PlayPhysics 2008-2011

An Emotional Student Model for Educational Gaming

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Outline

- Aims & objectives
- Background & literature review
- Research methodology
- Emotional student model
- PlayPhysics design & implementation
- Preliminary results & evaluation
- Relation to other work
- Project plan
- Publications & presentations
- Thesis outline
- Conclusion & future work

Aims & objectives

- Create an emotional student model that can reason about students' emotions using Control-Value theory (Pekrun et al., 2007) as a basis
- Provide & select suitable pedagogical and emotional feedback
- Design, implement & test PlayPhysics, an emotional game-based learning environment for teaching Physics at undergraduate level

Background & literature review

- Game-oriented learning (Oblinger, 2004; Bergeron, 2006)

  How to achieve & ensure effective learning?

  - Intelligent Tutoring Systems (ITSs) & Student Modelling

- Emotion & education (Pekrun et al., 2007)

  – Cognition, motivation & education deeply intertwined

  How emotion arises? What emotions are relevant to learning?

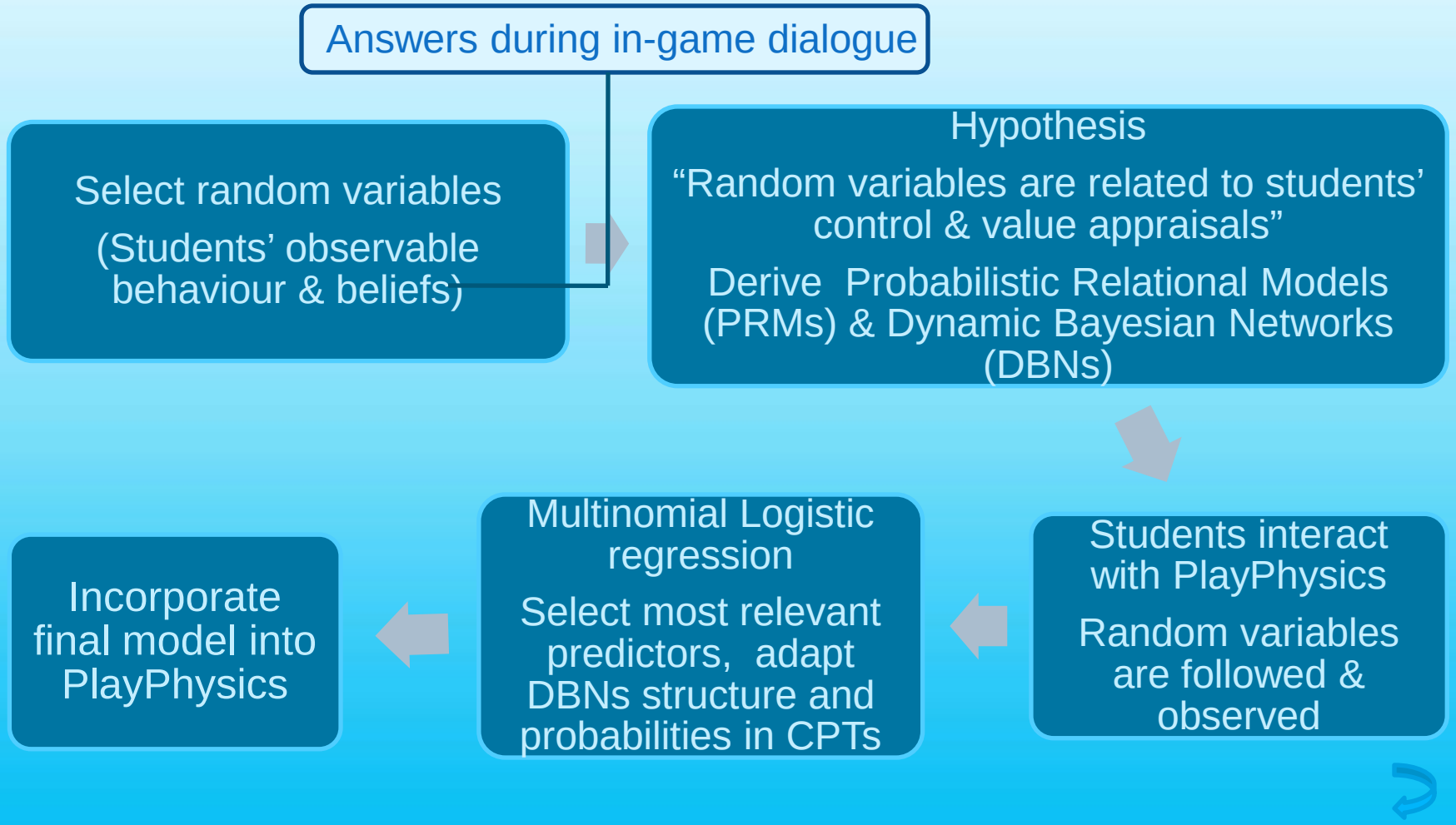
- Affective computing and affective gaming

  (Sykes, 2006; Picard et al., 2004)

- Approaches to recognising emotion
  - Recognising physical effects (Sarrafzadeh et al., 2008; D'Mello et al., 2008)
  - Reasoning about emotion from its origin (Jaques & Vicari, 2007)
  - Hybrid approach (Conati & Maclaren, 2009)
- Recognising students' motivation (Del Soldato & Du Boulay, 1995; Rebolledo-Mendez et al., 2006)
- Recognising students' self-efficacy (McQuiggan et al., 2008)
- Control-value theory of achievement emotions (Pekrun et al., 2007)

