Data Science and Network Intelligence

Programme syllabus (M2, S9/S10)

Data Science and Network Intelligence (DANI)

Coursework Description

This MSc (and VAP) in Data Science and Network Intelligence (DANI) is home for creative problem-solvers who want to use data strategically to advance the ITC society. We are cultivating a new type of quantitative thought leader who uses computational strategies to generate innovation and insights.

Artificial Intelligence (AI) and Machine Learning (ML) approaches, well known from IT disciplines, are beginning to emerge in the networking domain. These approaches can be clustered into AI/ML techniques for network management; network design for AI/ML applications and system aspects. Recently, networking has become the focus of a transformation enabled by new technological and economical models resulting from virtualization and cloud computing. These techniques provide novel architectures supported by emerging technologies such as Software-Defined Networking (SDN), Network Function Virtualization (NFV) and more recently, edge cloud and fog.

Data Science, as a discipline, apply ML models on IoT data, social media data and Big Data to perform tasks that ordinarily require human intelligence. By leveraging these heterogeneous data, businesses can model, generate insights, and make more effective decisions. The widespread popularity of Data Science, AI, and ML proves that many business operators enjoy technology-aided business decisions and even technology-guided competitive intelligence. AI, ML techniques and statistical analysis will continue to provide deep insights for human decision-makers.

DANI combines rigorous technical training with field knowledge, industry insights and practice in critical thinking, teamwork, communication techniques, and collaborative leadership to generate data scientists with a deep understanding of how telco/webcos evolve and who can add value to any technical field.

The program covers areas such as network intelligence, automation, communication services, large-scale data analytics, advanced machine learning and data-mining, information retrieval, natural language processing and web mining. It also includes foundational modules on topics such as programming for data analytics, Internet of things, services and optimization. Students enrolled in the program deepen their knowledge in an elective topic by working on a project in conjunction with either a research group or an industry partner. In addition to six key technical courses, a course on telecom management and economics, jointly taught with Institut Mines-Telecom Business School, gives students essential information about markets and business models. Moreover, each student becomes involved in concrete projects and produces a Master's thesis. The Master's thesis can be conducted in collaboration with industrial partners or research laboratories.

Students attend the ICIN international conference (www.icin-conference.org). In addition, World-renowned experts fromfrom Orange Labs, CISCO, and ETSI are invited to give lectures during the year.

English is the language of instruction and courses are taught jointly with MSc students from University Carlos III, Madrid (Spain), Asian Institute of Technology (international), Polytechnic University of Bucharest (Romania), University of Calabria (Italy), and National Chiao Tung University (Taiwan), Skoltech (Russia)

Career prospects

The demand for professionals who can interpret large quantities of data with a deep understanding of telcos and webcos has never been greater, and these skills are vital for scientific advancement and business success. Given the program's solid foundations, students acquire both an in-depth theoretical background and practical knowledge. It only takes a few weeks for graduates to find their first job in the field of ICT and most graduates are hired before graduation.

Prerequisite for TSP students: no S8 prerequisite.

Courses / modules: in S1 choose 8 modules among 11.

Module	Sem	ECTS	Code	Coordinator	Hours
Data visualisation	S1	4	IMA7201	M. Preda	18
Data Science and AI – theory to practice	S1	4	CSC7018	A. Maddaloni	27
Deep Learning, Transfer Learning - application to NLP and Image Recognition	S1	4	xxx	P. Rajapaksha / N. Crespi	26
Blockchain, Smart contracts, Bitcoin and off-chain payments	S1	4	CSC7208	J. Garcia Alfaro	15
Network Intelligence and Communication Services	S1	4	NET7012	N. Crespi	48
Internet of Things and Digital Twin	S1	4	CSC7016	R. Minerva	18 (+3 days if ICIN)
In-Network Computing for Distributed Networking	S1	4	CSC 7019	MJ. Montpetit	18
Service-oriented Computing	S1	4	CSC7017	W. Gaaloul	21
Wireless Access Networks	S1	4	NET7003	B. Jouaber	18
Optimisation: Theory and applications	S1	4	NET7006	W. Benameur	27
Business Modelling and ICT (in cooperation with IMT-BS)	S1	4	MGT7001	P.Vialle	15
MSc Thesis (for MSc only) or internship in the industry (for MSc or ingénieurs)	S2	28	NET7515	N.Crespi	6 months

