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School on Diagnosis of Industrial Systems and Processes: The Model-based Approach

Spanish Diagnosis School Report: & Questionnaire Results and Analysis

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1 Introduction

1.1 Purpose of this Document

The purpose of this document is partly to outline the activities that took place at the Spanish Diagnosis School (17th to 25th May 2004, Barcelona, Spain), but primarily to analyse the responses of the students to the event. This analysis will be used to look at how the students feel that diagnosis is being taught / used in the academic or industrial training settings and to look at how the situation could be improved.

1.2 Scope

The information presented in this document was taken from the results of a post event questionnaire that was circulated to students. It is also from a discussion session (Final Colloquium) that was held during the event, where students where encouraged to voice and discuss issues with the teaching staff of the event.

2 School on Diagnosis of Industrial Systems and Processes: The Model-based Approach

2.1 Introduction

This intensive seminar took place over nine days in Barcelona, Spain. Its main goal was to introduce students to two of the most well-known model-based diagnosis approaches emanating from two research communities. These were the two approaches that the MONET Bridge Task Group is working to bring together, i.e. the Control Engineering approach known as FDI (Fault Detection and Isolation) and the Artificial Intelligence approach known as DX (Diagnosis).

Once an introduction to these two technologies and their complementarities had been given, the event focused on different case studies and benchmarks. These were presented to fully illustrate all concepts of the two approaches.

Lessons were given by national and international experts in the field. This event also had two invited guest speakers; Louise Travé-Massuyès from LAAS-CNRS in Toulouse, France and Marcel Staroswiecki from LAIL, Lille University, France.

2.2 Content

The content of the school has been divided into five thematic blocks which have been structured as follows:

2.2.1 T1. Introduction

T1.1. Definitions: fault, detection, diagnosis, reliability, etc
T1.2. Foundations for fault detection and diagnosis in FDI and DX: detectability, observability, diagnosability
T.1.3. Where the models come from: Modelling and Identification
T.1.4. Modelling techniques

2.2.2 T2. Model-based Diagnosis: the FDI Approach

T2.1. Structural analysis and analytical redundancy

T2.2. Model-based detection methods: parameter estimation, parity equations, state observers for linear and non-linear models
T2.3. Fault detection: Residual evaluation by statistical tests and envelope generators
T2.4. Fault isolation structured and directional residuals
T2.5. Introduction to fault tolerant control
T2.6. Open problems in FDI: fault estimation, sensor network design for diagnosis, diagnosis on systems with delays

2.2.3 T3. Model-based Diagnosis: the DX Approach

T3.1. Qualitative, semi-qualitative and quantitative modelling for DX
T3.2. Consistency-based diagnosis (CBD): the Reiter's approach
T3.3. General Diagnosis Engine (GDE): the computational approach to CBD
T3.4. Other computational approaches to CBD
T3.5. Open problems in CBD: dynamics, fault modes, etc

2.2.4 T4. BRIDGE: Integration of FDI and DX Approaches

T4.1. Theoretical links and comparison
T4.2. Practical comparison and potential synergies

2.2.5 T5. Case Studies and Benchmarks

T5.1. Applications to naval industry
T5.2. Applications on continuous processes
T5.3. CHEM benchmark
T5.4. DAMADICS benchmark and TIGER

2.3 Schedule

Mon 17th	Tue 18th	Wed 19th	Thu 20th	Fri 21st	Sat 22nd	Mon 24th	Tue 25th
T1.1 + T1.2	T3.1	T2.1	T2.2	T23 + T2.4	T5.2	T5.3	T4.1
T1.2	T3.2	T2.2	T2.3	T2.4 + T2.5	T5.3	T5.4	T4.2
T1.3 + T1.4	T3.3	T3.4	T2.3	T2.5	(Free)	T5.4	Discussion Panel
T3.1	T5.1	T3.4	T3.5	T3.5	(Free)	T2.6	

2.4 Teachers

The teaching staff for this event were selected form both national and international teachers who have been working for several years in the field.

Louise Travé-Massuyès, from LAAS-CNRS (France) spoke about BRIDGE: Integration of FDI and DX approaches (T4).

Marcel Staroswiecki (University of Lille, France) covered most of the FDI approach (T2).

Joaquim Armengol (University of Girona, Spain) introduced some basic definitions for fault detection and isolation (T1) and also introduced envelope generators for fault detection (T2).

Rafael M. Gasca and Carmelo del Valle (University of Seville, Spain) provided an introduction to qualitative and semi-qualitative modelling for diagnosis (T3).

Teresa Escobet, Joseba Quevedo and Vicenç Puig (Politechnical University of Catalonia, Spain), introduced more basic definitions for fault detection (T1) and talked about diagnosis on systems with delays.

