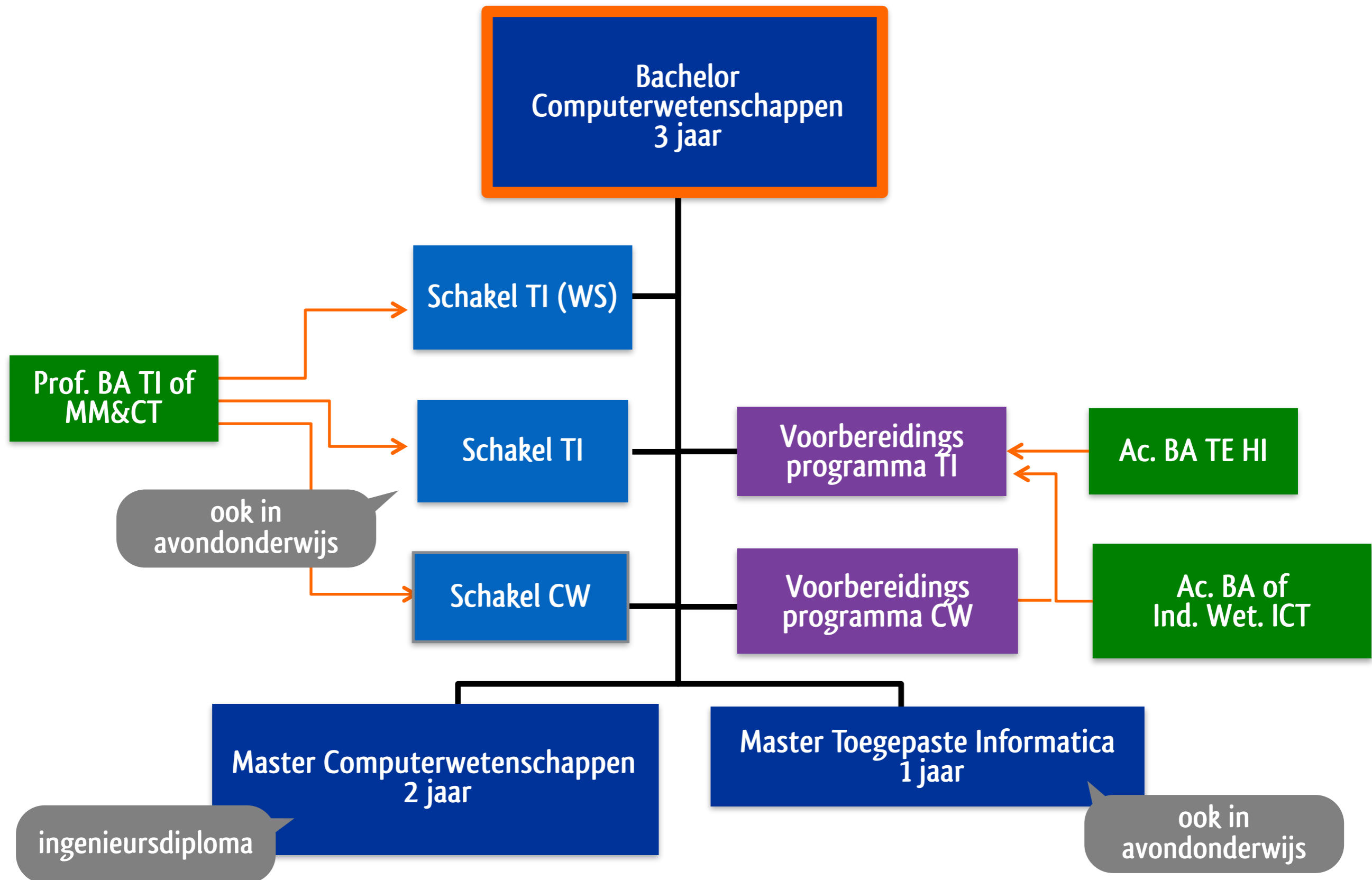
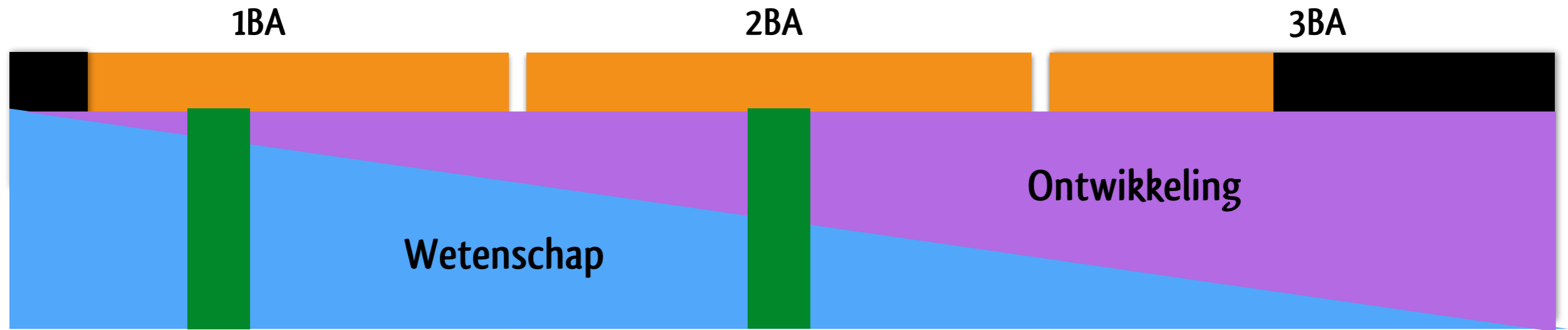


Bachelor Computerwetenschappen



Wetenschap + programmeertalen + ontwikkeling



Structuur van Computerprogramma's 1

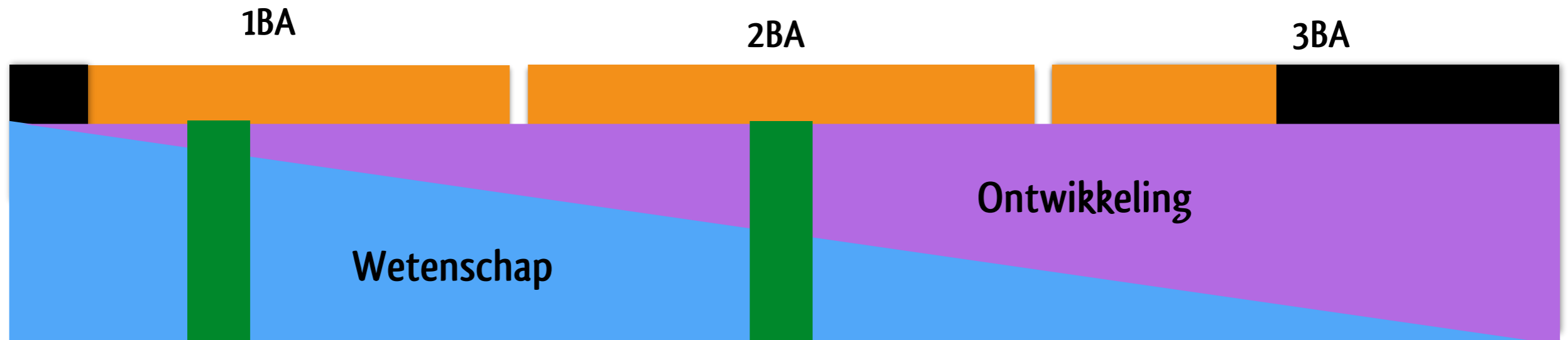
Algoritmen en Datastructuren 1
 Logica en Formele Systemen
 Wiskunde: Calculus en Lineaire Algebra
 Interpretatie van Computerprogramma's 1
 Besturingssystemen en Systeemfundam.
 Databanken
 Programmeerproject 1
 Basisvaardigheden - User Interfaces -
 Privacy op Internet

Discrete Wiskunde
 Algoritmen en Datastructuren 2
 Automaten en Berekenbaarheid
 Kansrekening en Statistiek
 Artificiële Intelligentie
 Computersystemen
 Structuur van Computerprogramma's 2
 Object-gericht Programmeren
 Object-gericht Modelleren
 Communicatievaardigheden
 Programmeerproject 2

Wetenschappelijk Rekenen
 Parallellisme en Distributie
 Software Engineering
 Economie en Bedrijfsleven
 Bachelorproef
 Keuze (33 ECTS)

- BA bereidt voor op MATI of MA CW ingenieursstudie
- Grote ruimte voor keuze en profilering in 3BA (33ECTS)

Wetenschap + programmeertalen + ontwikkeling



Structuur van Computerprogramma's 1
 Algoritmen en Datastructuren 1
 Logica en Formele Systemen
 Wiskunde: Calculus en Lineaire Algebra
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 Besturingssystemen en Steemfundam.
 Databanken
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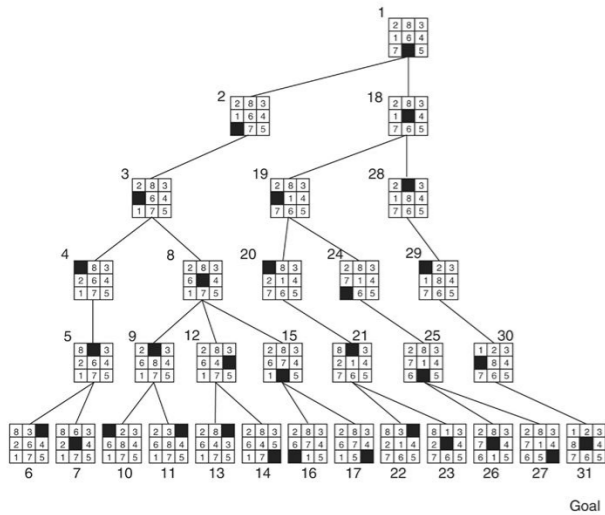
Discrete Wiskunde
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Computerwetenschappen