Module IMA7201	Data Visualisation

Department : ARTEMIS
Coordinator : Marius Preda **Phone:** 0175314442
Email: marius.preda@it-sudapris.eu **Room:** 4A342

Objectives

The goal of the course is to have an overview on the data structures and transformations for visualization, get familiar with various types of graphical representations and practice 3D and immersive representations.

The course is split into two parts:

- Traditional data visualisation techniques, mainly using 2D graphics components and numerical analysis.
- Advanced representation forms including 3D representations and immersive spaces.

Organisation
9 hours coursework, 9 hours practice

Evaluation

VR project to visualize and interact with a set of data of choice.

Programme

Introduction to Information Visualization & Data abstraction (course 3H)

Graphs and data transformation & Graphical components and mapping strategies (course 3H)

Introduction to Tableau (lab 3H)

VR for data visualisation (course 3H)

Unity hands on (lab 6H)

Module CSC70718	Data Science – from theory to practice

Department : RS2M
Coordinator : Noel Crespi **Phone :** 01 60 76 47 23
Email : noel.crespi@mines-telecom.fr **Room :** D107

Objectives

The goal of the course is to have a broad introduction on data science and artificial intelligence techniques. The course is split into three parts:

- Introduction to Data Science, in which we learn the why data is the value and what are the existing challenges that needs mining of the data.

- Unsupervised learning, in which we study the concept and some of the related algorithms: hierarchical clustering, kmeans, dbscan, hdbscan, etc.

- Supervised learning, in which we study the concept and some of the related algorithm: regression (linear and logistic), decision trees, Naïve Bayes, SVM, random forest

- Text analysis (supervised and unsupervised) in which we will review the specificities of text analysis

Each course is followed by practical work using R and/or python

In cooperation with Total.

Organisation
14 hour coursework, 20 hours practice

Evaluation
Practical session grading

Programme

- Data Science in scale
- Big Data problems
- Introduction to Data mining
- Data handling with R / Python
- Supervised Machine Learning algorithms
- Unsupervised Machine Learning algorithms
- Text mining

CSC…..	Deep Learning, Transfer Learning and application to NLP and Image Recognition

Department : RS2M
Coordinator : **Phone :**
Email : **Room :**

Introduction

Deep learning is a class of machine learning algorithms which enables computers to learn from examples. Deep learning techniques have been used successfully for variety of applications, including: automatic speech recognition, image recognition, natural language processing, drug discovery, and recommendation systems etc. This course will provide students to learn the fundamentals of deep learning, the architecture and core components of neural networks, NN optimization, hyperparameter selection and how to implement, train, and validate their own neural network (mainly an application of images).

The reuse of a previously learned model on a new problem is known as transfer learning. It is particularly popular in deep learning since it can train deep neural networks with a small amount of data and produce an accurate model. The knowledge of an already trained model for a long time on huge datasets is transferred to a different but closely linked problem throughout transfer learning. In this course, students will learn the evolution of transfer learning, Transformer architecture and how to implement, train, pre-train transformer-based models on a selected use case (mainly an application of NLP).