There is currently no computational & emotional model using this theory

Research methodology



Control-value theory

- Achievement emotions (Pekrun et al., 2007)
  - Domain dependent, uses motivational, cognitive & physiological variables
  - Defined according to focus & time frame: outcome-prospective, activity & outcome-retrospective emotions
- Control and value appraisals -> the most relevant to determining an emotion
  - Control related to students' beliefs & skills (task)
  - Value related to the importance of the activity & outcomes

Focus on/ Time frame	Value appraisal	Control appraisal	Emotion
Outcome/ Prospective	Positive (Seek Success)	High Medium Low	Anticipatory Joy Hope Hopelessness
	Negative (Avoid Failure)	Low Medium High	Hopelessness Anxiety Anticipatory relief

Emotional student model

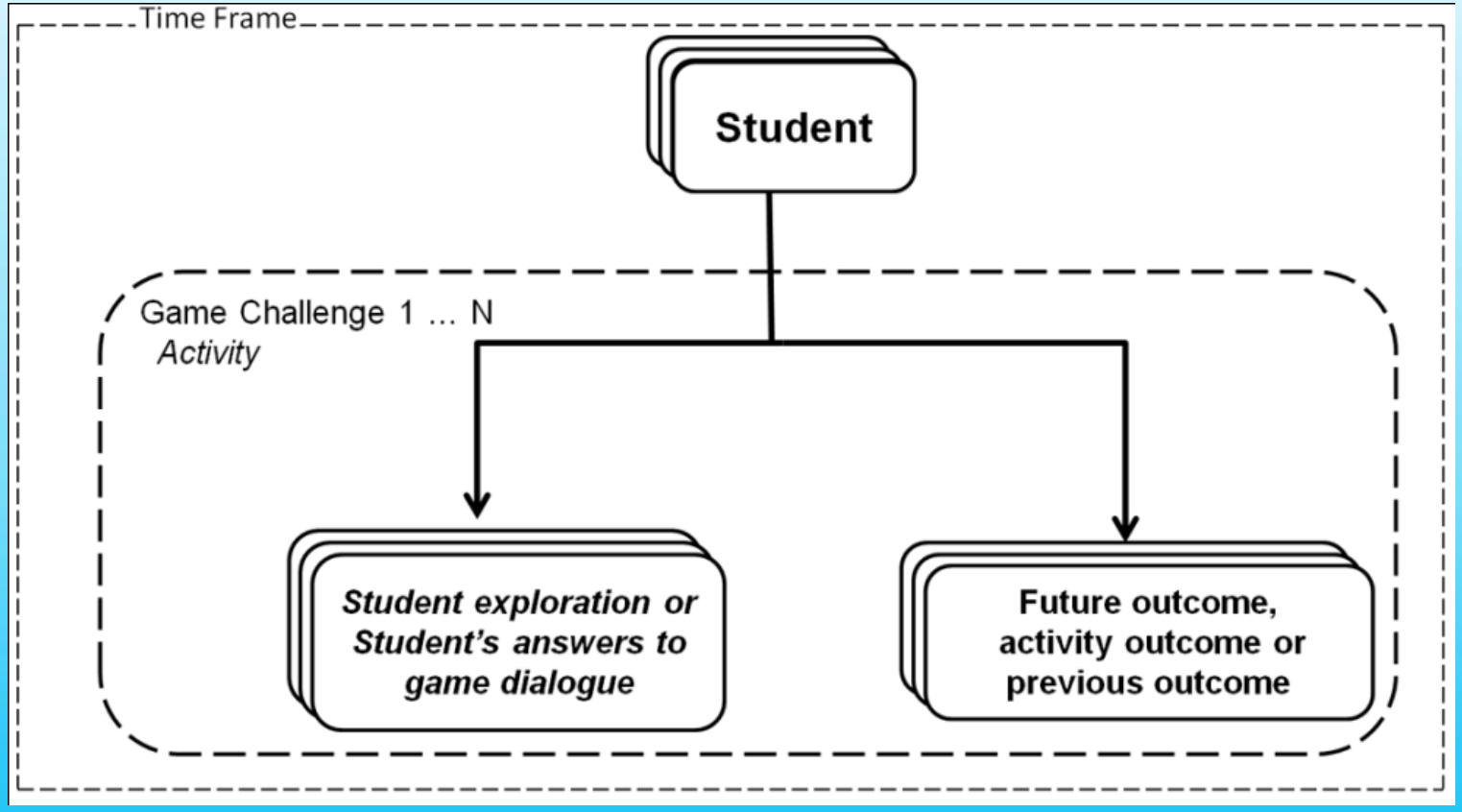


Fig. 1. PRM schema derived using the Control-Value theory as a basis.