Carlos Alonso and Belarmino Pulido (University of Valladolid, Spain) introduced the DX approach (T3).

2.5 Students

University	Student's name	PhD Subject
Universidad de Girona	Gabriela Calderón Espinoza	Interval Model-Based Fault Detection and Diagnosis
Universidad de Girona	Pau Herrero Viñas	Fault detection in dynamic uncertain systems by means of interval models. Interval constraint propagation
Universidad de Girona	David Alejandro Llanos Rodríguez	Case Based Reasoning, Residual Computation using Dynamic Time Warping, Fault Diagnosis of Dynamic Systems based on Case Based Reasoning
Universidad de Girona	Daniel Alexandre Macaya Masferrer	Process Expert Supervision, Case Based Reasoning for dynamic systems diagnosis.
Universidad de Girona	María Fabiana Terán	CBR for Supervision and diagnosis
Universidad de Girona	Marc Vinyoles Bataller	CBR for Supervision and diagnosis
Universidad de Girona	Sushu Zhang	Computer Vision and Robotics
Universidad Politécnica de Catalunya	Carlos Ocampo	Fault Tolerant Control for complex systems
Universidad Politécnica de Catalunya	Sebastián Tornil	Fault detection and Identification using Intervalar Models
Universidad de Sevilla	Maria Teresa Gómez	Model-based diagnosis using Constraint Databases
Universidad de Sevilla	Rafael Ceballos	Max-CSP and symbolic techniques for Software Diagnosis
Universidad de Huelva	Pedro J. Abad	Supervised learning for diagnosis of semiqualitative dynamic systems in the transitory state

Universidad de Huelva	Antonio J. Suárez	Supervised learning for semiqualitative diagnosis of dynamic systems in the stationary state
Universidad de Huelva	José Manuel Bravo	Robust Non-linear Predictive Control based on interval techniques
Universidad de Valladolid	Esteban Gelso	Model-based diagnosis of continuous processes using DX and FDI techniques
Universidad de Valladolid	Oscar J. Prieto Izquierdo	Data Mining for Supervision
Universidad de Valladolid	Fco. José González Cabrera	Integration of Qualitative modelling in a supervision system
Universidad de Valladolid	Esther Valverde Escorial	Model-based diagnosis: fault identification using possible-conflicts and quantitative models
Universidad de Valladolid	Brigitte Tiuso	Fault Detection and Diagnosis using FDI
IAI (Institute for Automatic Control: CSIC)	Maritzca Correa Valencia	Application of diagnosis techniques to industrial processes

3 Analysis of Results

3.1 Final Colloquium

The Final Colloquium was held on Tuesday 25th. In attendance were five teachers (Joachim Armengol, Teresa Escobet, Vicenç Puig, Belarmino Pulido and Louise Travé-Massuyès) and ten students.

The colloquium was focused towards the discussion of four issues.

- What was the students overall opinion of the School
- Did the students consider that DX / FDI techniques could be interesting for their area of research
- Did the students think that both techniques were of interest to them
- Did the students think that it was possible to apply these techniques in their field or place of work

The first topic discussed was that of the background of the students. Most of the students were in the initial stage of PhD and it was interesting to hear that almost all of them have received next to no background teaching in diagnosis in their degrees (Physics, Engineering or Computer Science).

Most of the students thought that the content of the School was much too complex and that having the event over nine days was also too long a time period to spend trying to absorb this level of complex information. The students also stated that they would very much like to have more time dedicated to the maturing or nurturing (and the long term understanding) of new concepts.

One recurrent point of discussion was that the students have very different backgrounds and that in order to fully understand DX / FDI topics you require a much wider background knowledge than any

one degree scheme appeared to contain. All the students stated that they found different student colleagues understanding different areas of the course at different speeds / levels of completeness. The teaching staff agreed that they had also found a great deal of difficulty in finding the right level of curriculum complexity to suit every student.

The Colloquium then discussed the BRIDGE concept. All present agreed that this was a very interesting area, but many stated that they have found difficulty in understanding every point in the schedule. The students suggested that, in the future, less and lighter subjects should be included in the scheduling and that the explanation of these basic principles should be expanded. They yet again pinpointed the need for more practical courses.

Most of the students felt that there was a lack of benchmarks and available tools which could be used in the School and in research in general. It is noteworthy that this opinion was also reflected by those students who had been actively working in the field for several years.

One student (who came from an Institute in Madrid, devoted to technological transfer from University to Industry), stated that although some FDI techniques were known in industry most DX techniques were not. They also stated that industrialists were rather reluctant to apply, what they saw as, novel methods. Another student working in research projects with industry also remarked that industrialists consider DX techniques as quite sophisticated and stated that industry does not want to be the 'guinea pig' for these technologies.

