NUANCES OF MODERN IT CURRICULUM

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Abstract. *The importance and the role of different curriculum topics in the domain of information technology (IT) and communications are discussed. Some connections and applications of these topics with the content of consecrated topics in an information technology program are explored. A special emphasis is given to the applications of classical and fuzzy logic in information technology.*

1. INTRODUCTION

The objective of the IT curriculum topics is to familiarize students with main concepts and techniques used in information technology.

The goal is not to provide detailed mathematical proofs but rather to make students comfortable in an environment where those techniques are increasingly used.

Therefore, the choice of presented topics is connected with the possibility of currently applying them in Information Technology and Communication.

2. DESCRIPTION

The computer has a finite structure. Therefore, its properties are well explained and interpreted in the context of finite mathematics (No such concepts as limit, derivative, integral, etc. are necessary).

The fundamental notions that will be studied will use the mathematical properties of finite sets. This branch of mathematics that studies discrete objects, i.e. objects composed of distinct and dispersed elements is called **discrete mathematics**, [2].

The main topics include: classical and fuzzy logic, sets and combinatory, functions, relations and matrices, induction, recursion, algorithms, graphs and trees, Boolean algebra, and some of their applications.

A laboratory using the software Maple7 or Mathematica will accompany the course. In each of these domains the studied concepts and their properties are chosen regarding their practical importance in Information Technology and Communication.

In accordance with their importance we will aim to provide appropriate motivations and comments.

In addition, numerous practical examples are inserted throughout the course to illustrate the current applications in other IT&C courses such as: knowledge management, databases, web search and web programming, modeling and simulations, data structures, computer architecture, etc. [1], [2], [4].

3. SOME APPLICATIONS IN IT&C

The formal language that permeates information technology is the **language of Fuzzy Predicate Logic** (crisp predicate logic is a particular case of fuzzy predicate logic).

The connections between logic and computers are a matter of engineering practice at every level of **Computer Organization**. A computer program is viewed as a **Formula**.

A programming language, with its formal syntax and with the proof rules that define its semantics, is a **formal system** for which program execution provides only a **model**.

The computers are conceived with the help of **logical devices** and are programmed in a **logical manner**.

The importance of Discrete Mathematics topics in core areas of information technology is illustrated by [2], [4]:

- Knowledge Management (Intelligent Information Systems; Expert Systems; Knowledge Representation; Automated Reasoning; Natural Language Processing, etc.)
- Database Systems (Data Models: relational, entity-relationship, etc.; Query-Processing Languages: model theory, completeness, consistency, deduction, etc.; Knowledge-Based Systems with incomplete, imperfect and tentative information requiring probabilistic, modal, possibilistic, belief and fuzzy reasoning; Natural Language Interfaces etc.)
- Software Engineering (Program Verification; Correctness; Formal Specifications; Formal Design; Requirements, etc.)
- Programming Languages/Data Structures (Language Design; Object-Oriented Approaches; Parallel Processing; Logic programming, etc.)
- Hardware Topics (Circuit Design/ Optimization; Hardware Design Languages; Processor verification; Correctness of OS kernel; Language Implementation of given processors, etc.)

3.1. Boolean Algebra

Computers are built up from integrated circuits (CPU, memory, etc.).

The integrated circuits are made up of transistors, resistors, capacitors, and other electronic components that are combined into circuits.

Transistors can act as amplifiers or switches. In the computers, these transistors switches are combined to form logic gates, which model operations in Boolean algebra.

Boolean algebra is the theoretical basis for computer logic design. Transistors are the bricks for implementation.

Digital circuits are used to perform arithmetic, to control the movement of data within the computer, to compare values for decision-making, etc.

Combinatorial circuits are circuits in which the results of an operation depend only of the present inputs to the operation (e.g. arithmetic circuit).

A sequential circuit is dependent on the previous state of an operation as well as the current sets of inputs (e.g. counter circuit, memory circuit, etc.).

3.2. Logic

Formal logic is the science that studies by means of mathematical tools the notions, judgments and reasoning as well as the laws of correct reasoning. It investigates how sentences are combined and connected, how theorems can be deduced formally from certain axioms, and what kind of object constitutes a proof.

Formal logic presents two parts: the formal language and its intended meaning, which refers to truth-values and is therefore called the truth structure.

Specification of a logic is in its syntax and semantic. For all kinds of logics one defines mathematically:

- Formulas (certain strings of symbols),
- Inferences (derivations of new formulas from old ones).