Organisation
14 hours coursework, 12 hours practice

Evaluation
Practical session grading

Programme

- Introduction to deep learning
- Architecture and core components of NN
- NN optimization
- Hyperparameter selection
- Implement, train and validate their own NN
- Discussion and hands-on session on MNIST dataset
- Introduction to Transfer Learning
- Architecture of the Transformer
- Pre-training transformer-based models
- Implement and train transformer-based models
- Discussion and hands-on session on an NLP application
- Deep transfer learning

Module CSC7208	Blockchain, Smart contracts, Bitcoin and off-chain payments

Department : RST
Coordinator : Joaquin Garcia Alfaro **Phone :** 01 75 31 44 10
Email : joaquin.garcia_alfaro@telecom-sudparis.eu **Room :** 4A 206

Objectives

Since its conception in 2008, Bitcoin and blockchain-based distributed ledgers have been presented to society as a technological revolution to transform industrial, economic and citizen worlds. This module will introduce the learners to different aspects of it, from basic use cases to real world applications. It will include as well an introduction to Ethereum and Smart Contract languages, as well as the use of off-chain payment channels and lightning networks.

[In collaboration with Orange Labs]

Hours

- 15 hours

Evaluation

- Written test or oral presentation.

Programme

1. The Bitcoin cryptocurrency
   - History of Bitcoin
   - Cyber-security & cryptocurrencies
   - Blockchain technologies
   - Blockchain definitions
   - Public vs. Private Blockchains
   - Blockchain explorers
   - Bitcoin P2P network
   - Bitcoin scripting language
   - DLTs & blockchain applications
   - Bitcoin transactions in depth

2. Ethereum and brief introduction to Smart Contracts (SC)
   - Ethereum & Distributed Networks
   - SC Basics
   - Ethereum Virtual Machine
   - Use Cases (Basic + Advanced)
   - SC advantages
   - How SC work?
   - Existing platforms and languages for SC
   - SC applications
   - Challenges of SC

3. Programming SC in Solidity
   - Introduction to Solidity
   - Enterprise Blockchain Real World Applications
   - Motivation and Perspective
   - Big Names
   - Auto and Mobility
   - Social Goods

4. Off-chain payment channels
   - UTXOs (Unspent Transaction Outputs)
   - Payment channels
   - Atomic swaps
   - Lightning networks

Module NET7012	Network Intelligence and communication services

Department : RS2M
Coordinator : Noël Crespi **Phone :** 01 60 76 46 23
Email : noel.crespi@telecom-sudparis.eu **Room :** D107

Introduction:
The course concentrates on service architectures and also covers today's networks, to allow the students understand the changes that the world of telecommunications and internet is facing. Message flows and procedures are thoroughly examined in class and in small student groups to strengthen understanding.

Network Intelligence course encompasses four main parts. The first part of the course aims to present the background on Autonomic computing and Networking as a core stone of Network intelligence. The Second part objectives are to zoom on the algorithmic part, the possible operations (classification, clustering, etc.). The third and fourth part target to practice the of machine learning for network data (data extraction, pre-processing, model set-up, configuration and validation, etc.)

In cooperation with Orange Labs and CISCO.

Organisation:
48h hour coursework .

Evaluation:
Group work and oral presentation.

Programme

Introduction to Network cognitive management
- Motivation
- Architecture
- Network Data
- Analytics and SDN & NFV

Zoom on machine learning algorithms for Network
- Basics
- Neural Network and deep learning algorithms
- Approach and process for ML in Networks

Tools, libraries and Hands-on (python based)
- Basics for a machine learning project set up, tools, manipulation of opensource dataset
- Network focused Hands-on (python based)
- Preprocessing of Network data:
- Model selection; Model execution; **Model validation**

From Telcos to WebCos
- SIP
- IMS, NGN architecture
- Service architecture
- Web-NGN convergence,
- SDN (Software Defined Networking)
- NFV (Network Function Virualisation)

Bibliography

E. Bertin, N. Crespi, T. Magedanz, "Shaping Future 6G Networks: Needs, Impacts and Technologies," Wiley-IEEE Press, ISBN: 978-1-119-76551-6, November 2021.