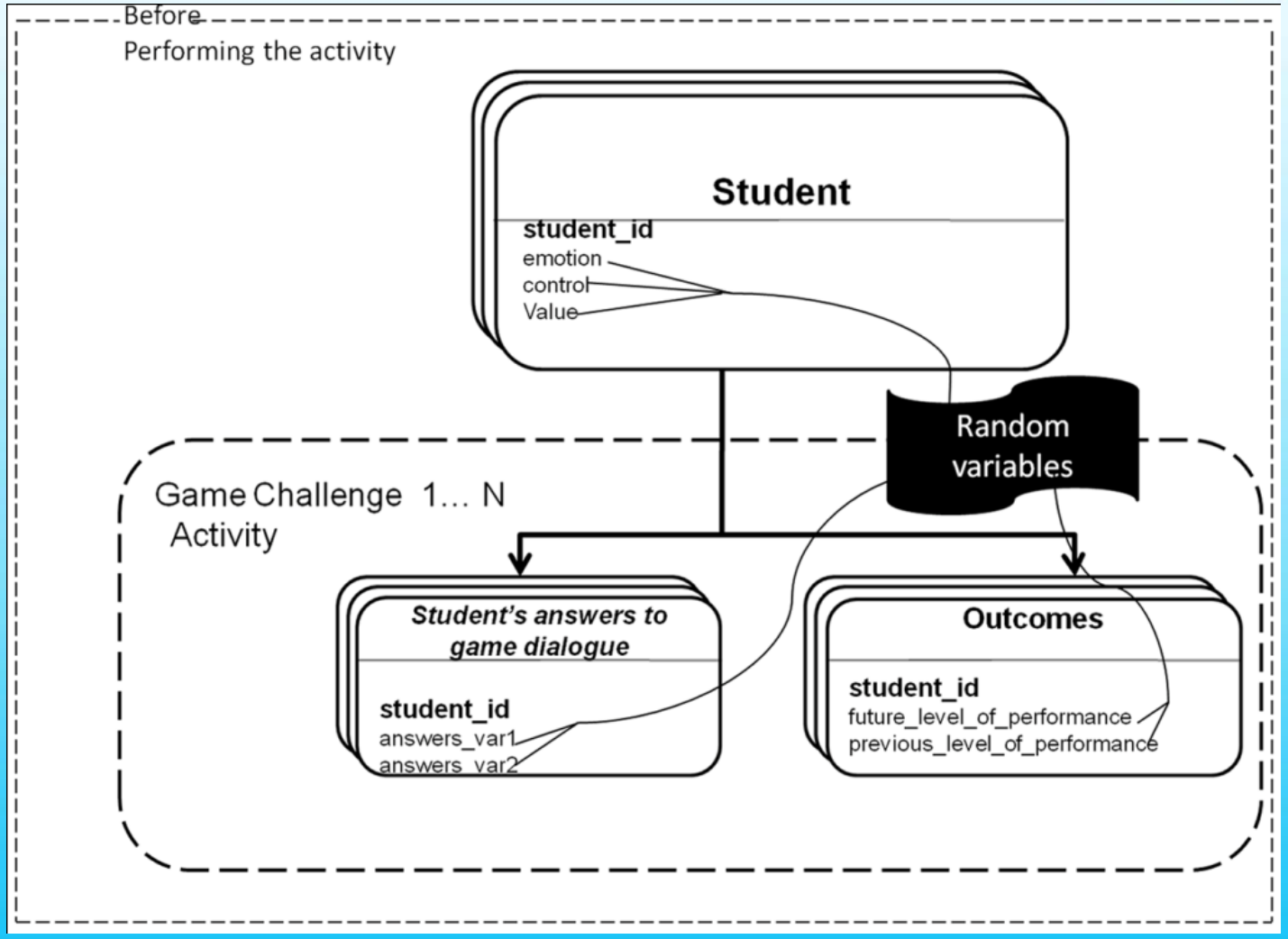


Fig. 2. Detailed PRM classes

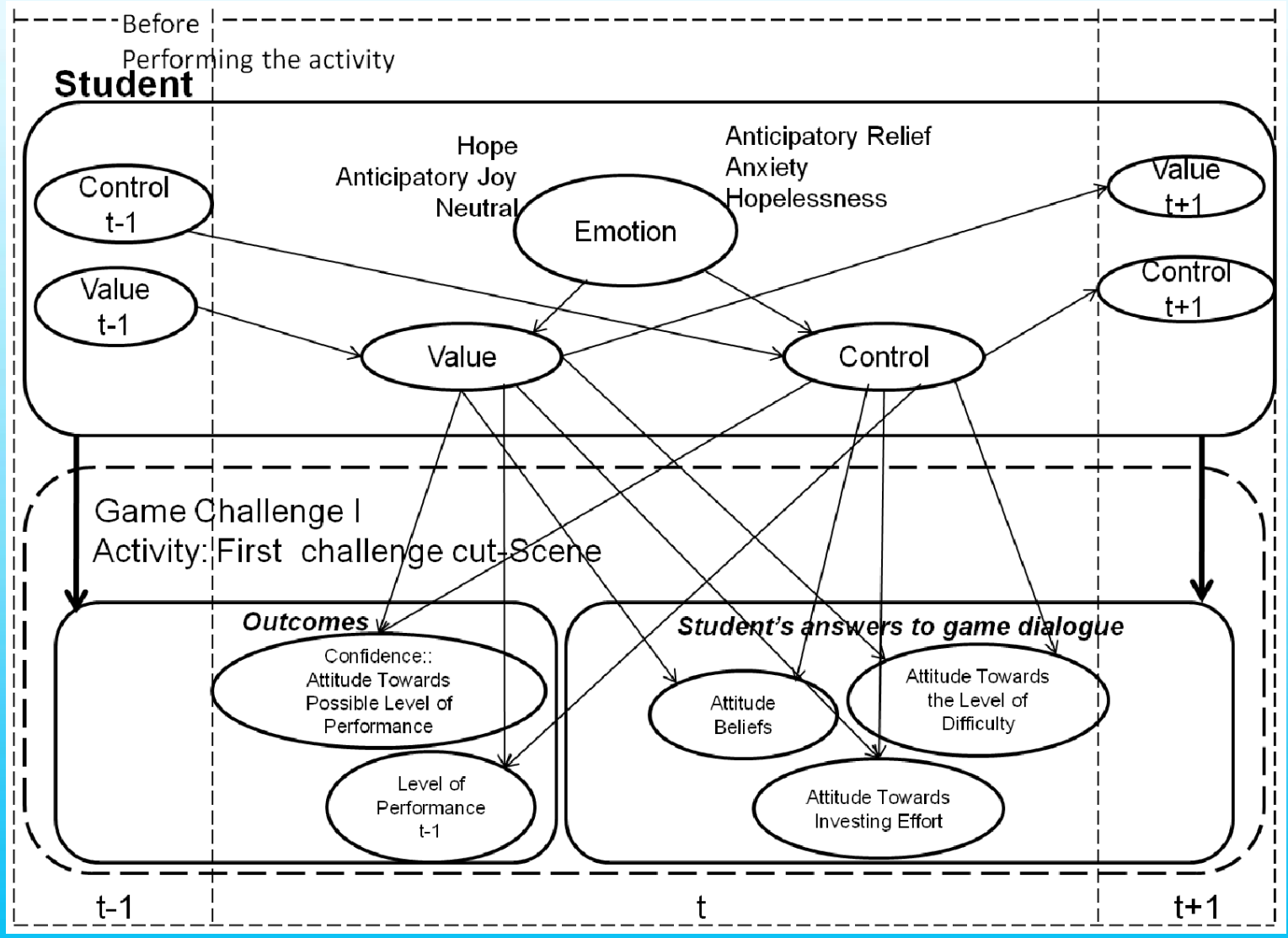


Fig. 4. Outcome-prospective emotions DBN

Selecting variables

- Achievement Emotions Questionnaire (AEQ) (Pekrun et al., 2005)
  - Structural Equation Modelling -> 389 students (Psychology)

Fig. 3. Fragment of AEQ Questionnaire

BEFORE STUDYING

The following questions pertain to feelings you may experience **BEFORE** studying. Please indicate how you feel, typically, before you begin to study.

	Strongly Disagree 1	2	3	4	**Strongly Agree** 5
81.	I look forward to studying.				
82.	I get so nervous that I don't even want to begin to study.				
83.	I feel confident that I will be able to master the material.				

Confidence: attitude towards possible level of performance

Variables for time frames: during & after

- From student models of motivation (Del Soldato & Du Boulay, 1995) & self-efficacy (McQuiggan et al., 2008)

Outcome	Time spent on each challenge	Level of difficulty perceived by the student	Publish final result
Number of times the student asked for help	Time effectively invested (focused)	Number of times the student quit	Average time required to solve problems and achieve goals
Number of times the student received help	Time since the student achieved a goal	Number of total attempts (Times restarted)	The rate of goal achievement
Time without succeeding	Quality of tutor's feedback	The rate of student's effectiveness	

PlayPhysics design & implementation

- Olympia architecture (Muñoz et al., 2009)
- Incorporate into Olympia our emotional student model
  - Provide adaptable pedagogical and emotional feedback (game-elements)
- Identification of the most difficult topics in an introductory Physics course
  - Online survey -> Tecnológico de Monterrey, Mexico City, Trinity College Dublin & Queen's University Belfast
    - Vectors, principles of linear & circular kinematics & Newton's laws for particles and rigid bodies
- PlayPhysics is a Role Playing Game (RPG) & space adventure
- Student achieves game goals using his|her Physics knowledge & understanding