3.3. Objectives of studying logic

- To familiarize students with formal logic which is a systematization of much of what we do daily when we communicate in natural language and when we draw conclusions using informal reasoning;
- To teach students to use the English language correctly, to understand the notion of formal language, to reason correctly, and to understand a mathematical proof;
- To provide applications of formal logic in information technology:
  - Switching and logic networks;
  - Introduction to PROLOG a programming language based on logic;
  - Verification of correctness of computer programs.

However, even predicate logic is not powerful enough to be able to express the imperfection of information (partial truths) [3].

E. g. *Most young men are healthy.*
It is likely that Alain is a young man.

Therefore, it is likely that Alain is healthy.

Fuzzy logic is a logical system that generalizes the classical (two-valued) logic and includes many-valued logic, i.e. a body of concepts, constructs and techniques which relates to modes of reasoning which are approximate rather than exact in order to deal with the imprecision of information [7].

A proposition is viewed as a fuzzy constraint and membership in a set is a matter of degree. Fuzzy logic plays a pivotal role in AI to knowledge representation and to make inferences from information that is imprecise, incomplete, and uncertain or partially true [6].

In order to study imprecise knowledge (not inexact), we can introduce certain functions of membership.

The values of these functions, contained within the interval (0, 1) will indicate the degree of membership of an element to a fuzzy sub-set.

To better understand the notion of fuzzy sub-sets, we consider "space X" of generic element x. We know that the classical sub-set family of X, $P(X) = \{A \mid A \subseteq X\}$, with its reunion, intersection and complementation operations $\{P(x), \cup, \cap, \neg\}$, forms a Boolean algebra.

We can easily establish the one-to-one correspondence that $A \rightarrow \Psi_A(x) = 1$, if $x \in A$ and 0 if $x \notin A$. $(\{0,1\}^x, \vee, \wedge, \neg)$, where $\vee$ = max, $\wedge$ = min, $\neg\Psi_A = 1 - \Psi_A$ is also a Boolean algebra.

Since this one-to-one correspondence commutes with the operations, the two sets are isomorphic, like Boolean algebra.

We can therefore identify a usual set A with its characteristic function and note that $x \rightarrow A(x)$.

The fuzzy sub-sets of space X are in one-to-one correspondence with the richer category of functions $\{\chi \mid \chi: X \rightarrow [0,1]\} = [0,1]^X$, which we call membership functions, and with which they will be identified and labeled A, B, C,…

Definition. A fuzzy sub-set of X is a sub-set $F \subseteq X \times [0, 1]$, such as:

(i) $pr_{ox}(F) = X$;

(ii) $(x,y_1) \in F$ and $(x,y_2) \in F \rightarrow y_1 = y_2$,

where pr_{OX} is the projection along axis 0x. Therefore, $F \in [0, 1]^X$, $x \rightarrow F(x) \in [0,1]$. We also know that $F = (x, F(x))$, where F is called the <u>membership function</u>.

Remark. It is important to note the net difference between the theory of probability and the mathematical techniques that operate with fuzzy concepts. The problematic "random element", for example, results from incertitude as to its belonging or non-belonging to a classical set, whereas a fuzzy phenomenon typically shows the existence of various degrees of belonging.

The notion of belonging then does not play the role here that it has traditionally played in the theories based on classical sets. It makes no sense, where a fuzzy set F is concerned, to state whether or not x belongs to F.

In a more precise manner, a specialist in information technology needs logical competence for:

- Showing that a problem can be solved by a computer program;
- Translating a problem description in a programming language;
- Arguing that a computer program is correct and efficient;
- Applying the new techniques of programming which require the mastery of different aspects of logic (e.g. in PROLOG, in knowledge representation within AI, in the database query languages, etc.)

The impressive advances in formal logic and the spectacular progresses in the chip technology made possible the development of today's computers.

Computers themselves are designed and built with the help of logical (crisp and fuzzy) devices and they are programmed in a logical (crisp and fuzzy) fashion.

4. SOME IT CURRICULUM PROPOSALS

4.1. School of IT at York University

A large segment of IT professionals now work in the IT consulting and services industry.

In an environment driven by global communications, business growth and technology innovation, consulting and services now account for about 75 percent of the labor force in Canada, the United States and the United Kingdom.

As economies shift, industrial and academic research facilities need to apply more scientific rigor to the practice of services, such as finding better ways to use mathematical optimization and other discrete mathematical techniques to increase productivity and efficiency on demand.

This shift to focusing on IT consulting and services has created a skills gap. The area of high value services requires people who are knowledgeable about business and information technology, as well as the human factors that go into a successful services operation.