Copy of the slides. Standards: selected technical specifications from 3GPP, IETF and ITU-T.

Module CSC7016	Internet of Things and Digital Twin

Department : RS2M
Coordinator : Roberto Miverva
Email : Roberto.minerva@telecom-sudparis.eu **Room :** D108-20

Introduction:
Internet of Things, IoT, is a set of technologies able to have a high impact on how people live, produce, and modify/interact with the environment. Such a transformation is driven by increasing technologies capabilities of sensors/actuators, communications, general purpose hardware, availability of software and programmability of devices. The integration of so different technologies is a problem in itself and it increases if very large scale systems are considered. IoT is also trying to solve cogent issues of specific problem domains, such as Assisted Living, e-health, transportation, manufacturing, smart cities and so on. The course will analyze the technologies, the current trends and the future challenges in this important real, considered under the possibilities of extreme softwarization of systems. At the end of the courses, Student will be able to design, evaluate and select the proper solutions within a large IoT system.

In addition to technological and problem domain specific challenges, there exist further challenges that fall in Business, Social and Regulation realms. They can greatly impact the deployment and the success of IoT. The course aims is to provide a view on some major technologies challenges of IoT and to cover a few critical Business and Social issues that could hamper the large deployment of IoT systems. The course requires basic notions about IP protocol communication and software architecture and programmability. It is devoted to PhD and graduate students willing to achieve a large perspective of the aims, goals and potentialities of the Internet of Things, and the possible impact on users.

In cooperation with ETSI.

Organisation: 18 hour coursework + optional ICIN conference.

Evaluation: Short project with design and possibly a draft implementation of a simple IoT service

Programme

The Context of IoT
- A Definition of IoT
- A few Challenges of IoT

IoT Technologies
_ What Things are
- Networks of Things
- Communications Technologies
- Access Technologies
- Protocols

Software
- SW Platforms

-Middleware

Standards
- major contributions to standardization

IoT Challenges
- Softwarization
- Identity, Data, and Ownership
- IoT and Artificial Intelligence
- Complex System
- Business and SOcial Perspectives on
- IoT Social Issues
- IoT Use Cases

Module CSC 7019	In-Network Computing for Distributed Networking

Department: n/a
Coordinator: Marie-José Montpetit **Phone:**
Email: marie@mjmontpetit.com **Room:**

Introduction

As more and more intelligence is distributed through the networks and that computing in network nodes especially is becoming prevalent it is g essential to address the impacts of this evolution on both existing and emerging new networks. Architecting of the cloud-edge continuum with processing nodes will enable more flexibility, enhanced performance, autonomy and less reliance on energy-inefficient cloud infrastructure. This course introduces students to the new rationale behind the meddling of computing and networking as well as for new Internet architecture. Applications as diverse as multimedia, distributed manufacturing, Internet of things and more recently distributed cognition will be included. A project illustrating a use case will be required. Links to conferences and research groups addressing the class topics will also be provided.

Objectives

- Learn current and emerging architectures and devices for in-network computing in the cloud/edge continuum.
- Design applications and analyze distributed architectures for advanced functionality using in-network capabilities.
- Apply in-network computing to real-world distributed systems.

Organisation
15 hour coursework

Evaluation
Project.

Programme

What is "in-network computing".
Heritage: active computing, compute-first networking, SDN, NFV, data-driven Internet architectures
Distributed network architectures and IPFS.
Tofino switch and P4.
Joint filtering/processing systems.
Impacts of in-network functionality on transport.
Impacts of in-network functionality on security, use of blockchain traceability.
Use cases and ideas for projects: intelligent automation.
Future Internet Architectures and 6G.
Presentation of term projects.