Interface module

Graphical environment

Interactive modules

Static modules

1. Physics & collisions
5. Networking
6. Utilities
7. Scripting
4. Input detection

Dynamic modules

2. Emotional feedback module
3. Interactive AI (game characters)
8. Graphics look & feel rendering

World module

Simulation model

World model

Game mechanics

Teaching & learning AI module

Interface analysis

Short-term memory

Current interaction events

Behaviour analysis

Common-sense base

Student model

Cognitive model

Affective model

Personality traits
Emotion

Adaptable tutor module

Motivational modulator

Affinity strategies
Motivational strategies

Cognitive modulator

Pedagogical strategies

Planner

Presentation content manager

Actions & resources base

Long-term memory

History of interaction student-tutor

Knowledge base

Media base

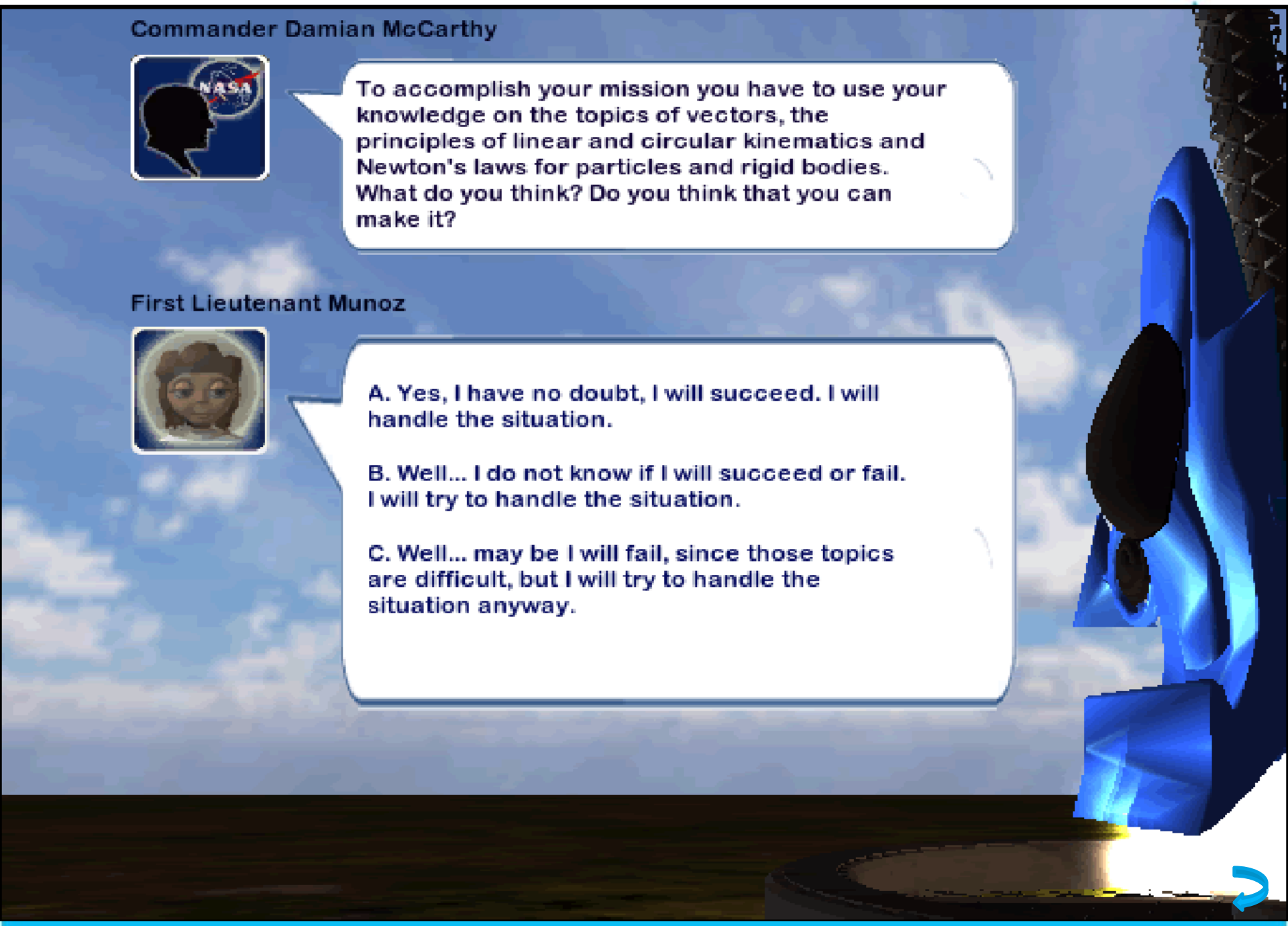


Fig. 5. Sample PlayPhysics game dialogue on student's self-efficacy

First level

- Docking the spaceship (Alpha Centauri) with the Space station Athena
  - Vectors, linear & circular kinematics & Newton's laws for particles & rigid bodies
- Interaction in first person
- Game challenges designed by Astrophysics domain expert (ITESM-CCM)
- Developed with Java, the Unity game engine, 3D Studio Max & Hugin Lite
- Four phases for accomplishing the mission (4 challenges)

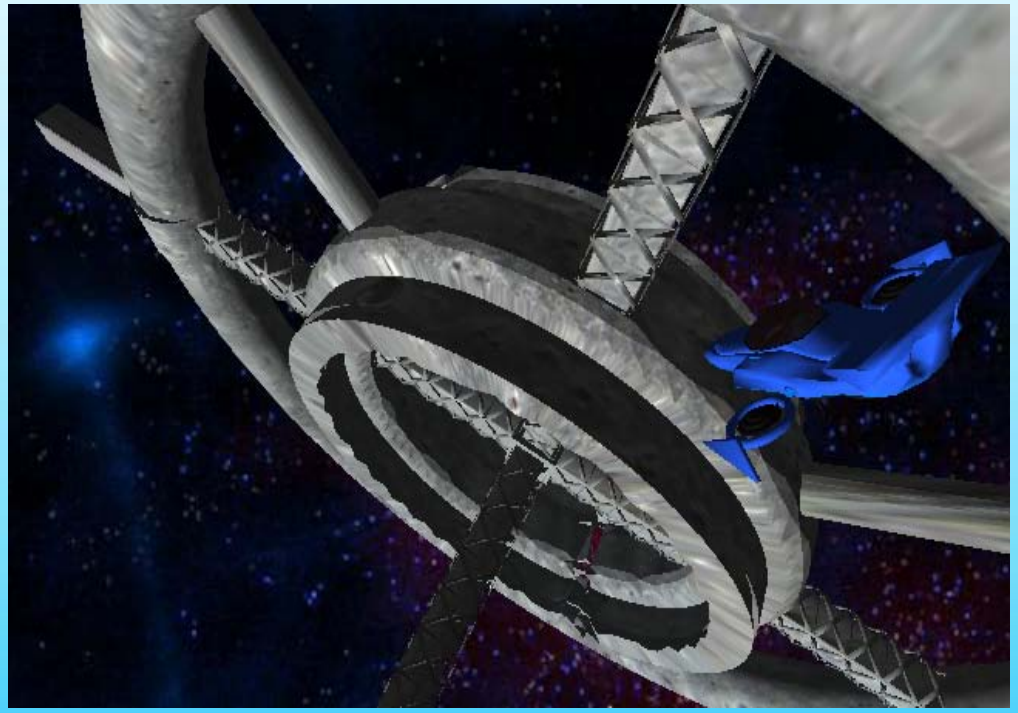


Fig. 6. PlayPhysics screenshot of the first level

Fig. 7. Player characters

- The robot “M8” is the students’ learning companion
  - Provides domain feedback
  - Reacts to the student’s self-reported emotional state

Student emotion	M8 behaviour
Anger	M8 makes a scared and sorry face
Frustration	It is similar to when feedback is asked -> M8 offers help
Enjoyment	M8 agrees and says “I am also having fun”