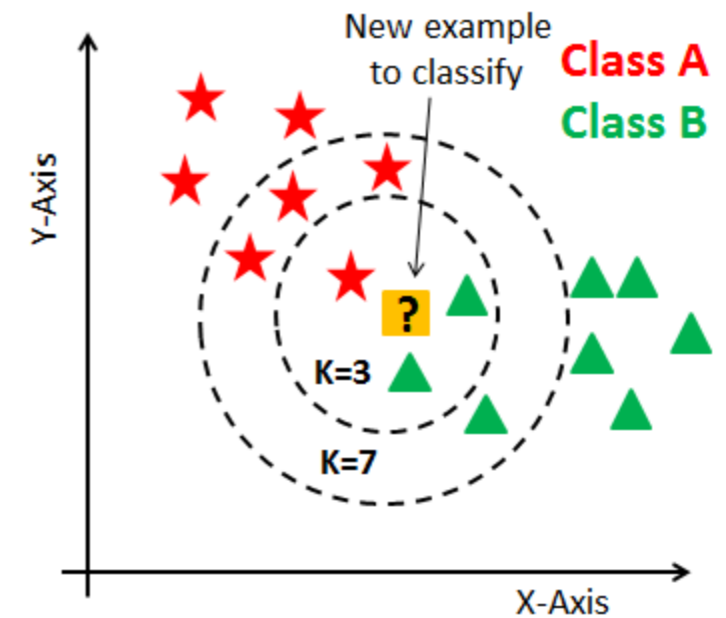
“Computer science is no more about computers than astronomy is about telescopes”
 (Edsger W. Dijkstra, 1930-2002)



zoeken

▶ Play All	▶ Insertion	▶ Selection	▶ Bubble	▶ Shell	▶ Merge	▶ Heap	▶ Quick	▶ Quick3
▶ Random								
▶ Nearly Sorted								
▶ Reversed								
▶ Few Unique								

sorteren



classificeren

Computerwetenschappen aan de VUB

The image shows a snippet of C code for a compiler, defining macros for lambda expressions and list operations. Below the code is a diagram illustrating the representation of a list as a sequence of pointers and memory vectors.

interpretatie van computerprogramma's

This block contains three sub-diagrams: a binary tree representing a heap, a graph illustrating the Hoop ADT structure, and a performance chart comparing different data structures.

algoritmen & datastructuren

A screenshot of a document discussing the Turing Machine Halting Problem, featuring mathematical notations and a diagram of a Turing Machine.

automaten & berekenbaarheid

Two pages from a textbook. The left page is titled 'Chapter 15. Probabilistic Reasoning over Time' and the right page is 'Chapter 16. Learning from Examples'. Both pages contain text, diagrams, and graphs.

artificiële intelligentie

Two pages from a technical paper. The left page is titled 'Assigning Lamport & Vec Timestamps' and the right page is 'Parallelism & Distribution'. Both pages contain diagrams and text.

parallisme & distributie

A collage of images related to a bachelor thesis. It includes a photo of a person at a conference, a presentation slide, and social media posts discussing software quality and research.

bachelor thesis

o samen met wiskunde-vakken, een **solide wetenschappelijke basis**

o proeven van onderzoek in bachelor thesis

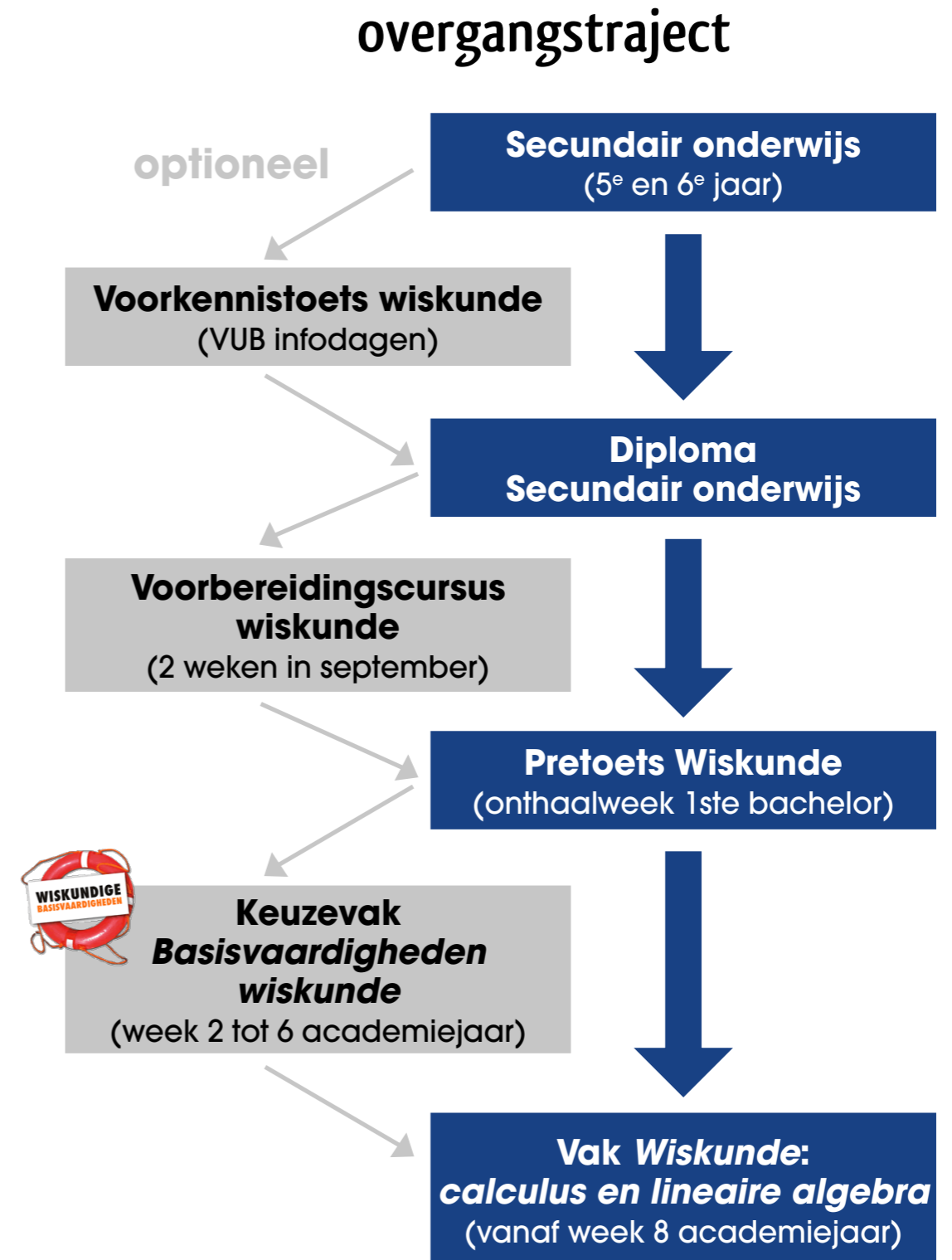
Wiskunde ter ondersteuning van **computerwetenschap**

1ste BA
Logica en Formele Systemen
Wiskunde: Calculus en Lineaire Algebra

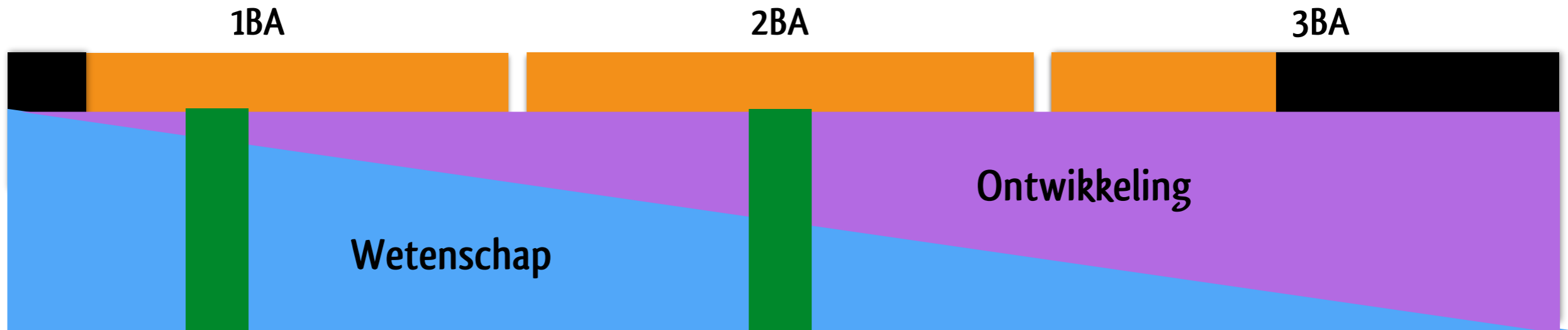
2de BA
Discrete Wiskunde
Kansrekening en Statistiek

3de BA
Wetenschappelijk Rekenen

<https://www.vub.be/voorbereiden>



Wetenschap + programmeertalen + ontwikkeling



Structuur van Computerprogramma's 1

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Wetenschappelijk Rekenen
 Parallellisme en Distributie
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 Economie en Bedrijfsleven
 Bachelorproef
 Keuze (33 ECTS)

Programmeertalen

Scheme

```
(define (fac n)
  (if (= n 0)
      1
      (* n (fac (- n 1)))))
(fac 5)
```

Java

```
public class Factorial {
  public static long factorial( int n ) {
    if( n <= 1 )
      return 1;
    else
      return n * factorial( n - 1 );
  }
  public static void main( String [ ] args {
    System.out.println( factorial( 5 ) );
  }
}
```