In conclusion, the students were asked what they felt was the most significant issue that the teaching of / training in Diagnosis faced. They stated that in their opinion this was the lack of available tools to build general diagnosis applications, also most of the tools which are available are specially tailored for individual domains. They then went on to state that they were strongly of the opinion that, without these tools, it would not be easy to transfer the required knowledge to implement these systems to mid-level operators in plants. They specified this, as it would probably be these operators who would be utilizing any application that was introduced into a real world scenario.

3.2 Questionnaire Results

Below is the frequency of the answers given to the questionnaire and a graphic representation of the results is shown in Annex One.

1. I found the amount of material taught during the SDS:	Too Much	Just Right	Too Little
Comments:	12	2	0
2. I found the complexity of material taught during the SDS	Too Complex	Just Right	Too Simple
Comments:	3	11	0
3. I found the balance between theory and practical applications during the lectures in the SDS:	Too much theory	Just about right	Too much application
Comments:	9	5	0
3 (a) Because of the SDS my interest in Diagnosis has:	Increased	Stayed the same	Decreased

Comments:	11		3		0	
4. The chances / likelihood that I will use Diagnosis for my research and/or applications in the near future is:	0	1	2	3	4	5
Comments:	0	1	1	2	2	8
5. Due to the SDS I see new potential / possibilities for using Diagnosis techniques in my research and/or applications in the near future:	None	A few	Stayed the same	Some	Many new possibilities	
Comments:	0	2	4	4	4	
6. By attending the SDS I learned ... about Diagnosis:	A lot		Enough		Not enough	
Comments:	8		6		0	
7. As an overall impression I found the SDS	0	1	2	3	4	5
	0	0	2	3	5	4
8. As an overall evaluation I would like to give the SDS the following grade (please give a number between 0 and 10):	4, 4, 6, 6, 7, 8, 8, 8, 8, 9, 9, 9, 9, 9					
9. Should we organize more (summer) schools on Diagnosis?	Yes			No		
	11 + (1?)			0		
Comments:						

3.3 Analysis of the Questionnaire Results

The feedback that we gained from the students, both during the colloquium and from the questionnaire, was, on the whole, highly positive. The students did, however, give some highly focused constructive criticisms of their experience of both the event itself and of the learning of / training in Diagnosis in general.

When asked to rate their increase (between 0 and 5) in interest in the subject area due to the School, 57% of the Students gave the maximum mark, with the average mark given being a 4.2. Over half stated that they could see new potential / possibilities for using Diagnosis techniques in their research and/or applications in the near future. 57% stated that they had learned a lot from attending the event. When asked to rank their impression of the event (again between 0 and 5) the students gave an average of 4.57 and their value of the event (ranked between 0 and 10) gave an average of 7.43. When asked if this event should be repeated not one single student answered that it should not be.

There were, however, criticisms of the event. 85% of the students felt that there was too much information to absorb in the time available and many felt that nine days was probably too long to concentrate at the level that the event required. That said, however, only 21% felt that the actual

content was too complex. 64% of students stated that there was too much theory and during the Colloquium many voiced the opinion that they would appreciate more practical examples and more time to understand them.

The Colloquium offered the students a chance to discuss their experiences with diagnosis as a whole and this provided some interesting results. One continuing theme was that many students struggled with some areas of the study due to having an insufficient background to one or more areas of the domain. They stated that their previous studies had not prepared them for the subject matter, regardless of what those previous degrees were, and they felt that this handicapped their full understanding of the subject matter.

In conclusion, the event has been seen as a genuine success. Although there were some issues of complexity and volume of information, this was not unexpected. The level of the content took the students from the basics right through to the higher end of student understanding (in each and every topic) and it was almost inevitable that some students could struggle at this highest level. The content of the course was extensive but the teaching staff hoped that the students would now have a basic understanding as well as a wealth of knowledge in their notes and hand-outs that would enable them to continue their learning in the future. The teachers also hope that the information / hand-outs given to the students will form the basis of a very valuable domain specific resource for their future research.