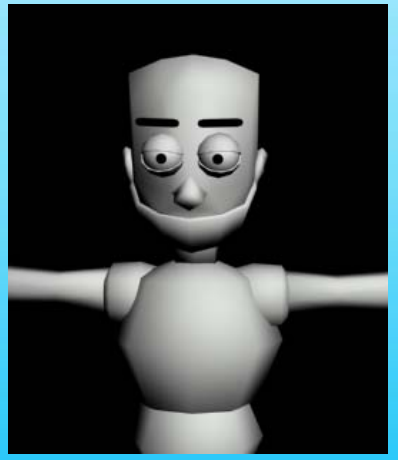


Fig. 8. M8 learning companion characterised from Max created by Peter Starostin

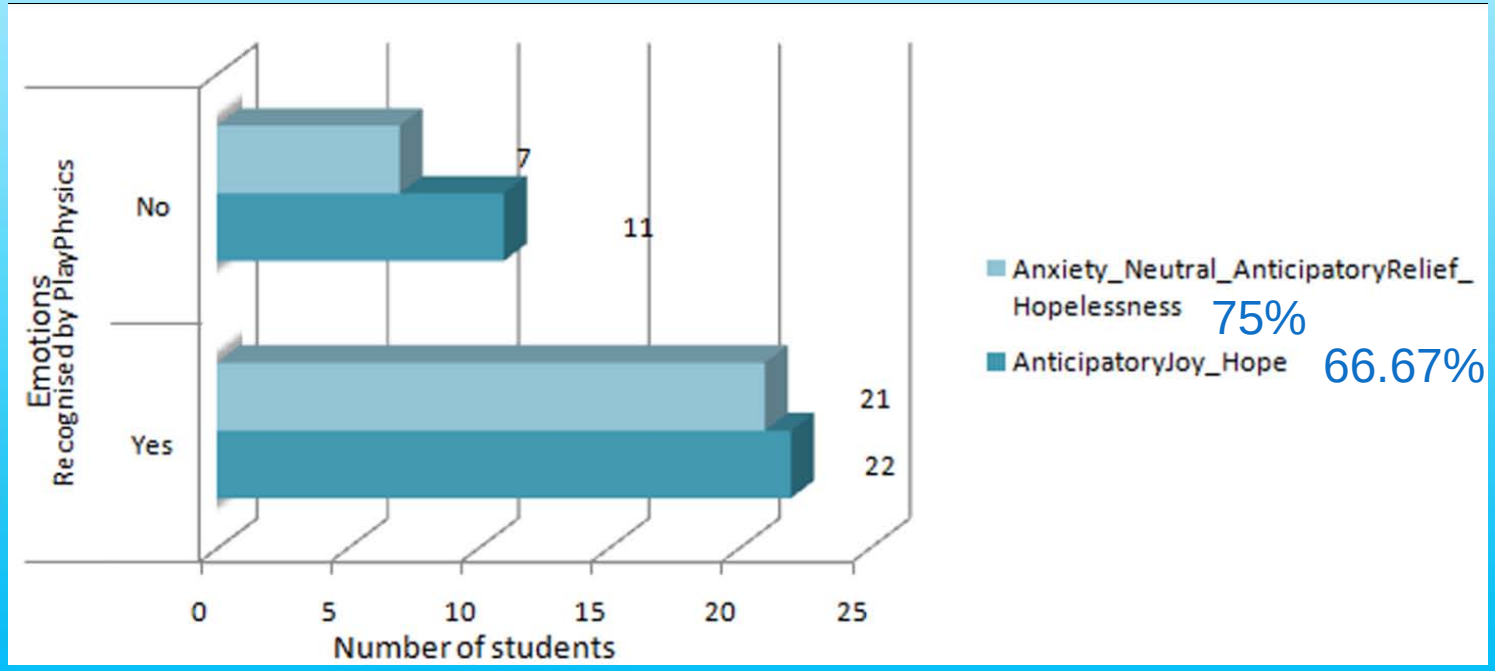
Preliminary results & evaluation

- 61 students of Engineering -> ITESM-CCM
  - (37 males & 24 females, aged18 to 23)

- Procedure:
  1. Solve pre-test
  2. Interact with PlayPhysics in-game dialogue
  3. Students self-report emotion before starting PlayPhysics' first level
  1. Transform each emotion into-> control & value
  2. Analyse variables -> Multinomial Logistic Regression (SPSS)

- Two variables were identified as best predictors of category membership

Dependent variable	Predictors	Significance (p-values)	Odds ratios	95% C.I. (confidence intervals)	% cases correctly classified
Value	Confidence: attitude towards the possible level of performance	0.002	6.000	1.957-18.398	70.5
Control	Attitude beliefs towards Physics	0.021	7.885	1.364-45.577	88.5