Haskell

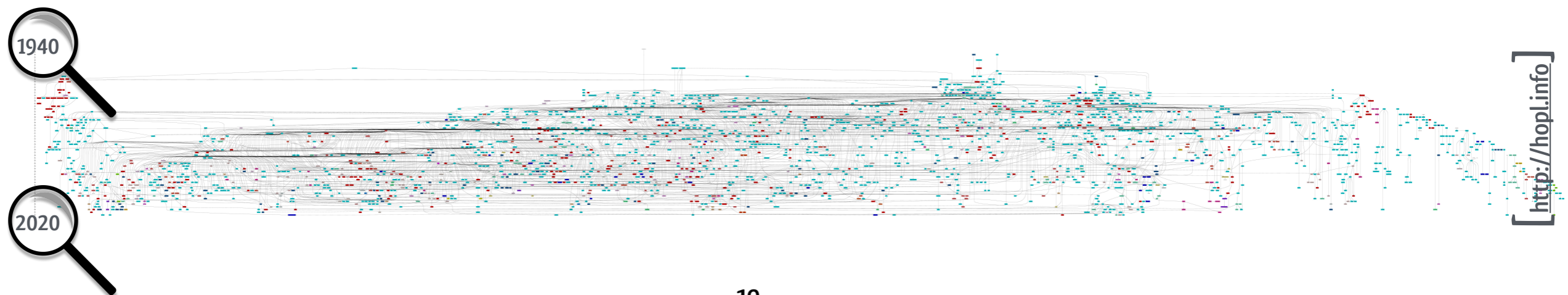
```
fact :: Integer -> Int
fact 0 = 1
fact n = n * fact (n - 1)
fact 5
```

Python

```
def fact(x):
  return (1 if x==0 else x * fact(x-1))

print(fact(5))
```

volgens bepaalde schattingen >5000 in gebruik



[<http://hopl.info>]

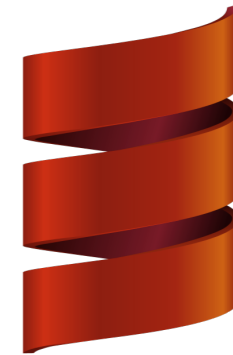
Programmeertalen aan de VUB



Scheme



C



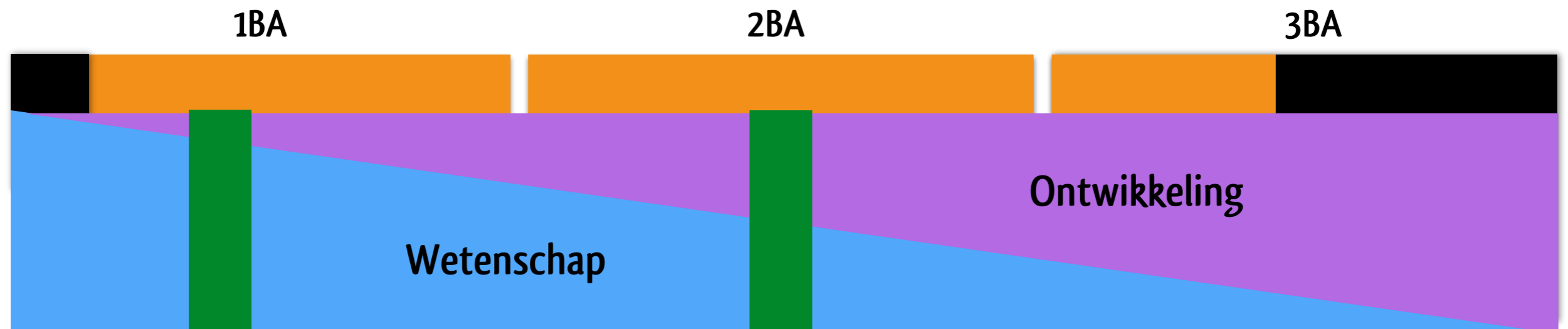
Scala

paradigma	multi-paradigmatisch	procedureel	object-gericht
typering	dynamisch	zwak statisch	sterk statisch
geheugenbeheer	automatisch	manueel	automatisch
jaar	1ste BA	2de BA	vanaf 2de BA



- doordachte keuze die het volledige **spectrum aan paradigma's** afdekt
 - geen voorkennis verondersteld, zelfde talen gebruikt in andere vakken
 - loopbaan van 44 jaar: zelfstandig nieuwe talen kunnen leren
- belangrijke onderzoeksgroep in programmeertalen
 - aandacht voor ontwerp en implementatie van programmeertalen

Wetenschap + programmeertalen + ontwikkeling

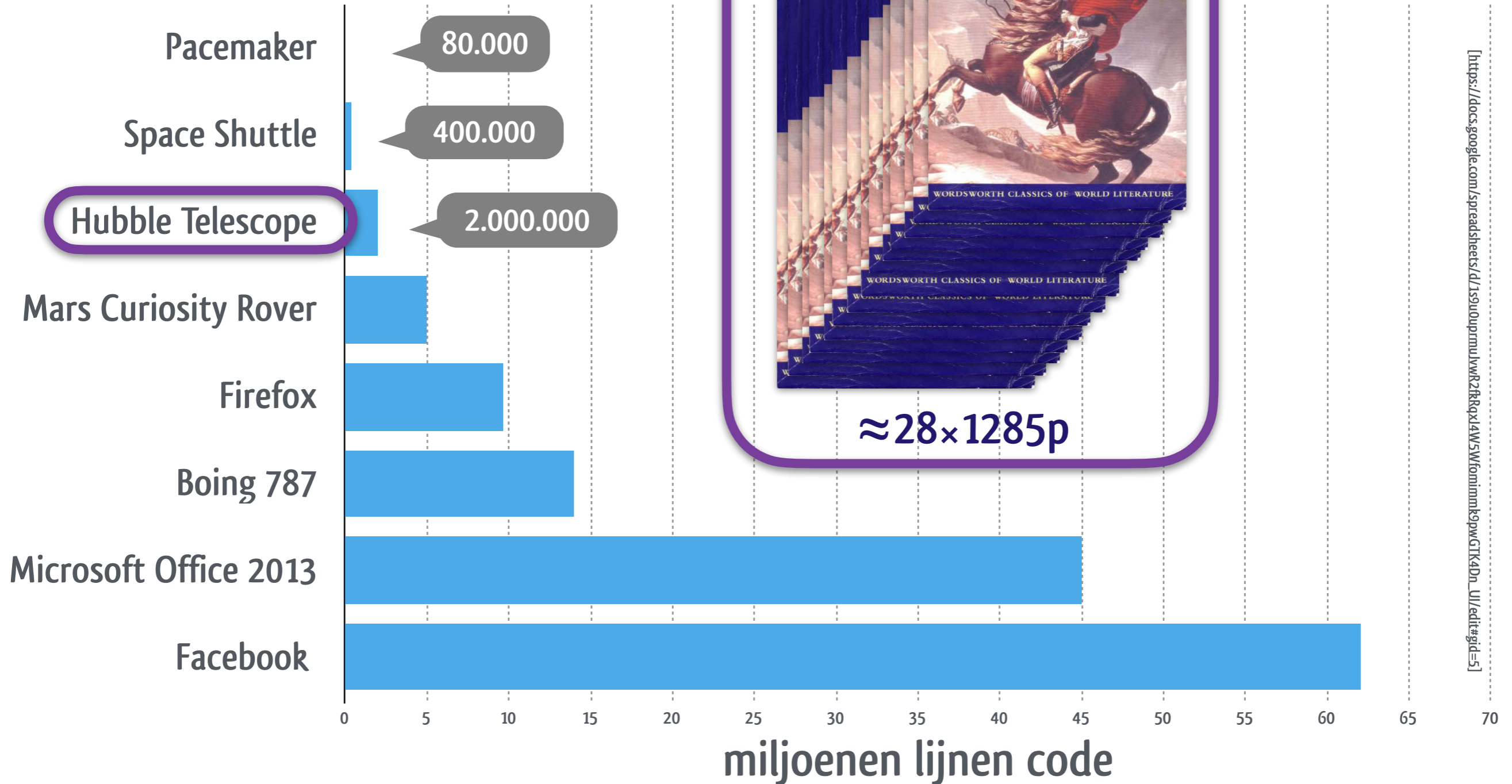


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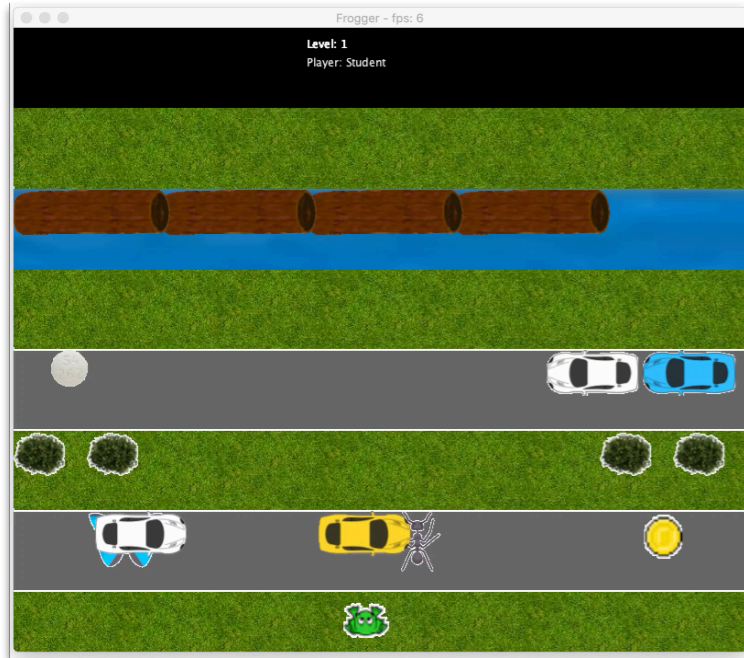
Discrete Wiskunde
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Wetenschappelijk Rekenen
 Parallellisme en Distributie
 Software Engineering
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 Bachelorproef
 Keuze (33 ECTS)

