/

3.5 Afrikka

3.5.1 Egypti

Cairo University: Operations Research and Decision Support DS Department
Operations Research and Decision Support -laitoksella opetetaan ja tutkitaan systeemitiedettä, operaatioanalyysia ja päätöstiedettä. Tutkimusaiheisiin kuuluu näiden mm. näiden aiheiden sovellukset taloudessa sekä niiden tilastollinen analyysi.
http://fci.cu.edu.eg/Operations_Research_and_Decision_Support__DS_Department_

3.6 Aasia

Israel Institute of Technology: System Analysis and Engineering
Israel Institute of Technology:sta löytyy useita tutkimusryhmiä liittyen systeemi- ja operaatioanalyysiin, kuten *The Haim and Eugenie Pardo Enterprise System Modeling Laboratory*.
https://web.iem.technion.ac.il/site/labsresearch_groups/
https://esml.technion.ac.il/research-areas/
https://web.iem.technion.ac.il/site/research/system-analysis-and-engineering/

3.6.1 Japani

The University of Tokyo: Mathematical Informatics
Laitoksen tavoitteena kehittää ja analysoida matemaattisia malleja käytännön tekniikan ja siihen liittyvien ongelmien mallintamiseen ja ratkaisemiseen. Perimmäisenä tavoitteena on edistää yhteiskunnan kehitystä.
https://www.i.u-tokyo.ac.jp/edu/course/mi/index_e.shtml

3.6.2 Kiina

Tsinghua University: Institute of Operations Research and Statistics
Kymmenen vuoden kehitystyön jälkeen instituutti on saavuttanut merkittäviä saavutuksia akateemisessa tutkimuksessa, akateemisen ohjelman kehittämisessä ja akateemisessa vaihdossa. Tutkimus kattaa monia operaatioanalyysin ja tilastotieteen osa-alueita. Teoreettisesta näkökulmasta tarkastelemme aloja kuten globaali optimointi, diskreetti optimointi, stokastinen optimointi, päätös-teoria ja tiedon louhinta. Mitä sovelluksiin tulee, tutkimusta on tehty logistiikan ja toimitusketjun hallinnan, käyttäytymisen ja palvelutoimintojen hallinnan sekä kuljetusten hallinnan aloilla.
https://www.ie.tsinghua.edu.cn/eng/Research/Institute_of_Operations_Research___Statistics.htm

3.6.3 Singapore

National University of Singapore: Institute of Operations Research and Analytics (IORA)
Tällä hetkellä maailman johtava tiimi algoritmien suunnittelussa suuren mittakaavan konveksi-optimointiongelmien ratkaisemiseen, muiden rahoitussuunnittelun työkalujen kehittämiseen, robustiin optimointiin ja oppimisalgoritmeihin. Ryhmällä on vahva kiinnostus laajamittaisten optimointiongelmien ratkaisemiseen data-analytiikan sovelluksilla.
Viimeaikaisia tutkimusprojekteja:

- Multi-sample Change-point Detection
- Variational Inference Methods
- Approximate Bayesian Computation
- Mean Field Games
- Algorithms and solvers for Large-scale Composite Conic Programming and its applications to Data Analytics

https://iora.nus.edu.sg/

3.7 Australia

The University of Queensland: Operations Research
Tutkimuksen avainaiheita:

- Matemaattinen ohjelmointi
- Laskennallinen geometria
- Optimaalinen hallinta
- Sovellettu todennäköisyys
- Stokastinen matemaattinen biologia
- Riskien mallinnus
- Jonoteoria
- Monte Carlo -simulaatio
- Sovellukset kuljetukseen ja logistiikkaan
- Sovellukset luonnonvarojen hallintaan
- Sovellukset luonnonsuojelubiologiaan

4 Kirjoja ja julkaisuja liittyen systeemiajatteluun sekä systeemi- ja operaatioanalyysiin

Uusimmatkin suomenkieliset kirjat systeemi- ja operaatioanalyysiin liittyen ovat 70- ja 80-luvuilta.