Bibliography (preliminary)

Computing in the Network – COIN – IRTF research group. https://datatracker.ietf.org/rg/coinrg/about/
Xin Jin et al. 2017 *NetCache: Balancing Key-Value Stores with Fast In-Network Caching,* https://www.cs.jhu.edu/~xinjin/files/SOSP17_NetCache.pdf
Dirk Kutscher, Protocol Design and Socioeconomic Realities, http://dirk-kutscher.info/blogroll/great-expectations/?fbclid=IwAR1jCHSqMtIcMHj1Ie_6cVPLEzSArFTN7YHc76tTt1Wp-a5fNZk6rxcPwxQ

Module CSC7017	Service-oriented Computing

Department : INF
Coordinator : W. Gaaloul **Phone :** 01 75 31 44 30
Email : walid.gaaloul@telecom-sudparis.eu **Room :** 4A310

Objectives

This course introduces fundamental concepts for Service-Oriented Computing (SOC) and business process management (BPM). SOC is a computing paradigm that is used by major enterprises and government agencies. SOC represents computing in a collection of loosely coupled services. BPM includes methods, techniques, and tools to support the design, enactment, management, and analysis of operational business processes. This course aims at presenting concepts, principles, and tools for SOC and BPM. It provides students with a comprehensive introduction to service-oriented computing by covering most known technical solutions and the research opportunities that exist. Students will also learn about the programming model of Web services and business processes and apply this knowledge to a group project in which they practice team work.

Evaluation

- Evaluated Lab (30%)
- Mini project (70%)

Programme

- Introduction to Service Oriented Architecture (SOA)
- Web services
  - SOAP-based Web services
  - RESTful Web services
- Introduction to Business Process Management (BPM)

- SOAP-based Web service deployment with Axis2 (auto deployed by Eclipse WTP)
  - Simple Web service deployment
  - Multi-web services deployment on a Tomcat server
  - Web Service Client deployment with Eclipse WTP

- Outils pour la conception d'API REST
  - Structure et endpoints.
  - Sécurité; vulnérabilités et bonnes pratiques
  - Frameworks pour construire votre API
  - Tester une API : Postman
  - OpenAPI et Swagger

- Service composition
  - Business process model and notation (BPMN 2.0)
  - Workflow Management systems (Bonita, Activiti)

News trends
  - Cloud services, servless, micro-services
  - Process intelligence

Bibliography

http://www-inf.it-sudparis.eu/cours/CSC4503/
http://www-inf.it-sudparis.eu/cours/WebServices/
Site de W3C (normes) : www.w3.org
Site de Zvon (tutoriel XML) : http://www.zvon.org/

Module NET7003	Wireless Access Networks

Department : RS2M
Coordinator : Badii Jouaber **Phone :** 01 60 76 42 08
Email : Badii.jouaber@telecom-sudparis.eu **Room :** A106.01

Objectives
This course addresses Wireless networks' technologies and architectures.

The first and major emphasis is on radio access network architectures, procedures and methods. We will address resource sharing and radio resource allocation, control and management from GSM to LTE networks (i.e. TDMA/FDMA, CDMA and OFDMA systems).

The course addresses Uplink and downlink interference management, scheduling issues and capacity evaluation for the air interface or the radio access network.

Physical to logical channel mapping for cellular networks are also described along with the RAN architecture and the associated procedures and protocols.

QoS management and service classes will be presented and debated.

The impact of current choices on QoS and mobility management as well as the trends and evolutions toward beyond 5G and C-RAN networks will be discussed.

Organisation :18 hour coursework

Evaluation: Written test.

Programme

RAN architecture
Radio Access Network Architecture for GSM, GPRS, UMTS and LTE, network devices, interfaces and protocols
QoS definition and management in cellular networks
Access methods and radio resource management in mobile networks, mainly for
- TDMA/FDMA systems,
- CDMA systems and
- OFDMA systems.