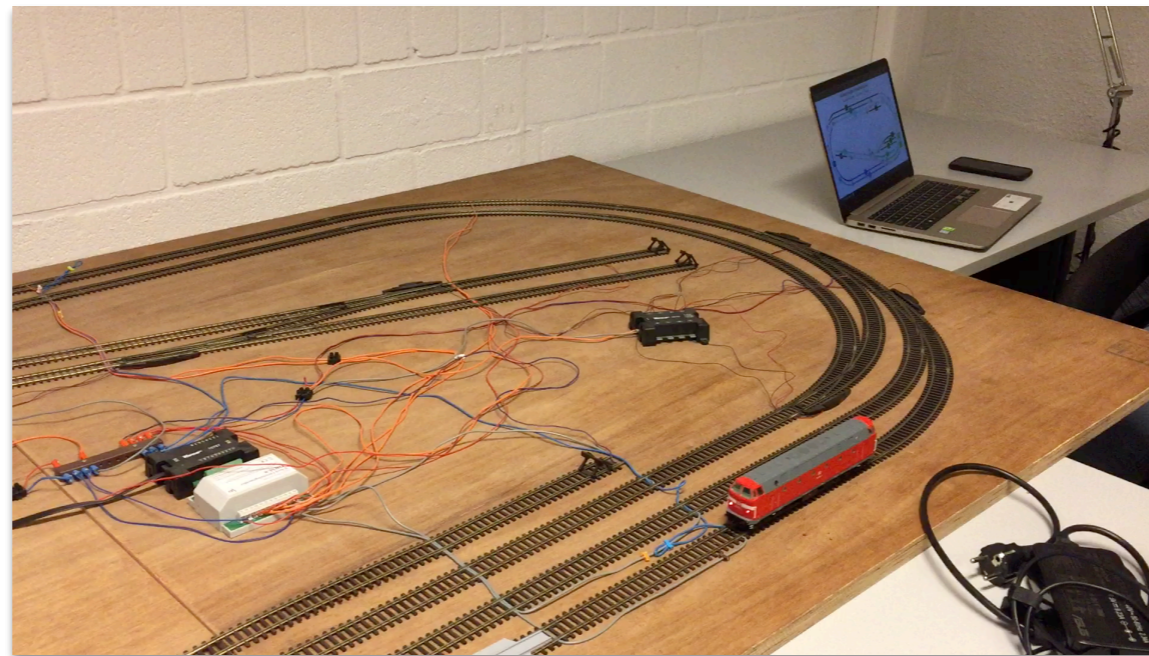
Software-ontwikkeling



Software-ontwikkeling aan de VUB



1ste BA



2de BA



3de BA



retrospelletje

~2000 LOC

individueel

van nul

programmeren

simulatie Infrabel+NMBS

~3000 LOC

individueel

van nul

algoritmes + wereld eromheen

editor interieurplannen

> 10.000 LOC

groepsverband

uitbreiding bestaande code

professionalisatie

33ECTS keuzevakken in 3de bachelor

verdiepend

6ECTS credits - Interpretation of Computer Programs 2

3ECTS credits - Digitale wiskunde

6ECTS credits - Machine Learning

6ECTS credits - Multimedia Processing Tools

6ECTS credits - IT Networks

6ECTS credits - Web Technologies

3ECTS credits - Bachelor onderzoeksstage

3ECTS credits - Privacy, veiligheid en eigendom op internet

3ECTS credits - Gebruikersinterfaces

3ECTS credits - Evolution of Software Languages

onderwijs

6ECTS credits - Leren van individuele leerlingen

6ECTS credits - Urban Education

3ECTS credits - Onderwijssociologie en onderwijsbeleid

verbredend

3ECTS credits - Fysica: inleiding mechanica

3ECTS credits - Evolutie

3ECTS credits - Biotechnologie

3ECTS credits - Business Aspects of Software Industry

3ECTS credits - Academic English 2

3ECTS credits - Academic English I

3ECTS credits - Redelijk eigenzinnig. Nadenken over Mens en Maatschappij

6ECTS credits - Inleiding tot de algemene taalwetenschap

3ECTS credits - De grote stromingen in de wijsbegeerte van de oudheid tot het heden

6ECTS credits - Cognitieve psychologie I

6ECTS credits - Marketingcommunicatie

6ECTS credits - Chemie: bouw van de materie en chemische reacties I

6ECTS credits - Inleiding tot het recht

6ECTS credits - Management

6ECTS credits - Wiskunde voor Data Science

6ECTS credits - Marketing

6ECTS credits - Algemene biologie

6ECTS credits - Sociologie I

3ECTS credits - Sociale psychologie I

6ECTS credits - Digitaal mediagebruik

3ECTS credits - Inleiding tot het bedrijfsbeheer

6ECTS credits - Geo-informatiekunde

4ECTS credits - Marketing

Organisatie en ondersteuning

- **gecoördineerde** uurroosters en examenroosters
- regelmatige **taken** in 1BA:
 - elke week één taak (1 per 3SP)
 - centrale coördinatie
- **tussentijdse evaluaties** in week 7:
 - logica en formele systemen
 - structuur van computerprogramma's 1
 - (basisvaardigheden wiskunde)
- ondersteuning vanuit **SBC**:
 - vakspecifieke studiebegeleidster
 - VIP-classes
 - opvolggesprekken
 - massaprogrammeren

Infrastructuur: hoorcolleges en werkcolleges



Infrastructuur: afstandsonderwijs

The image shows a Panopto video player interface. The top window displays a course overview for '1920 - Software Architectures - 005419' with various video thumbnails. The bottom window shows a detailed view of a video titled '1.1 Meta-circulaire interpretatie (deel 1)' with a 'Contents' sidebar and a video player. The video player shows a lecture slide titled 'Procedure eval' with Scheme code and annotations.

Course Overview (Top Window):

- 1920 - Software Architectures - 005419
- Sort by: Name, Duration, Date, Rating
- Thumbnails include: Software Architectures 2019-2020, OO basics: case classes, Expression problem, 3.2 Component-and-Connector Patterns, Implementing Pipe-and-filter using Akka Streams, Akka Streams: manipulating materialized values, 3.2 C&C patterns: Shared Data, Cl... Pipe-and-Filter, 3.2 C&C patterns: Pipe-a... Akka Streams (part 1), 3.2 C&C patterns: Pipe-... Model-View-Controller, 3.2 C&C patterns: Micro-services ill... Akka (part 2), 3.2 C&C patterns: Publish-Subscribe, ... Tier, 4.1 Asynchronous Messaging Patterns: Telenet, 4.3 Flow Control Patterns, 4.4 Fault-Tolerance Patterns... Circuit Breaker, Telenet.

Video Player (Bottom Window):

1920 - Interpretatie van computerprogramma's 1 - 000089 > 1.1 Meta-circulaire interpretatie (deel 1)

Contents:

- 1. Meta-circulaire interpretatie 0:03
- Discussion Interpreters 0:18
- Notes Context in cursus 1:40
- Bookmarks
- Why interpreters bestuderen 4:07
- Why interpreters bestuderen 4:41
- 1.1 Een meta-circulaire interpreter voor Scheme 21:10
- Interpretatie-fasen: read-eval-print 22:31
- Interpretatie-fasen: read-eval-print 29:31
- Interpretatie-fasen: read-eval-print 29:36
- Interpretatie-fasen: read-eval-print 29:52
- Interpretatie-fasen: read-eval-print 35:55
- 40 36:09
- read 36:25
- Implementatie van read-eval-print loop 36:30
- Read-eval-print loop: print 40:52
- Implementatie van read-eval-print loop 53:03
- Read-eval-print loop: print 54:27
- (define input-prompt ";; M-Eval input:")(define... 54:37
- (define (prompt-for-input string) (newline) ... 54:44
- Read-eval-print loop: read 55:02
- Read-eval-print loop: zonder read 1:00:46
- Structuur van de evaluator 1:02:06
- Interessant op : : respect voor het "groene... 1:05:42
- Procedure eval 1:08:18

Procedure eval (Video Content):

```

(define (eval exp env)
  (cond ((self-evaluating? exp) exp)
        ((variable? exp) (lookup-variable-value exp env))
        ((quoted? exp) (text-of-quotation exp))
        ((assignment? exp) (eval-assignment exp env))
        ((definition? exp) (eval-definition exp env))
        ((if? exp) (eval-if exp env))
        ((lambda? exp)
         (make-procedure (lambda-parameters exp)
                          (lambda-body exp)
                          env))
        ((begin? exp)
         (eval-sequence (begin-actions exp) env))
        ((cond? exp) (eval (cond->if exp) env))
        ((application? exp)
         (apply (eval (operator exp) env)
                  (list-of-values (operands exp) env)))
        (else
         (error "Unknown expression type -- EVAL" exp))))
  
```

Annotations:

- analyseert de syntax van de te evalueren expressie
- rechtstreekse aanmaak van waarde
- evaluatie van eenvoudigere expressie
- expressiesoorten boven deze tak zijn "speciaal"
- evaluatie van een expressie in een omgeving
- delegatie naar gespecialiseerde procedures