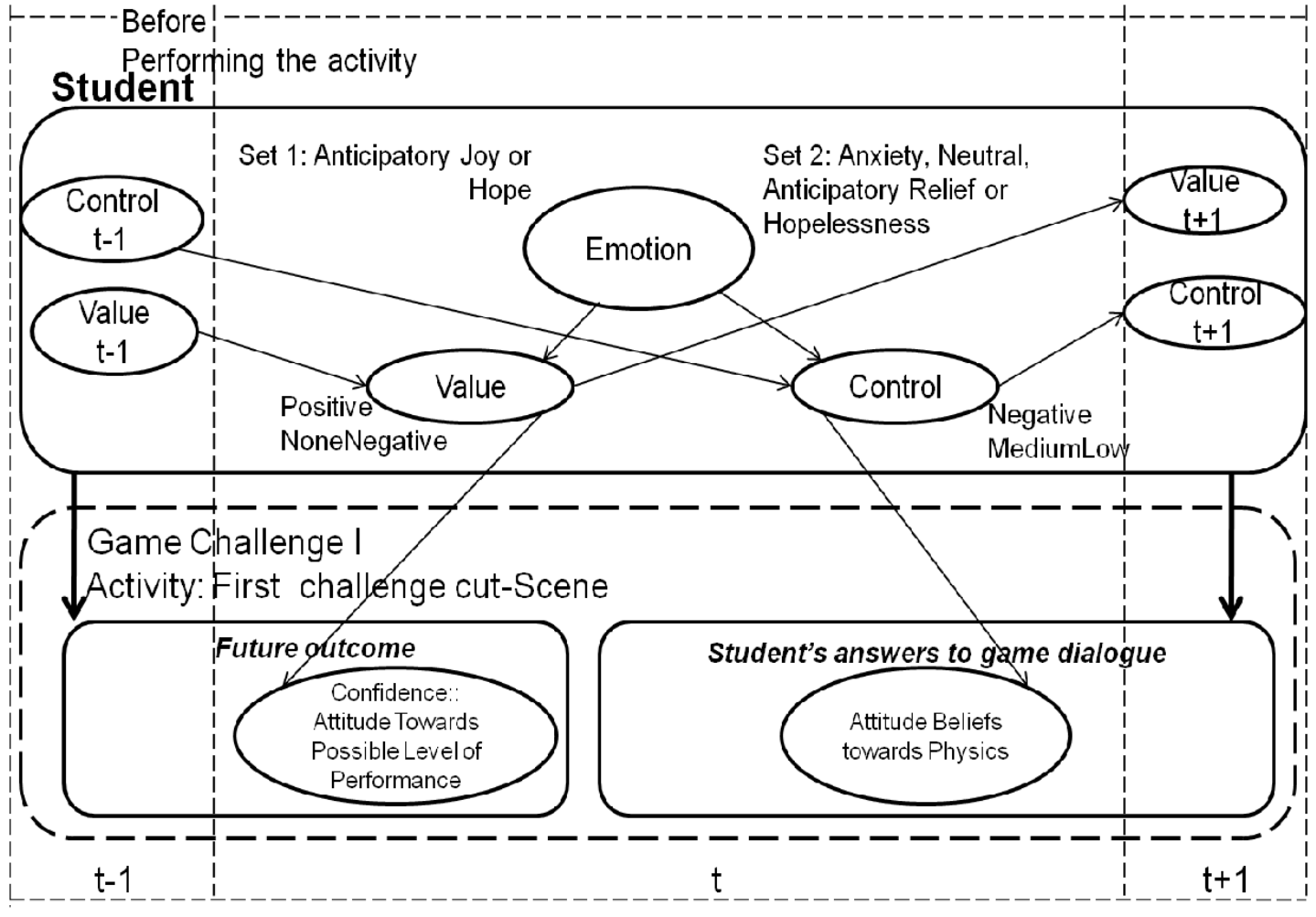


Fig. 9. Outcome prospective emotions DBN according to Multinomial Logistic Regression

Relation to other work

Comparison of emotional student modelling

Research	Tutoring modelling		Education technologies		Teaching subject	Selected features	Online	AI technique to recognise emotions	Recognised affective features		Approach affect recognition		Targeted educational level		Affective states	Using as a basis
	ITS[1]	IA[2]	Educational game	VLE[3]					Moods	Emotions	Identifying physical effects	Predicting emotion from its origin	Primary Level	Undergraduate Level		
Chalfoun et al. (2006)	✓	×	×	✓	Emotional Intelligence, Sports & other areas of general knowledge	Observable behaviour	✓	Decision tree with ID3 algorithm & genreation of rules	×	✓	×	✓	-	-	disappointment, distress, joy, relief, satisfaction and fear	OCC model
Neji & Ben Ammar (2007)	×	✓	×	✓	Communications technology	facial gestures	✓	Multi agent system	×	✓	✓	×	×	✓	satisfaction, confidence, surprise, confusion & frustration.	Ekman & Friesen
Jaques & Vicari (2007a)	×	✓	×	✓	-	Observable behaviour	-	Agent system	×	✓	×	✓	-	-	satisfaction/disappointment, joy/distress, gratitude/anger & pride/shame	OCC model
Sarrafzadeh et. al (2008)	✓	×	×	✓	Maths	facial gestures & body language	✓	ANN[3] & SVM	×	✓	✓	×	✓	×	boredom, confusion, frustration, inattention & anxiety	Ekman & Friesen Justine Cassell
D'Mello et. al (2008a)	✓	×	×	✓	Newtonian Physics, Computer Literacy & Critical Thinking	Written natural language, facial gestures & body language	×	Supervised learning methods & LSA[5]	✓	×	✓	×	×	✓	Frenquently observed affective states: boredom, engagement, confusion and frustration	Ekman & Friesen & other approaches to identify affective patterns(ANNs[4])
Conati & Maclaren (2009)	✓	×	✓	✓	Maths	Biometrics	×	Dynamic belief networks and Influence diagrams	×	✓	✓	✓	✓	×	joy/distress & admiration/reproach	OCC model
Muñoz et. al (2008- 2011)	✓	×	✓	✓	Physics	Observable behaviour & answers to posed questions	✓	Dynamic Bayesian networks	×	✓	×	✓	×	✓	Achievement emotions	Control-value theory by Pekrun et al. (2007)