4 References

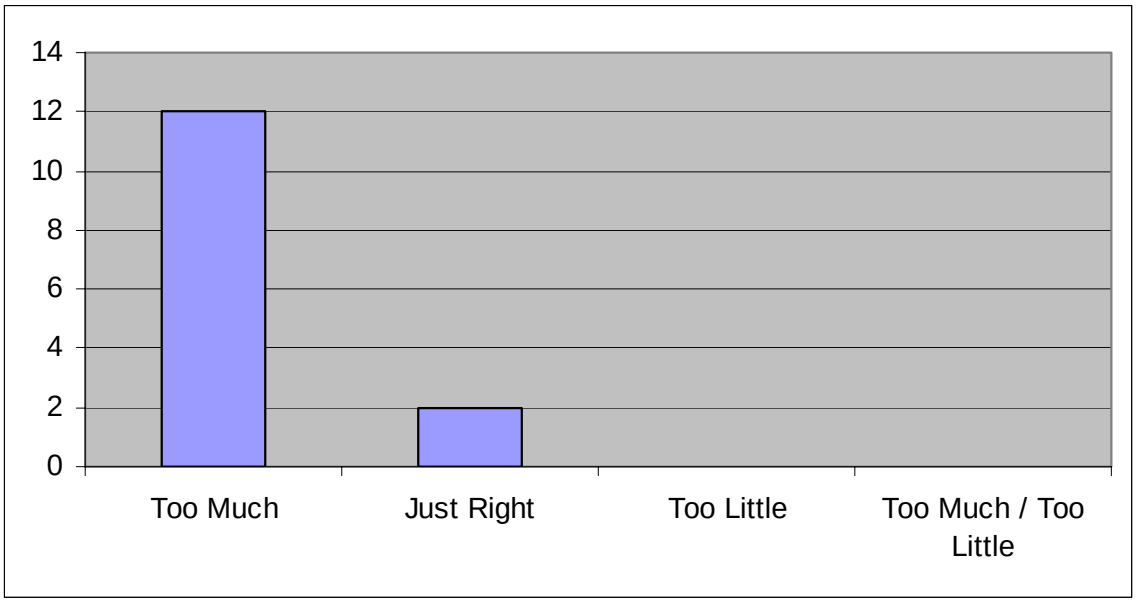
http://www-esaiiterrassa.upc.es/escuela/

5 Document History

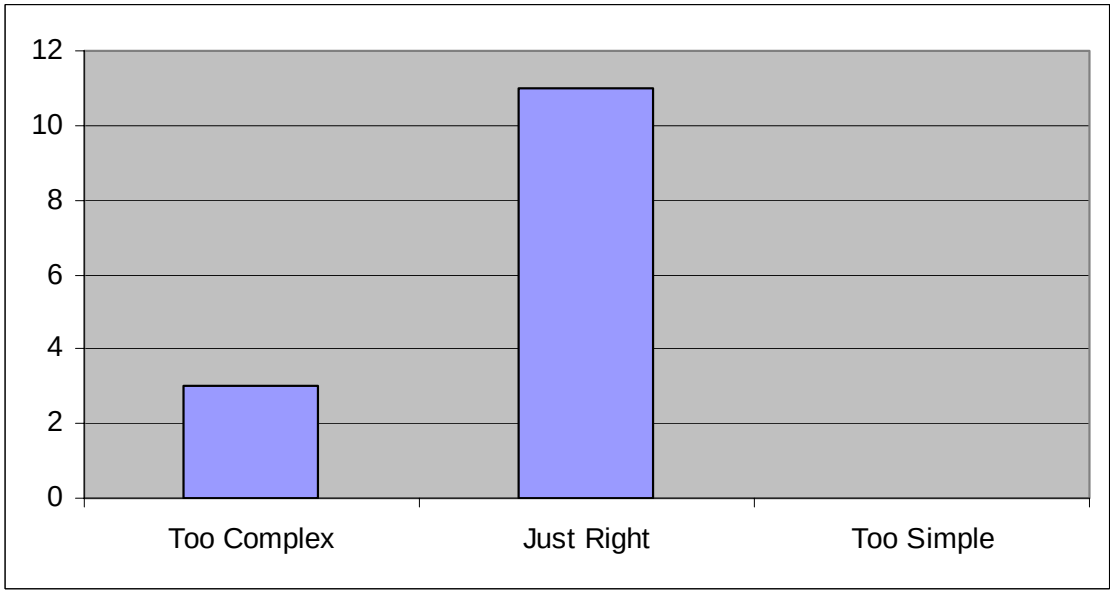
Version	*Date*	*Changes made to document*	*Changed by*
1.0	14th July 2004	Draft of Document Produced	RIR
1.1	15th July 2004	Minor Amendments	RIR
1.2	28th July 2004	Minor Amendments	LTM
1.3	30th July 2004	Minor Amendments	BPJ
1.4	6th September 2004	List of Students and PhD Topics from Belarmino Pulido	RIR
1.5	7th December 2004	Proof-read / Minor Amendments	RIR/JNT
	20th January 2005	Document status set to Release	RIR