16

1:09:56 | -13:07 | 1x Speed | Quality

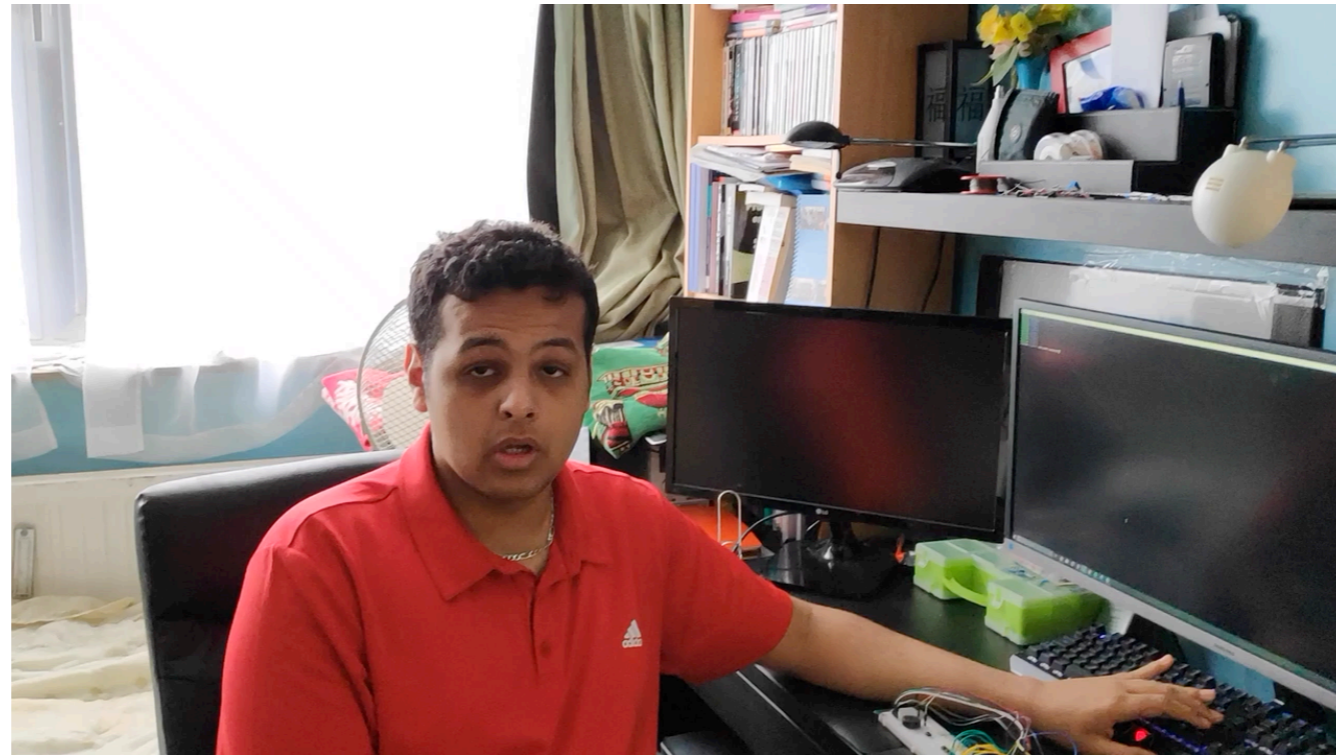
Infrastructuur: in alle maten en kleuren

2018-2019 Kevin Coorens



2018-2019 Jasper Zucka

2018-2019 Hicham Azmani



Voorbeeld lessenrooster

1^{ste} jaar Computerwetenschappen
Voorbeeld week 5 (oktober)

	Maandag	Dinsdag	Woensdag	Donderdag	Vrijdag
8h-9h					
9h-10h				Basisvaardigheden wiskunde (praktijk) <i>Vb keuzevak</i>	Basisvaardigheden wiskunde (praktijk) <i>Vb keuzevak</i>
10h-11h					
11h-12h	Structuur van computerprogramma's I (praktijk)			Structuur van computerprogramma's I (theorie)	
12h-13h					
13h-14h		Algoritmen en datastructuren I (theorie)			
14h-15h	Structuur van computerprogramma's I (theorie)			Structuur van computerprogramma's I (praktijk)	Basisvaardigheden wiskunde (theorie)
15h-16h		Logica en formele systemen (theorie)			
16h-17h	Logica en formele systemen (praktijk)			Algoritmen en datastructuren I (praktijk)	
17h-18h					

Focusgesprek met studenten tijdens kwaliteitsbewaking



Alle bevroagde studenten
zouden opnieuw voor de
opleiding kiezen!

- **Interessant** programma en **goede hoorcolleges**
- Goede volgtijdelijkheid en **samenhang** van de vakken
- **Kleine groepen**
- Docenten en assistenten zijn zeer **toegankelijk en aanspreekbaar**
- Veel **projectwerk** doorheen het hele jaar
- Goede **ondersteuning** door het SBC
- Goede **fundamentele aanpak** van programmeren, makkelijk andere talen te leren
- Het schakelprogramma is goed opgebouwd en is goed verdeeld
- Wat verwacht wordt voor een examen is meestal duidelijk
- Studenten worden fair en objectief beoordeeld

Wist je dat?



pionier sinds 1978

AGORIA

30.000 ICT vacatures voor ICT experts in 2018



Felix Van de Maele



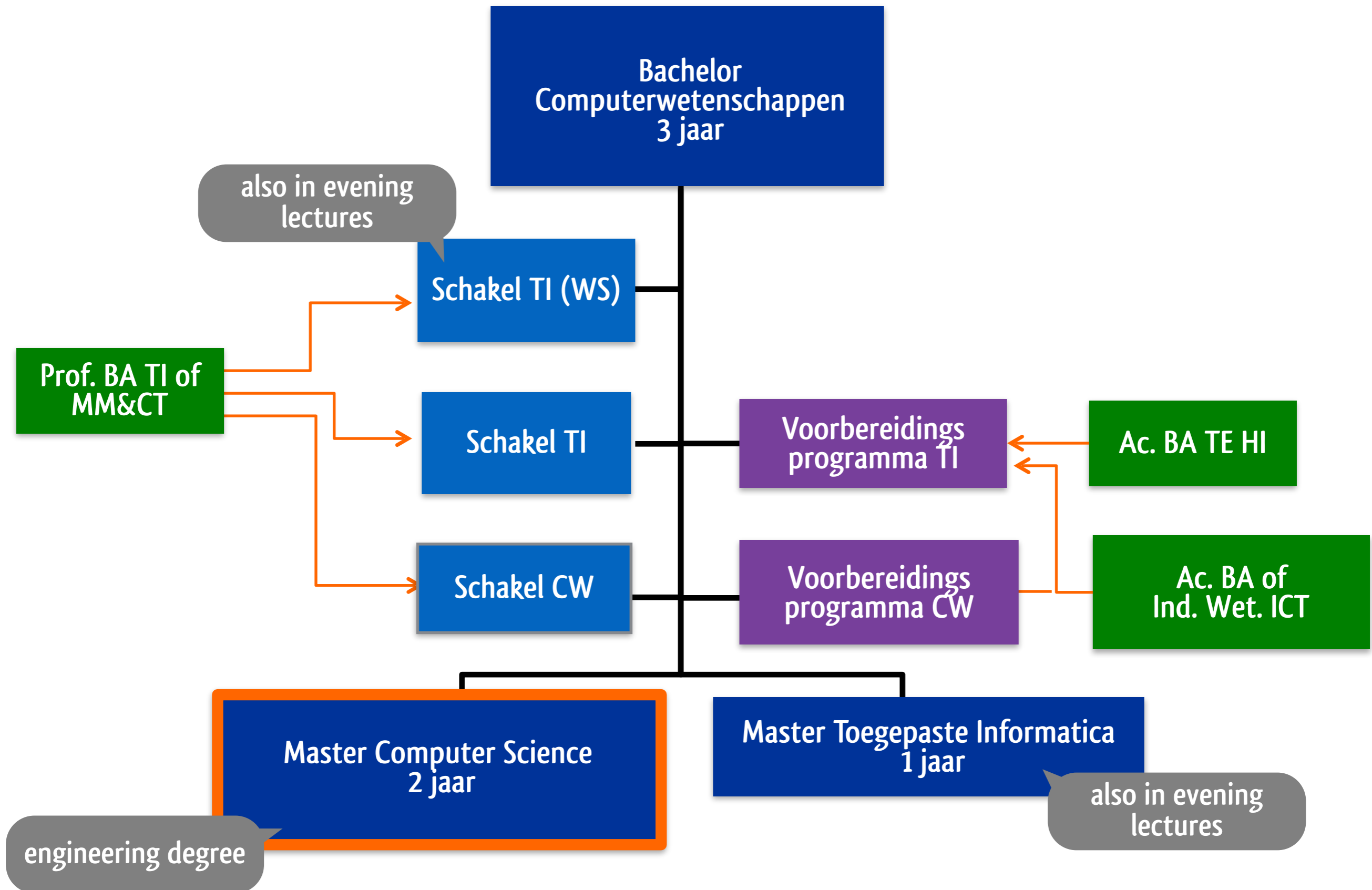
Pattie Maes

STATBEL

België in cijfers

bruto gemiddeld van 4.666€ voor een ontwikkelaar tot 7.160€ voor een manager in 2016

Master of Applied Sciences and Engineering in Computer Science



Architecture of the programme

30 ECTS Mandatory Common

Methods of Scientific Research
Scientific Integrity
Information Theory
Theory of Computation
Open Information Systems
Declarative Programming
Software Architectures