Scheduling issues for
- downlink
- uplink

Procedure and protocol used for resource allocation
Transport technologies in the RAN
- Circuit versus Packet modes
- QoS Classes and QoS mapping between radio and transport layers

C-RAN
Green IT

Bibliography
3GPP documents and scientific papers

Module NET7006	Optimisation: Theory and Network applications

Department : RS2M
Coordinator : Walid Benameur **Phone :** 01 75 31 44 24
Email : walid.benameur@telecom-sudparis.eu **Room :** 4A244

Introduction

Designing a minimum cost network with high performance is an important challenge for network operators. Some mathematical and computer science tools are required to model and solve complex network optimization problems. This course will provide students with analysis, modelling and optimization capabilities by presenting principles from combinatorial optimisation and game theory. These notions will be applied to wireless systems, networks design and optimization problems.

Objectives

This course focuses on the fundamentals of optimization theory: graph algorithms, linear programming, integer programming, and complexity theory. Some network optimization problems will be solved using some of the mathematical methods presented in the course. An introduction to game theory applied to wireless communication networks will also be provided. A main focus will be given to traffic engineering, network topology design, frequency assignment, network routing, dimensioning, and pricing problems.

Organisation

27 hour coursework

Evaluation

Written test.

Programme

- Some graph algorithms
- Linear programming basics
- Introduction to Integer programming
- Traffic engineering
- Network topology calculus
- Network optimal routing and dimensioning
- Frequency assignment
- Pricing
- Game theory

Bibliography

Telecommunication Network Design Algorithms, A. Kershenbaum, Mcgraw-Hill;
Network Optimization, Balakrishnan, Moire, Chapman Hall/CRC;
Network Optimization: Continuous and discrete models; Bertsekas, Athena Scientific
Routing, Flow, and Capacity Design in Communication and Computer Networks, M. Pioro, D. Medhi, Morgan Kaufmann
Game Theory for Wireless Engineers, A. MacKenzie and L. DaSilva

Module MGT7001	Business Modelling and ICT

Department: MMS, IMTBS
Coordinator: Pierre Vialle **Phone:** 01 60 76 47 93
Email: pierre.vialle@telecom-em.eu **Room:** E415

Technological and service innovation induce the rise of innovative business models based on varying manners of managing revenues, costs and exchanges. This course develops the theory and practical applications of business modelling in the case of ICT-based businesses.

Objectives

- Define the various dimensions of business models and their interaction
- Examine the main parameters of successful business models
- Design business cases and models
- Learn from successful business models in various contexts
- Appraise successful strategies

Expectations: Participation in courses, teamwork, document research. Pedagogical methods : Course, case studies, student's presentations

Class schedule :

- Introduction
- Theoretical foundations for business modelling
- The dimensions of business models and their interaction: value-chains and activity model, supporting infrastructure, role model, value proposition, financial model
- The evolution of business models with technological innovation
- Tactics for capturing value
- The role of user's participation
- Analyses of various cases (i.e. mobile business models, web business models, digital games business models, TV and movie business models)

Organisation: 15 hours lecture, workload 30 hours.

Evaluation: Personal work, teamwork, test

Bibliography

Leading the revolution., G. Hamel, Boston, Harvard Business School Press, 2000.
Place to space: Migrating to eBusiness Models., P. Weill and M. R. Vitale, Boston,Harvard Business School Press, 2001.
Internet Business Models and Strategies, A. Afuah and C. Tucci, Boston, McGraw Hill, 2003.

NET7515	MSc Thesis / Internship

Department : RS2M
Coordinator : Noël Crespi **Phone :** 01 60 76 46 23
Email : noel.crespi@telecom-sudparis.eu **Room :** D107

Objectives	**Topics**
In parallel to this specialization coursework students can either do their Master thesis in a lab or follow a 6 months internship in the industry (mandatory for ingenieurs). For Master thesis, students are involved in concrete projects requires personnel and team work. The student can choose his/her advisor in any department in Telecom SudParis as well as Telecom Business School. **Organisation** 6 months. **Evaluation** Written report and oral defense.	Topics are jointly proposed by advisors or students.