6 Annex One: Questionnaire Results Graphs

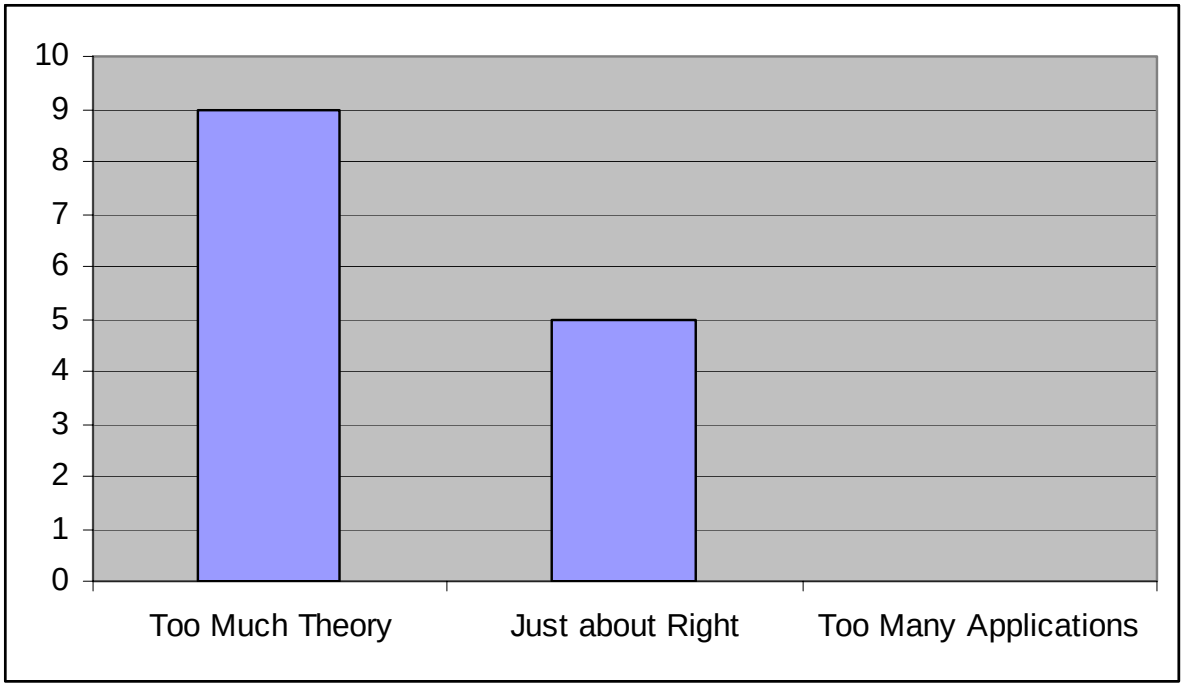
1. I found the amount of material taught during the SDS:



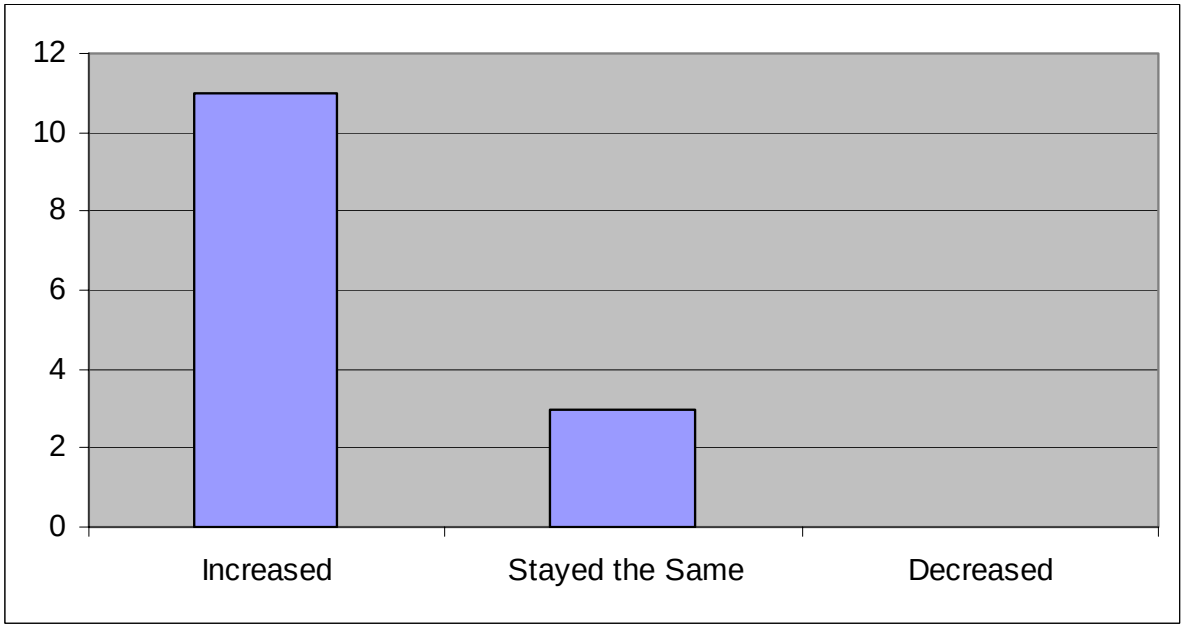
2. I found the complexity of material taught during the SDS:



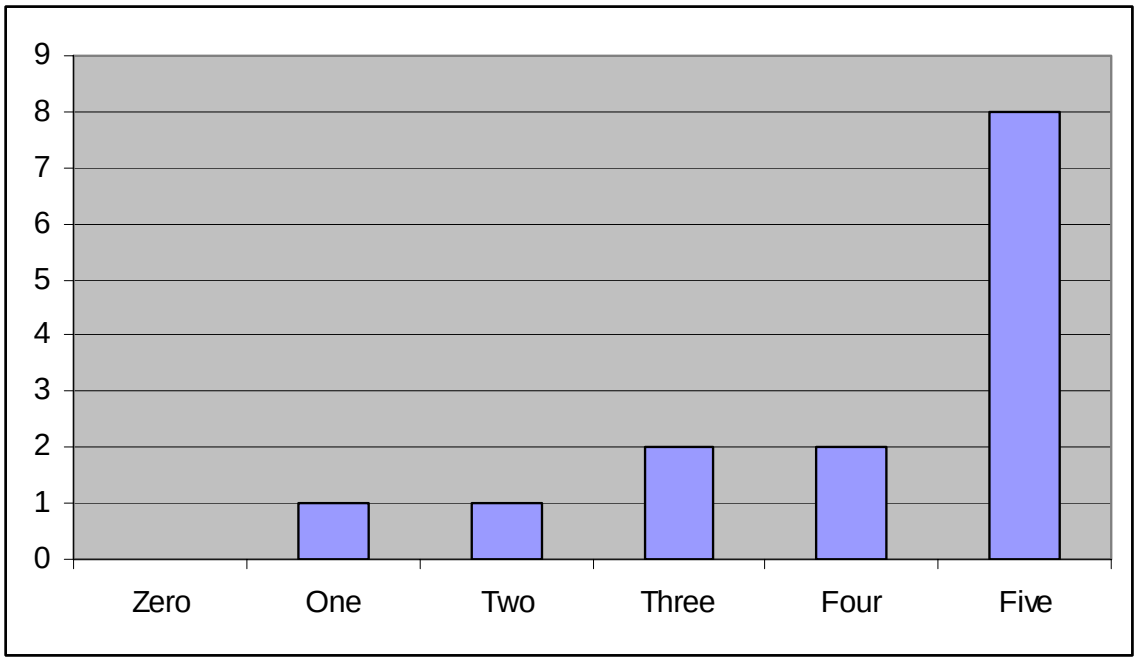
3. I found the balance between theory and practical applications during the lectures in the SDS:



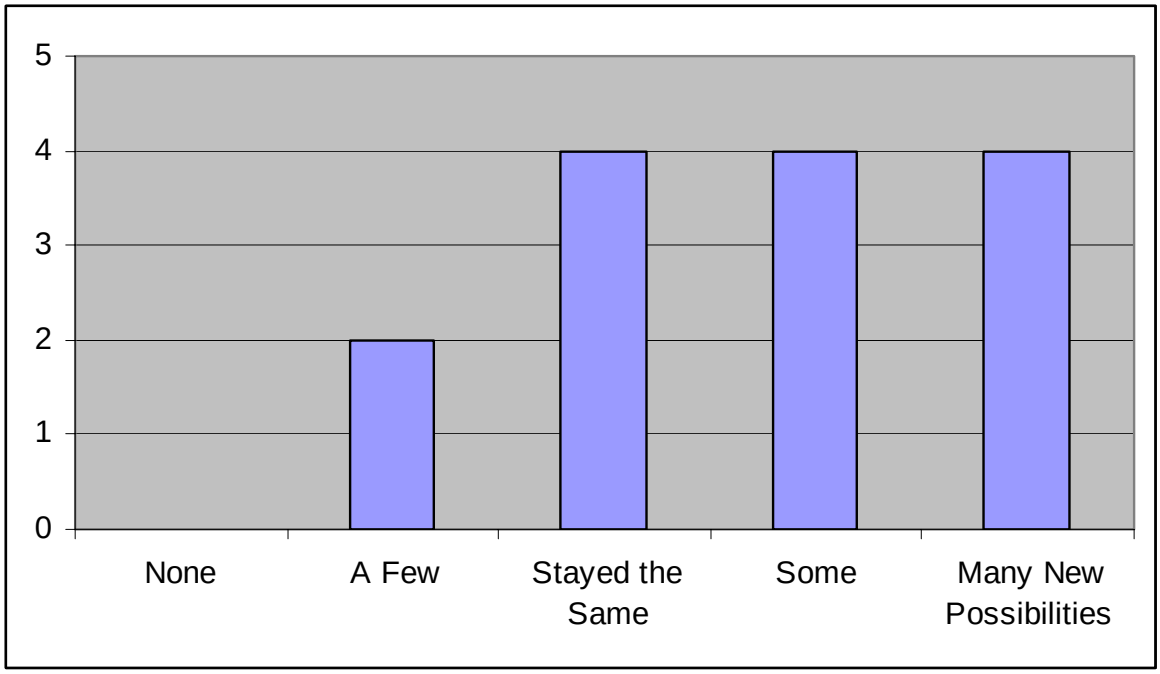
3 (a) Because of the SDS my interest in Diagnosis has:



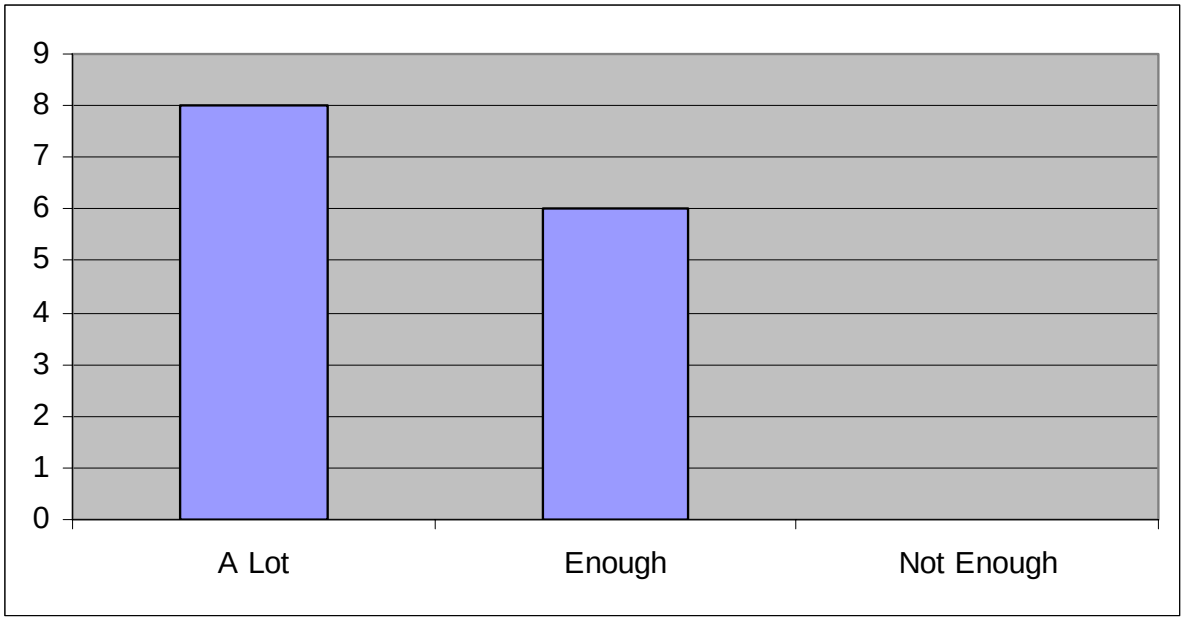
4. The chances / likelihood that I will use Diagnosis for my research and/or applications in the near future is:



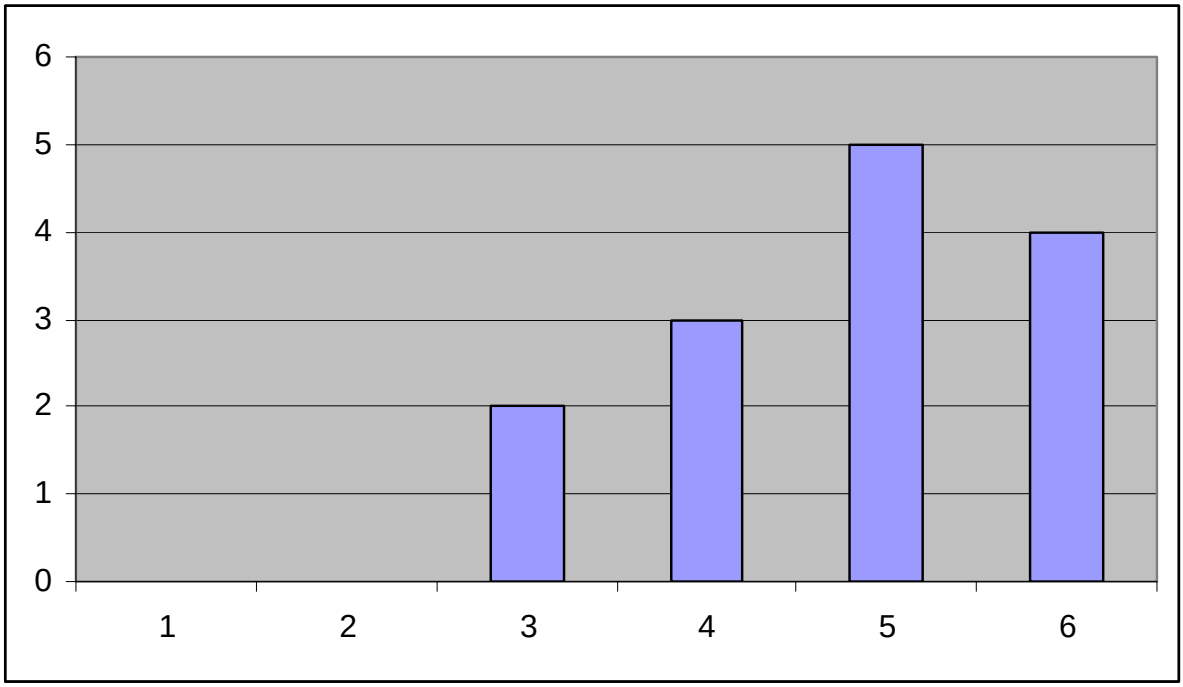
5. Due to the SDS I see new potential / possibilities for using Diagnosis techniques in my research and/or applications in the near future:



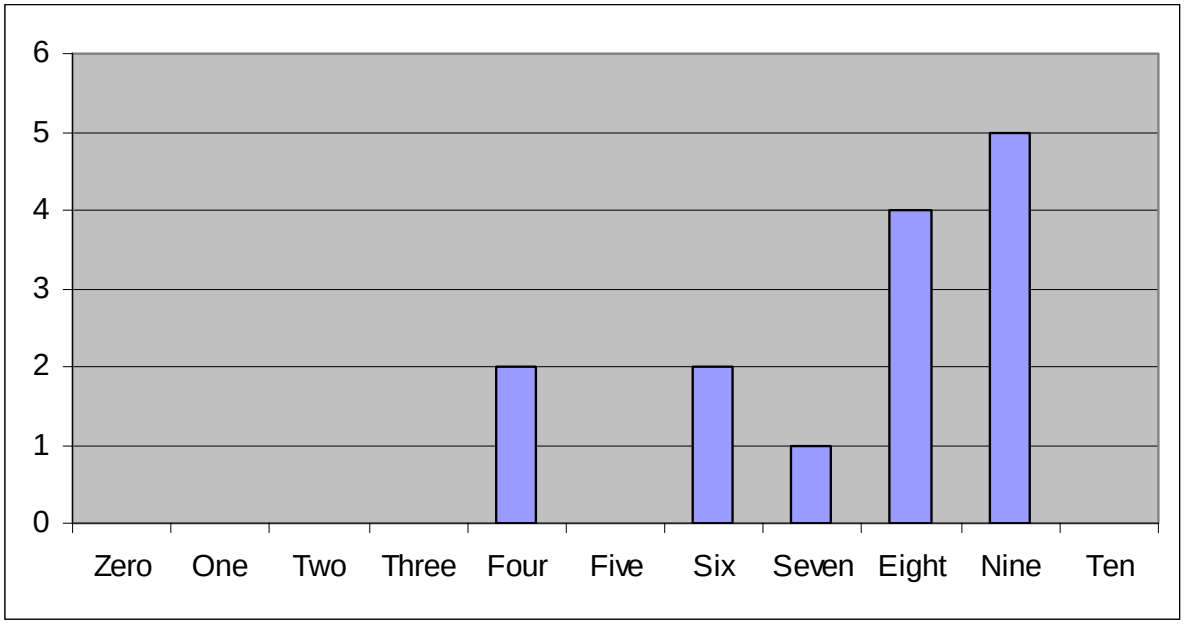
6. By attending the SDS I learned ... about Diagnosis:



7. As an overall impression I found the SDS:



8. As an overall evaluation I would like to give the SDS the following grade (please give a number between 0 and 10):



9. Should we organize more (summer) schools on Diagnosis?