30 ECTS Specialisation

Mandatory + Electives

30 ECTS Electives Common



Mobility
Window

6 ECTS

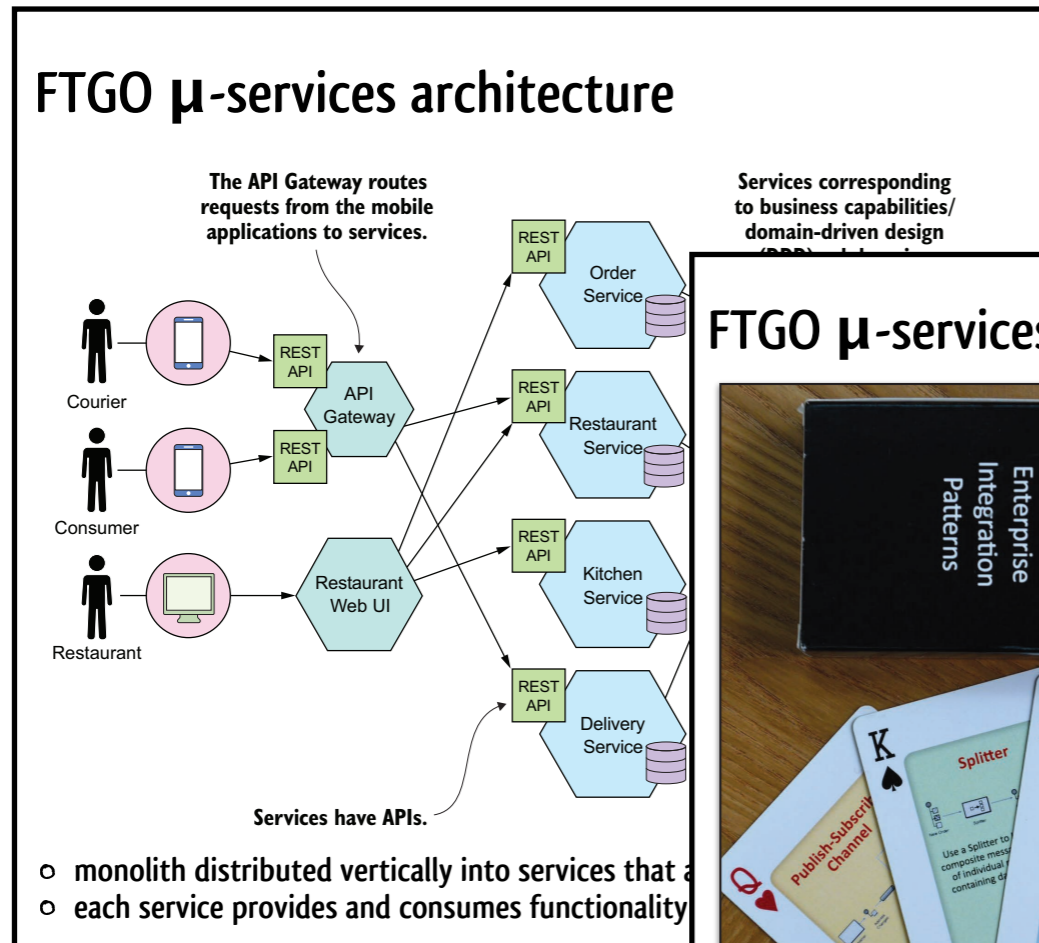
Research Training

24 ECTS

Master Thesis in
Specialisation

- strongly embedded in ongoing research activities of the labs
- prepares for role in CS research and development, in academia and industry

Example course from the core: Software Architectures



But resilience remains difficult to get right ...

```

4 trait Event
5 case class Plus(amount: Int) extends Event
6 case class PlusEvent(amount: Int) extends Event
7 case class CountCommand(id: Long, amount: Int)
8 case class ConfirmEvent(id: Long) extends Event
9 case class Confirm(id: Long)
10
11 class GuaranteedDeliveryActor(ref: ActorRef)
12 extends PersistentActor with AtLeastOnceDelivery {

```

Ongoing research

FTGO μ -services: messaging (2/2)

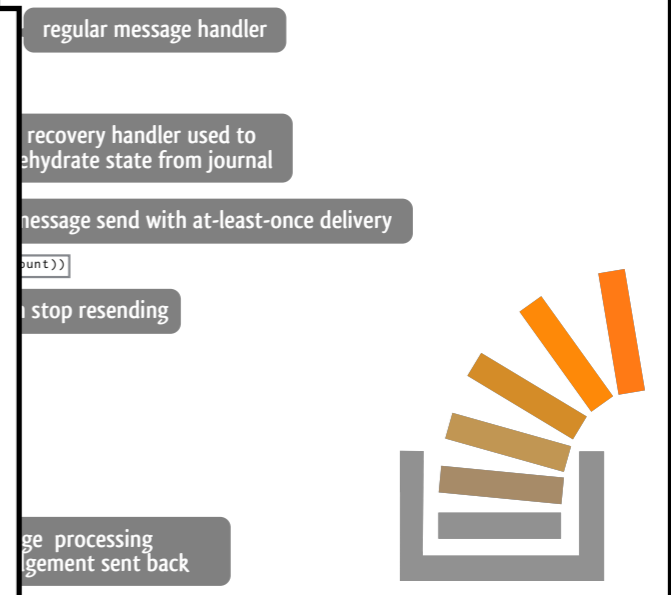
Enterprise Integration Patterns

Twenty Years of Patterns' Impact

A Decade of Enterprise Integration Patterns: A Conversation with the Authors

[Hoppe et al., IEEE Software 2013]

[Zimmermann et al., IEEE Software 2016]



- large-scale systems operating worldwide with millions of concurrent users
- architectural patterns for reactivity (react in a timely manner), elasticity (react to variable load conditions), resilience (recover from failures)
- instantiate well-known frameworks in projects

Four specialisations

Artificial Intelligence

Machine learning
Game Theory
Bio-informatics
Natural Language Processing
Computational Intelligence

Data Management & Analytics

Data Mining
Big Data Management
Information Retrieval
Human-Data Interaction
Data Visualisation

Software Languages & Software Engineering

Language Design and Implementation
Development Tools and Methods
Program Analysis
Program Evolution

Multimedia

Image Processing
Data Compression
Computer Vision
Speech Synthesis and Coding

- designed for students with solid, fundamental background in CS
- provides deep knowledge of CS in general, and in one of four specialisations

Four specialisations

Artificial Intelligence

Machine learning
Game Theory
Bio-informatics
Natural Language Processing
Computational Intelligence



- study and apply **state of the art** techniques
 - logic-based, statistical, probabilistic, neural inference systems
 - multi-agent systems with emergent intelligence
 - language processing and computational intelligence
- rigorous **mathematical and scientific** context
- supported by **oldest AI group** on the European continent (1982)

Four specialisations



Data Management & Analytics

Data Mining
Big Data Management
Information Retrieval
Human-Data Interaction
Data Visualisation

- at the confluence of **Big Data** and **Interactive Data Science**
 - new since 2020-2021!
- study and apply algorithms, techniques, architectures
 - big data management, mining, visualisation, interaction
- supported by all research groups of the department

Four specialisations

- the **art, science, and engineering of software construction**
 - theoretical foundations: type theory, formal proofs, program analysis
 - language design: paradigms for distribution and concurrency
 - language implementation: compilers and interpreters
 - software engineering: software quality, meta-programming
- supported by a leading research group in PL and SE