Today's Information Systems and Technology specialists require not only a strong technical education but also a good understanding of the organizations in which they work and the capability to communicate and interact effectively with both technical and non-technical end-users of information.

The proposed Masters of Information Systems and Technology (MAIST) being developed by the School of Information Technology represents York University's contribution to this area of research which combines knowledge of technical, business and human factors.

The IT courses are listed below [8]. Only ITEC 6310 is mandatory, and students will choose the other courses after consultation with their research supervisor and/or Graduate Program Director.

**ITEC 6310 3.00 Research Methods in Information Technology*
ITEC 4010/5210 3.00 Systems Analysis and Design
ITEC 4305/5205 3.00 Web Mining
**ITEC 6110 3.00 Workflow Systems and Service Oriented Architecture*
**ITEC 6120 3.00 Systems Requirements Management*
**ITEC 6130 3.00 Autonomic Service Oriented Computing*
**ITEC 6210 3.00 Advanced Information Retrieval Systems*
**ITEC 6220 3.00 Advanced Information Management*
**ITEC 6230 3.00 Health Information Systems*
**ITEC 6320 3.00 Information Technology and Organizational Strategy*
**ITEC 6330 3.00 Designing and Building e-Business Applications*
**ITEC 6970 3.00 Advanced Topics in Information Technology*

4.2. School of IT at Carleton University

The School of Information Technology offers two distinct programs in collaboration with Algonquin College geared towards the high-tech industry and the current trends of today; these programs are as follows:

- The four-year **Interactive Multimedia & Design (IMD)** program is aimed at students who are both artistically inclined and technologically adept.

  The students will acquire the tools needed to take an idea or a problem and advance it through the entire process from concept to design, prototyping, testing, and delivery.

  The program provides the students with a multidisciplinary education covering topics in **computer animation, video effects, game design and development, virtual reality systems, graphic design, 3D visualization, human-computer interaction (HCI)**, and combining them with courses in mathematics, business, and social science.

- The four-year **Network Technology (NET)** program focuses on the design, installation, operation, and management of future complex information networks such as those that make up the Internet.

  The program is multidisciplinary in nature as you combine courses in computer and network technology with courses in physics, mathematics, communications, and social sciences.

  In this program the students not only explore theories and concepts, but also learn by doing.

  State-of-the-art networking labs offer hands-on training with real-world equipment. The NET program has a partnership with the **Cisco Networking Academy** program, whereby the students are trained to successfully write the **Cisco Certified Network Associate (CCNA) and Professional (CCNP)** certification exams.

For IMD program the IT curriculum includes [9]:

Year 1
BIT1100 Mathematics I for IMD
BITEE11 Art & Humanities Elective I
IMD1000 Introduction to IMD
IMD1001 Graphic Design
IMD1002 Visual Dynamics
BIT1002 Physics for Information Technology I
BITEE12 Art & Humanities Elective II
IMD1003 Computer Programming
IMD1004 Software Tools
IMD1005 Web Development

Year 2
BIT1101 Mathematics II for IMD
IMD2000 Multimedia Data Management
IMD2001 Design and Authoring I
IMD2003 Audio and Video
IMD2004 Intermediate Programming
BIT2001 Introduction to Business
BIT2100 Intro to Statistics for IMD
IMD2002 Design and Authoring II
IMD2900 Design Studio

Year 3
BIT2002 Marketing in the IT Sector
IMD3003 Communication Skills for IMD
IMD3004 Human Computer Interaction & Design
IMD3900 Design Studio 2
BIT3003 Elective
IMD3001 Aspects of Product Design Methodology
IMD3002 3D Computer Graphics
IMD3901 Design Studio 3

Year 4
BITEE41 Elective
IMD4002 Technology and Culture
IMD4003 3D Computer Animation
IMD4902 Design Studio 4
BITEE42 Elective
IMD4005 Advanced Topics in Multimedia
IMD4901 Senior IMD Project

For the NET program, the IT curriculum includes:

Year 1
BIT1000 Mathematics I for NET
BIT1002 Physics for Information Technology I
NET1000 Problem Solving
NET1001 Computer Technology Basics
NET1002 Networking Fundamentals
BIT1001 Mathematics II for NET
BIT1003 Physics for Information Technology II
BIT2003 Elective
NET1004 Assembly and Machine Language
NET1005 Basic Network Routing