Project plan

Activities	2008	2009				2010				2011		
	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
Literature Review: Background and focal theory												
Graduate Research School Training												
100 Day Review report and viva												
39th Annual Conference, Frontiers in Education (FIE)												
Preparing a survey to find functional and non-functional requirements and justify the execution of the research												
Applying the survey												
International Symposium of Electronic Arts (ISEA 09)												
Selecting the tools to develop the web application												
Selecting the tools to develop the 3D design of the educational game												
Selecting the tools to manage and produce sound												
Selecting the tools and methodologies to recognise aspects of emotion												
Selecting the tools and methodologies to recognise aspects of personality												
Selecting the AI tools to implement the enhanced student and adaptable tutor model												
Testing the viability of the research work by carrying a pilot study												
Designing PlayPhysics												
Confirmation report and viva												
2nd year poster presentation												
Developing and Implementing PlayPhysics												
Testing and deploying the PlayPhysics												
Experimentation over the subject sample												
Data collection and analysis												
Writing up book chapter for Springer												
Elsevier Journal of Computing & Education												
3rd year presentation												
Writing up thesis												
Submission of thesis												

Publications & presentations

- Journal papers

  Muñoz, K., Mc Kevitt, P., Lunney, T., Noguez, J., Neri, L. (2011a) An emotional student model for game-play adaptation. In M. Ma, N. Antonopoulos, M.F. Oliveira (Eds.), Special Issue on Serious Games Development and Applications, Entertainment Computing . EUA: Elsevier. doi:10.1016/j.entcom.2010.12.006

- Book chapters

  Muñoz, K., Mc Kevitt, P., Lunney, T., Noguez, J., Neri, L. (2011b) Affective Educational Games and the Evolving Teaching Experience. In M. Cruz-Cunha, V. H. Carvalho & P. Tavares, (Eds.) Business, Technological and Social Dimensions of Computer Games: Multidisciplinary Developments. EUA: IGI Global. (forthcoming)

  Noguez J., Muñoz K., Neri L., Robledo-Rella V., Aguilar G. (2010) Dynamic Decision Networks Applications in Active Learning Simulators. In L.E. Sucar, E.F. Morales, J. Hoey (Eds.) Decision Theory Models for Applications in Artificial Intelligence: Concepts and Solutions. EUA:IGI Global

- Conferences

  Muñoz, K., Noguez, J., Mc Kevitt, P., Lunney, T., Neri, L.(2010a). Work in Progress - Towards an Emotional Learning Model for Intelligent Gaming. In Proc. of the 40th IEEE International Conference Frontiers in Education (FIE-10), Crystal Gateway Marriott, Virginia, Washington D.C., USA, October 27 - 30. USA: IEEE Press, T3G-1 - T3G-2.

Muñoz, K., Mc Kevitt, P., Lunney, T., Noguez, J., Neri, L. (2010b). PlayPhysics: An Emotional Games Learning Environment for Teaching Physics. In Y. Bi & M.A. Williams, (Eds.) Proc. of the 4th International Conference on Knowledge, Science, Engineering & Management (KSEM-10), Belfast, Northern Ireland, UK, September 1 - 3. Heildelberg, Berlin: Springer Verlag, 400-411.

Noguez, J., Neri, L., Robledo-Rella, V., Muñoz, K. (2009a). Inferring Knowledge from Active Learning Simulators for Physics. In A. Hernández, R. Monroy & C.A. Reyes, (Eds.) Proc. of the 8th Mexican International Conference on Artificial Intelligence (MICAI-09): Advances in Artificial Intelligence, Guanajuato, México, November 9 - 13. Heildelberg, Berlin: Springer Verlag, 533-544.

Muñoz, K., Noguez, J., Mc Kevitt, P., Neri, L., Robledo-Rella, V., Lunney, T. (2009b). Adding features of educational games for teaching Physics. In Proc. of the 39th IEEE International Conference Frontiers in Education (FIE-09), Hotel Hilton Palacio del Rio, San Antonio, Texas, USA, October 18 - 21. USA: IEEE Press, M2E-1 - M2E-6.

Muñoz, K., Mc Kevitt, P., Noguez, J., Lunney, T. (2009c). Combining educational games and virtual learning environments for teaching Physics with the Olympia architecture. In Proc. of the 15th International Symposium on Electronic Art (ISEA-09), Waterfront Hall, Belfast, Northern Ireland, August 23 - September 1.

- Poster presentations

  Poster presented in the First International Workshop of Serious Games Development & Applications, University of Derby, Kedleston Rd, Derby, UK, July 8, 2010

  Poster Presented in the First Summer School on Affective Computing and Social Signal Processing, University of Edinburgh, UK, August 30 - September 1st, 2010

Thesis outline

0. Prelims
   Title page, Table of Contents, List of Figures, List of Tables, Acknowledgements, Abstract, List of Acronyms and Note-on-access-to-contents
Chapter 1: Introduction
Chapter 2: Literature review
Chapter 3: Theoretical contribution
Chapter 4: Olympia architecture, Emotional student model & PlayPhysics design & implementation
Chapter 5: Evaluation of PlayPhysics' emotional student model
Chapter 6: Conclusion
7. Appendices
8. References

Conclusion & future work

- Creating an emotional student model -> reason about observable behaviour & answers during in-game dialogue
  - Control-Value theory, DBNs & PRMs
- Evaluation of the outcome-prospective emotions DBN was undertaken (61 students) -> overall accuracy of 70.49%
  - effective identifying neutral & negative emotions
- Multinomial Logistic Regression: validate categories, dependencies & CPTs
- Future work
  - Conduct further experiments with the other two DBNs
  - Complete implementation of PlayPhysics' first level
  - Incorporate refined model into PlayPhysics -> adapt feedback
  - Explore incorporation of biofeedback signals (galvanic skin response)

Questions

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