Software Languages & Software Engineering

Language Design and Implementation

Development Tools and Methods

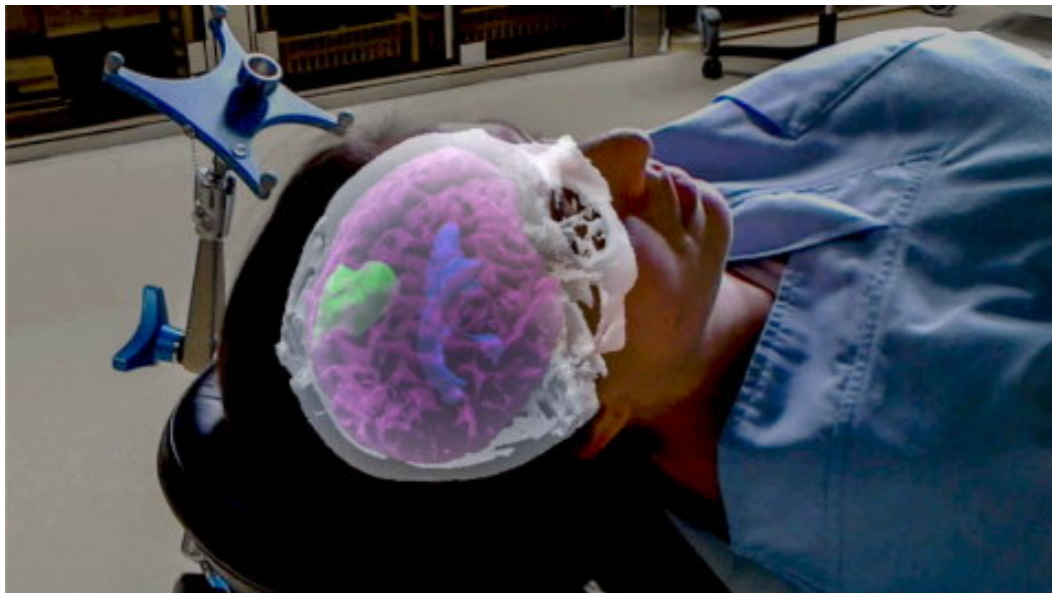
Program Analysis

Program Evolution



Four specialisations

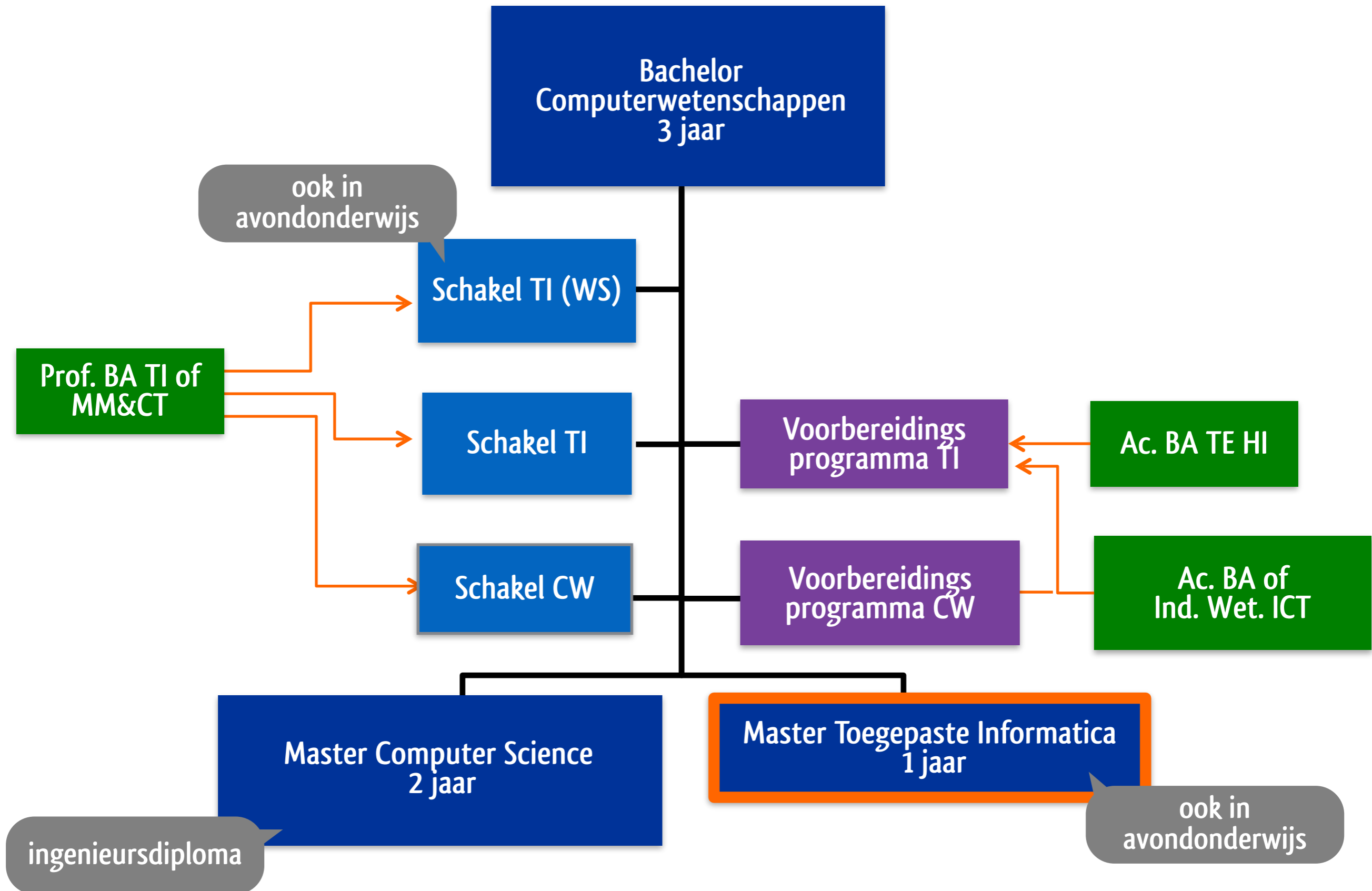
- study **signal processing and transmission** for multimedia content
- supported by a leading research group in electronics and holography



Multimedia

Image Processing
Data Compression
Computer Vision
Speech Synthesis and Coding

Master of Science in Toegepaste Informatica



Programma 1-jarige Master Toegepaste Informatica

48 ECTS verplicht

Methoden van Wetenschappelijk Onderzoek

Schaalbare Datamanagementsystemen

Information Retrieval en Data Mining

Informatievisualisatie

Cloud computing en Big Data Processing

Statistical Foundations of Machine Learning

Masterproef (15 ECTS)



12 ECTS keuzevakken

Software Architecturen

Security in Computing

Natural Language Processing

Declaratief Programmeren

(+ mits goedkeuring: stage, reparatievakken)

**Informatica-aspecten
van Data Science en
Big Data toepassingen**

- na academische bachelor of schakel -en voorbereidingsprogramma
- meer toepassingsgericht dan 2-jarige master
- theoretische basis met mogelijkheid om kennis in de praktijk toe te passen

Voorbeeldvak: Informatievisualisatie

102 5. Marks and Channels

Channels: Expressiveness Types and Effectiveness Ranks

➤ **Magnitude Channels: Ordered Attributes**

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

➤ **Identity Channels: Categorical Attributes**

- Spatial region
- Color hue
- Motion
- Shape

Effectiveness: Most (top), Least (bottom)

Figure 5.6. Channels ranked by effectiveness according to data and channel type. Ordered data should be shown with the magnitude channels, and categorical data with the identity channels.

The limitations and benefits of 3D are covered in Section 6.3.

types. This primacy of spatial position applies only to 2D positions in the plane; 3D depth is a much lower-ranked channel. These fundamental observations have motivated many of the vis idioms illustrated in this book, and underlie the framework of idiom design choices. The choice of which attributes to encode with position is the most central choice in visual encoding. The attributes encoded with position will dominate the user's **mental model**—their internal mental representation used for thinking and reasoning—compared with those encoded with any other visual channel.

These rankings are my own synthesis of information drawn from many sources, including several previous frameworks, experimental evidence from a large body of empirical studies, and my

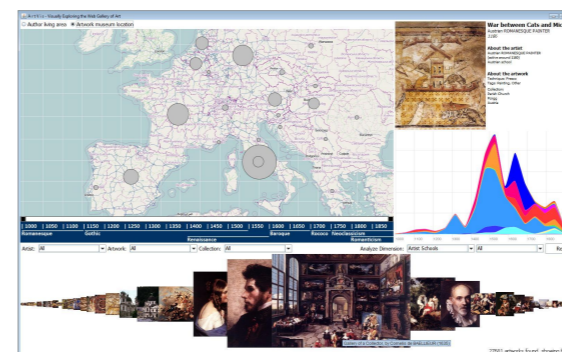
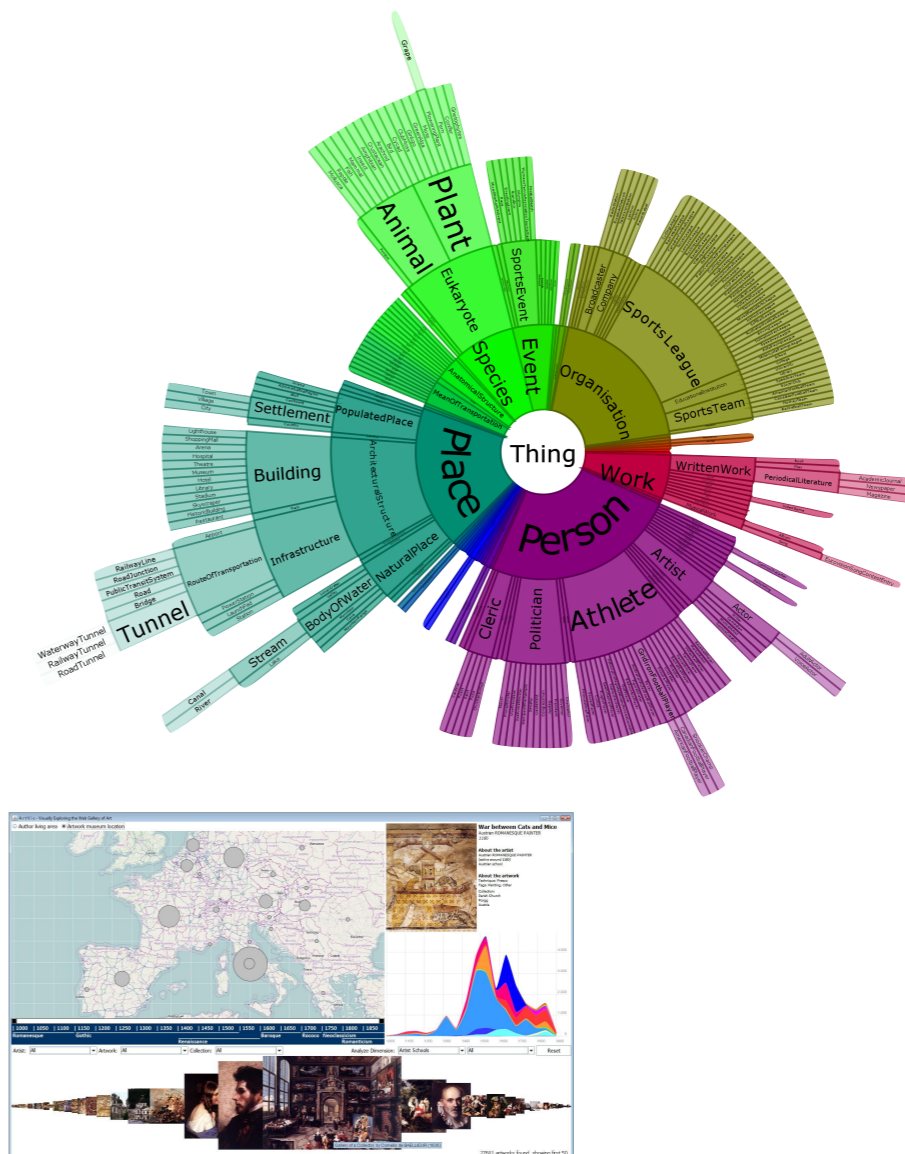
20 Foundations for a Model of Perception

Despite these reservations of affordances, loose The idea suggests t and useful ways. W pressing. If compon tually evident, perh object to another. T famous book, *The P* gets present afforda our ability to repre world. Therefore, w but we cannot expe visualization.