Year 2
BIT2000 Intro to Statistics for NET
BIT2001 Introduction to Business
NET2000 Enterprise Inter-networking
NET2002 Desktop Operating Environments
NET2006 Object-Oriented Programming
BIT2002 Marketing in the IT Sector
NET2001 Wide Area Networking
NET2003 Unix/Linux Operating Systems
NET2004 Communication Skills for NET
NET2007 Basics of Transmission Systems

Year 3
NET3000 Database Concepts and SQL
NET3001 Real-Time Systems
NET3008 Advanced Network Routing
NET3009 Software Engineering
NET3900 Wireless Networks
NET3002 Advanced Wide Area Networks
NET3004 Data Structures
NET3006 Network Management and Measurements
NET3007 IT Security Issues
NET3901 Information Technology Networking Project

Year 4
NET4001 Network Simulation
NET4002 Web Programming
NET4003 Computer Systems Architecture
NET4005 Networked Applications
NET4008 Multilayer Switched Networks
BITEE43 Art & Humanities Elective
NET4000 Emerging Network Technologies
NET4006 Scalable Network Architecture
NET4007 Multimedia Networking
NET4900 Network Technology Project

4.3. Faculty of Engineering, University of Pitesti

The Faculty of Electronics, Communications and Computers at the

University of Pitesti offer bachelor programs in area of engineering as follows: Computers, Applied electronics, Networks and Software for Telecommunications and Electromechanics.

All programs are four-year being focused on the students who are interested in industrial careers and also in IT and communications business opportunities.

These programs give to the students a solid basis of knowledge and abilities so that they are able to go directly in practice or to continue a master program in science and engineering.

Traditionally, the IT curricula is well represented in bachelor programs in area of electrical and computers engineering.

Obviously, the Computers program includes the largest palette of disciplines in the field of IT. In the followings we present an excerpt of the curricula that define the IT component of the bachelor program in Computer engineering.

We are also providing the number of hours per week allotted to the activities:

- C-course,
- S-seminary,
- L-laboratory,
- P-design,

Also, the number of credit points (CP) per disciplines is specified.

<u>Year 1</u>

Applied Informatics 2C, 2L, 4CP
Computers Programming and Languages 2C, 2L, 1P, 5CP
Modeling and Simulation 1C, 1L, 3CP
Elective:
Programming in Matlab 1C, 2L, 3CP
Programming in visual environments 1C, 2L, 3CP
Numerical Methods 2C, 2L, 3CP
Statistics and Experimental Data Processing, 1C, 2S, 3CP
Computer Assisted Graphics 2C, 2L, 3CP
Logic Design, 2C, 2L, 4CP
Data Structures, 2C, 2L, 4CP
Introduction in Data Basis, 1C, 1L, 3CP

<u>Year 2</u>

Object Oriented Programming 2C, 2L, 4CP
Algorithms Design 2C, 1L, 4CP
Elements of Computer Graphics 2C, 2L, 4CP
Algorithms Analysis 2C, 2L, 3CP
Basics of Artificial Intelligence 2C, 2L, 4CP
Optional:
Programming Paradigms 2C, 2L, 4CP
Logic Programming and Functional programming 2C, 2L, 4CP.

<u>Year 3</u>

Programs Engineering 2C, 2L, 1P, 5CP
Optional:
Formal languages and Automata 2C 2L, 5CP
Formal languages and Translators 2C 2L, 5CP
Data basis 2C, 2L, 1P, 5CP
Parallel and Distributed Algorithms 3C, 1S, 1L, 5CP
Operating Systems 2C, 2L, 4CP
Optional:
Computer Networks 2C, 2L, 4CP
Communications Protocols 2C, 2L, 4CP
Elective:
Bioinformatics 2C, 1L, 3CP,
Programming in Java 1C, 2L, 3CP

<u>Year 4</u>

Advanced data Basis Systems 2C, 2L, 4CP
Formal Methods for Testing and Checking 1C, 2L, 4CP
Optional:
Advances Interfaces 2C, 2L, 5CP
Engineering of AI Systems 2C, 2L, 4CP
Computer Local Networks 2C, 2L, 5CP
Parallel Programming 2C, 2L, 5CP
Optional:
Internet Technologies 2C, 2L, 4CP
Web Programming 2C, 2L, 4CP
Neural Networks 2C, 2L, 4CP
Expert Systems 2C, 2L, 4CP

Finally, we find useful for the analysis to present also the group of IT disciplines included in a few programs in the field of electrical, electronics and telecommunications engineering.

The disciplines are presented in Table 1.