Operaatioanalyysi (Luoma, Martti) 1977
https://jyu.finna.fi/Record/jykdok.491167

Operaatioanalyysi (Järvinen, Pertti) 1968
https://jyu.finna.fi/Record/jykdok.331934

Operaatioanalyysi (Rantanen, Jaakko; Atk-instituutti) 1987
https://jyu.finna.fi/Record/jykdok.113077

Operaatioanalyysi (Rantanen, Jaakko) 1987
https://keski.finna.fi/Record/keski.51050

Operaatiotutkimuksen ja systeemianalyysin mallien käyttö tutkimuksessa (Karhu, Markku; Seppälä, Yrjö) 1986
https://www.finna.fi/Record/tuni.99636575305973

Introduction to Decision Analysis (David C. Skinner) 2009
https://www.decisions-books.com/IntroDA.html

Operations research: an introduction to linear optimization and decision analysis (Charles M. Harvey) 1979
https://jyu.finna.fi/Record/jykdok.330352

Introduction to Decision Analysis (Bruce F. Baird) 1978
https://jyu.finna.fi/Record/vaari.1437419

Decision making based on data analysis methods (Sirola, Miki; Sulkava Mika) 2016
https://jyu.finna.fi/Record/jykdok.1575091

Introduction to Operations Research (Ecker, Joseph G.; Kupferschmid, Michael) 1988
https://jyu.finna.fi/Record/jykdok.264133

Introduction to Operations Research (Hillier, Frederick S.; Lieberman, Gerald J.) 1969
https://jyu.finna.fi/Record/jykdok.330171

Operations Research : an introduction (Taha, Hamdy A.) 1992/2011
https://jyu.finna.fi/Record/jykdok.1184067

A Decision Analysis Reading List
https://people.duke.edu/~rnau/readlist.htm

Decision-analytic books
https://www.bayesfusion.com/books/

Yugoslav Journal of Operations Research
http://yujor.fon.bg.ac.rs/index.php/yujor

Further Reading (Wikipedia)
https://en.wikipedia.org/wiki/Operations_research#Further_reading

INFOR: Information Systems and Operational Research
https://www.tandfonline.com/journals/tinf20

European Journal of Operational Research
https://www.journals.elsevier.com/european-journal-of-operational-research

Advances in Systems Sciences and Applications (ASSA)
https://ijassa.ipu.ru/index.php/ijassa

Operations Research: Selected relevant journals (Hamburg University of Technology: Institute of Operations Research and Information Systems)
https://www.tuhh.de/oris/en/research/journals.html

5 Yhteenveto

Kuten jo johdannossa mainittiin, raportissa listattuja opinto-ohjelmia yhdistäviä aiheita ovat erityisesti matematiikka, tilastotiede, ohjelmointi, optimointi ja algoritmit. Lisäksi systeemi- ja operaatioanalyysi liittyvät hyvin moneen eri alaan, kuten ilmastonmuutoksen torjumiseen, hallintoon, logistiikkaan, liikenteeseen, lääketieteeseen ja maanpuolustukseen.

Suurimmassa osassa opinto-ohjelmia vaaditaan esitietoina sopivia pohjaopintoja matematiikasta, tilastotieteestä, algoritmeista sekä tietotekniikasta tai tietojärjestelmätieteestä. Näitä opintoja on tarjolla myös Jyväskylän yliopistossa, joten systeemi- ja operaatioanalyysin opetusta olisi tämän osalta mahdollista lisätä JYU:ssa.

6 Lähteet

[1] https://en.wikipedia.org/wiki/Operations_research
[2] https://en.wikipedia.org/wiki/Systems_engineering
[3] https://en.wikipedia.org/wiki/Systems_analysis
[4] https://fi.wikipedia.org/wiki/Operaatioanalyysi

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