A Model of Pe

In this section, we visual perception. A we should always b work is useful in pe gives a broad schem information is proc

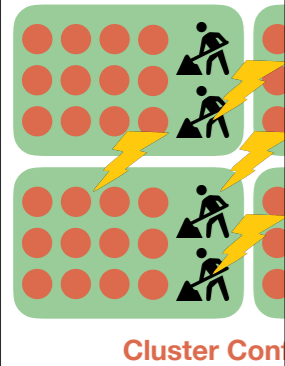
Figure 1.11 A three-stage model of visual information processing.



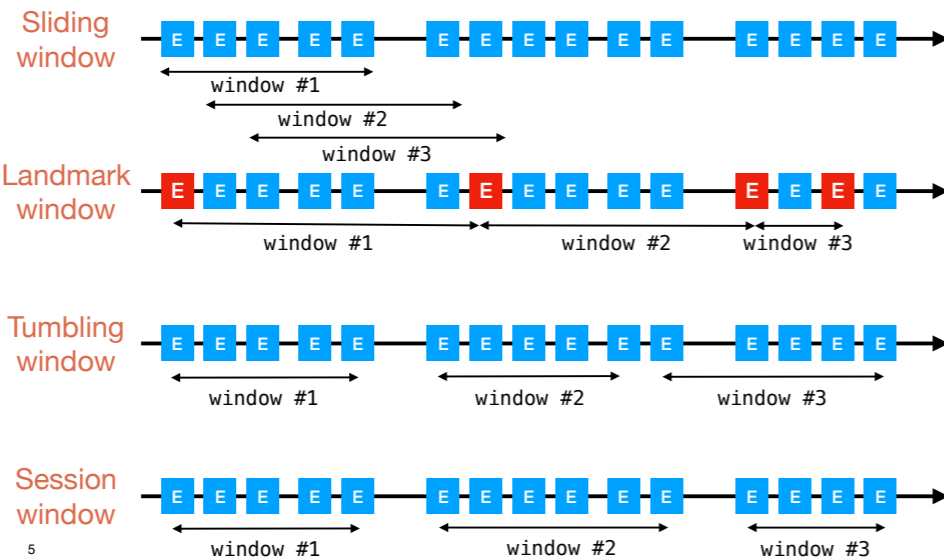
- o visualisatietechnieken voor exploratieve analyse van grote datasets
- o case studies illustreren perceptietheorie en interactietechnieken
- o in groepsverband visualisatieoplossing ontwikkelen

Voorbeeldvak: Cloud Computing & Big Data Processing

From Data-Parallel to Distributed Data-Parallel



Different Temporal Windows



Proof of work for block #n

make adding a block artificially difficult

(often) useless

Bitcoin mining stats

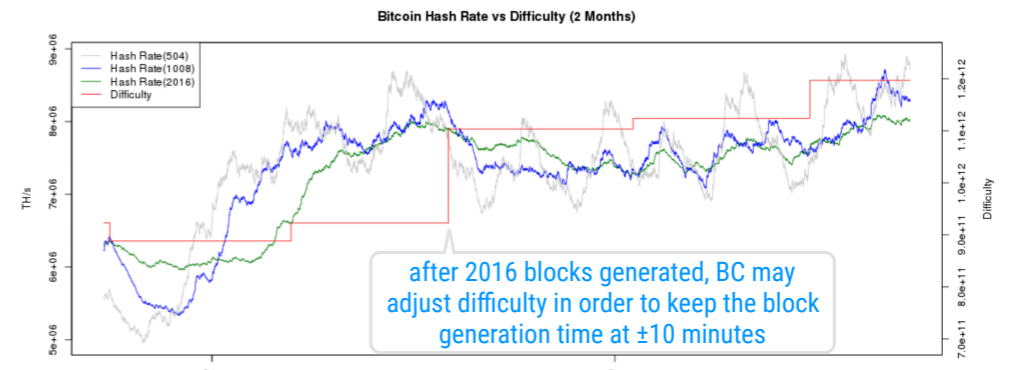
<https://bitcoinwisdom.com/bitcoin/difficulty>

Bitcoin Difficulty: 1,196,792,694,099
 Estimated Next Difficulty: 1,163,876,864,166 (-2.75%)
 Adjust time: After 742 Blocks, About 5.3 days
 Hashrate(2): 8,736,302,324 GH/s
 Block Generation Time(2): 1 block: 10.3 minutes
 3 blocks: 30.9 minutes
 6 blocks: 1.0 hours
 Updated: 17:0 (2.2 minutes ago)

hash upper bound

calculator: hashes/s → BC earnings

Difficulty: 1196792694098	BTC/USD: 2546	
1000000 KH/s	8.755e-9 BTC/hour	0.0002229 USD/hour
1000 MH/s	2.101e-7 BTC/day	0.005349 USD/day
1 GH/s	0.00001471 BTC/week	0.003745 USD/week
0.001 TH/s	0.00006303 BTC/month	0.01605 USD/month

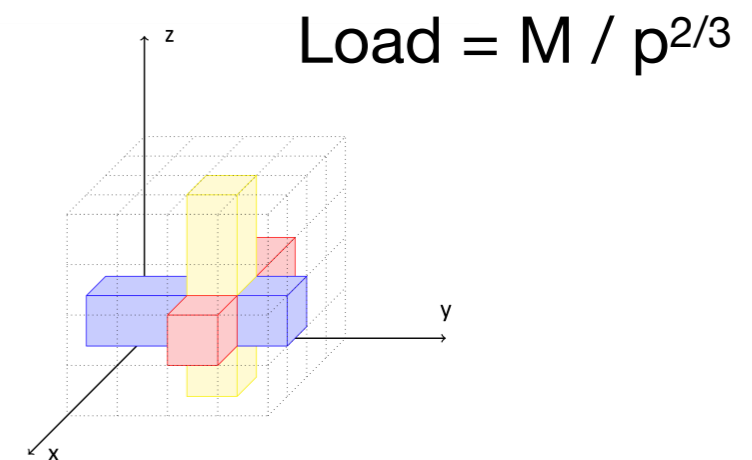
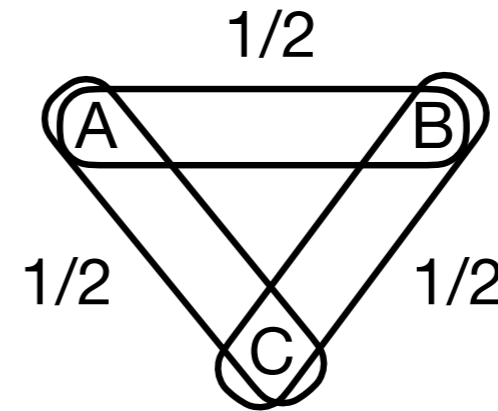
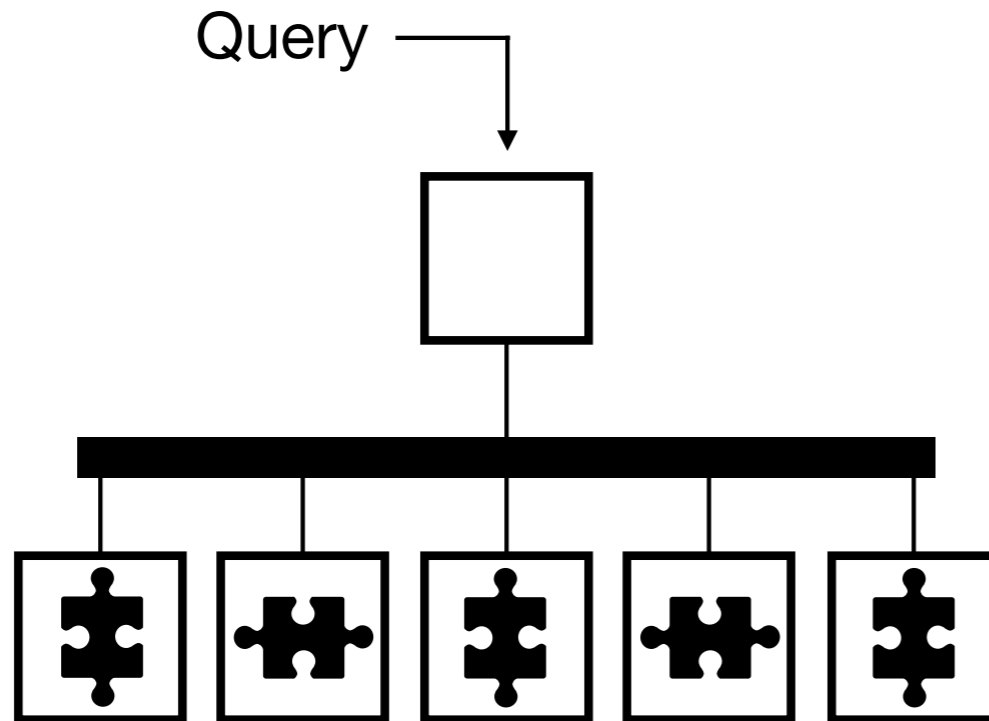


- cloud computing: decentralisatie (Blokchain), consistentie, beveiliging, ...
- big data processing: cluster computing, gegevenslocaliteit, streaming (Spark)
- raamwerken illustreren fundamentele concepten van beide domeinen

Voorbeeldvak: Schaalbare Datamanagementsystemen

What is the “best” algorithm to compute a query?

$R(A,B) \bowtie S(B,C) \bowtie T(C,A)$



- gedistribueerde databanken voor beheer van grote datasets
- principes onderliggend aan systemen zoals MapReduce
- uitdagingen van partitionering, query planning, transactieverwerking