5. FINAL REMARKS

The main topics covered by an IT curriculum include: Discrete Mathematics, System Analysis and Design, Web Programming, Object-Oriented Programming, Databases, Networking, Software Engineering, and some specialization courses such as business, multimedia or network technology.

It is important to notice that in the context of information technology, the modeling computation topics (languages and grammars, finite-state machines and Turing machines) are not covered being mainly theoretical developments.

A special emphasis is given to fuzzy logic techniques, which generalize crisp logic, model human perceptions (computing with words, precisiated natural language, generalized theory of uncertainty, computational theory of perceptions, etc.) and plays a major role in Soft Computing with numerous practical implementations.

Table 1. IT and related disciplines in engineering programs

<table>
<tr><th>Applied electronics</th><th>Networks and Software for Telecommunications</th><th>Electromechanics</th></tr>
<tr><td colspan="3">Year 1</td></tr>
<tr><td colspan="3">Applied Informatics 2C, 2L, 4CP</td></tr>
<tr><td colspan="3">Computer Assisted Graphics 1C, 2L, 4CP</td></tr>
<tr><td colspan="3">Elective: Programming in Matlab 1C, 2L, 3CP</td></tr>
<tr><td colspan="3">Computers Programming and Languages 2C, 2L, 1P, 5CP</td></tr>
<tr><td colspan="2">Numerical Methods 2C, 2L, 3CP</td><td>Practice in informatics 2 weeks=60hours, 3CP</td></tr>
<tr><td colspan="3">Statistics and Experimental Data Processing, 1C, 1S, 3CP</td></tr>
<tr><td colspan="3">Year 2</td></tr>
<tr><td colspan="2">Object Oriented Programming 2C, 2L, 4CP</td><td>Numerical Methods 2C, 1S, 2L, 4CP</td></tr>
<tr><td colspan="2">Theory of Information Transmission 2C, 1L, 4CP</td><td></td></tr>
<tr><td colspan="2">Decision and estimation in Information Processing 2C, 1S, 3CP</td><td></td></tr>
<tr><td colspan="2">Optional: Data Basis 2C, 1L, 3CP
Operating Systems 2C, 1L, 3CP</td><td></td></tr>
<tr><td colspan="3">Year 3</td></tr>
<tr><td colspan="2">Programming in Labview 1C, 1L, 3CP</td><td>Expert Systems and Technical Diagnosis 2C, 1L, 3CP</td></tr>
<tr><td colspan="2">Elective: Bioinformatics 2C, 2L, 3CP,
Programming in Java 1C, 2L, 3CP</td><td></td></tr>
<tr><td></td><td>Human-Machine communication Systems 2C, 2L, 4CP</td><td></td></tr>
<tr><td></td><td>Networks and Services 2C, 2L, 4CP</td><td></td></tr>
<tr><td colspan="3">Year 4</td></tr>
<tr><td>Software Engineering for industrial processes 2C, 1L, 4CP</td><td>Software Engineering for Telecommunications 2C, 2L, 1P, 5CP</td><td>Software Engineering for Industrial process control 2C, 2L, 3CP</td></tr>
<tr><td></td><td>Multimedia communications 2C, 1L, 4CP</td><td></td></tr>
</table>

6. REFERENCES

[1] Gersting, J., *Mathematical Structures for Computer Science*, Freeman & Cie, Publisher: W. H. Freeman; Fifth Edition edition (July 19, 2002), ISBN-10: 0716743582

[2] Hein, J. L., *Discrete Mathematics*, Jones and

Bartlett Publishers, Publisher: Jones & Bartlett Publishers; 2nd edition (January 2002), ISBN-10: 0763722103

[3] Reghis, M. Roventa, E., *Classical and Fuzzy Concepts in Mathematical Logic and Applications*, CRC Press, 1998.

[4] Rosen, H. K., *Discrete Mathematics*, McGraw-Hill, 2003.

[5] Roventa, E, Spircu, T., *Manegement of Knowledge Imperfection in Building Intelligent Systems*, Springer, 2009

[6] Zadeh, L. A., *Toward a Generalized Theory of Uncertainty (GTU) – An Outline*, Information Sciences, Elsevier, Vol. 172, pp.1-40, 2005.

[7] Zadeh, L. A., *Probability Theory and Fuzzy Logic Are Complementary Rather Than Competitive*, Technometrics, August 1995, Vol. 37, No. 3

[8] York University - School of Information Technology,http://www.yorku.ca/laps/itec/research/ MAIST.html, Accessed 20.12.2011

[9] Carleton University - School of Information Technology, http://www.csit.carleton.ca/, Accessed 20.12.2011