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Calculated Moves: Generating Air Combat Behaviour

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List of publications

The work that is presented in this thesis is based on the following publications.

1. A. Toubman, J. J. Roessingh, P. Spronck, A. Plaat and H. J. Van den Herik (2014a). Dynamic Scripting with Team Coordination in Air Combat Simulation. In: *Modern Advances in Applied Intelligence: 27th International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems, IEA/AIE 2014, Kaohsiung, Taiwan, June 3-6, 2014, Proceedings, Part I*. Ed. by M. Ali, J.-S. Pan, S.-M. Chen and M.-F. Horng. Vol. 8481. Lecture Notes in Computer Science. Kaohsiung, Taiwan: Springer International Publishing, pp. 440–449. ISBN: 978-3-319-07455-9. DOI: 10.1007/978-3-319-07455-9_46
2. A. Toubman, J. J. Roessingh, P. Spronck, A. Plaat and H. J. Van den Herik (2014b). Centralized Versus Decentralized Team Coordination Using Dynamic Scripting. In: *Proceedings of the 28th European Simulation and Modelling Conference - ESM'2014*. Ed. by A. C. Brito, J. M. R. Tavares and C. Braganca de Oliveira. Porto, Portugal: Eurosis, pp. 129–134
3. A. Toubman, J. J. Roessingh, P. Spronck, A. Plaat and H. J. Van den Herik (2015a). Rewarding Air Combat Behavior in Training Simulations. In: *Systems, Man, and Cybernetics (SMC), 2015 IEEE International Conference on*. Hong Kong: IEEE Press, pp. 1397–1402. DOI: 10.1109/SMC.2015.248
4. A. Toubman, J. J. Roessingh, P. Spronck, A. Plaat and H. J. Van den Herik (2015b). Transfer Learning of Air Combat Behavior. In: *2015 IEEE 14th International Conference on Machine Learning and Applications (ICMLA)*. Miami, Florida: IEEE Press, pp. 226–231. DOI: 10.1109/ICMLA.2015.61
5. A. Toubman, J. J. Roessingh, J. Van Oijen, M. Hou, L. Luotsinen, J. Harris, R. A. Løvlid, C. Meyer, R. Rijken and M. Turčaník (2016a). Modeling Behavior of Computer Generated Forces with Machine Learning Techniques, the NATO task group approach. In: *Systems, Man, and Cybernetics (SMC), 2016 IEEE International Conference on*. Budapest, Hungary: IEEE. DOI: 10.1109/SMC.2016.7844517
6. A. Toubman, J. J. Roessingh, P. Spronck, A. Plaat and H. J. Van den Herik (2016b). Rapid Adaptation of Air Combat Behaviour. In: *ECAI 2016 - 22nd European Conference on Artificial Intelligence*. Ed. by G. A. Kaminka, M. Fox, P. Bouquet, E. Hüllermeier, V. Dignum, F. Dignum and F. Van Harmelen. Vol. 285. Frontiers in Artificial Intelligence and Applications. The Hague, The Netherlands: IOS Press, pp. 1791–1796. DOI: 10.3233/978-1-61499-672-9-1791
7. A. Toubman (2019). Validating Air Combat Behaviour Models for Adaptive Training of Teams. In: *Adaptive Instructional Systems*. Ed. by R. A. Sottilare and J. Schwarz. Springer International Publishing, pp. 557–571. DOI: 10.1007/978-3-030-22341-0_44

Curriculum vitae

Armon Toubman was born on October 8, 1988 in Amsterdam, the Netherlands. He attended the Zaanlands Lyceum in Zaandam, where he received his gymnasium diploma in 2006. His love for science fiction, computer programming, and video games led him to start his study of Artificial Intelligence in the same year, at the VU in Amsterdam. He received his bachelor's degree in 2009. During an internship at the Netherlands Organisation for Applied Scientific Research (TNO), he completed his master's thesis on the subject of adaptive autonomy in unmanned ground vehicles. In 2012 he received his master's degree with a specialisation in computational intelligence and self-organisation.

The following year, he joined a collaboration between the Netherlands Aerospace Centre (NLR) and Tilburg University as a PhD candidate. During his research, Armon was supervised by Prof. dr. H.J. van den Herik, Prof. dr. ir. P.H.M. Spronck, Prof. dr. A. Plaat (Tilburg University), and dr. J.J.M. Roessingh (NLR, daily supervision). It is at the NLR that Armon discovered his fourth love, aviation. Midway through his research, he joined professor Van den Herik in his move to establish the Leiden Centre of Data Science (LCDS) at Leiden University. Armon's research has been published at international refereed conferences. At the NLR, he co-supervised four MSc theses together with dr. Roessingh.

Currently, Armon resides in Almere. He works as an R&D engineer at NLR, with a focus on the development of behaviour modelling techniques and machine learning applications. On the web, he can be found at `http://www.armontoubman.com`.

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Most of my time was spent at the department of Training, Simulation, and Operator Performance at NLR. My sincere gratitude goes to the head of the department, Harrie Bohnen, for providing me with the resources that I needed to complete my research. Many thanks also go to the NLR colleagues who graciously shared their expertise with me.

Reaching outside of my own workplaces, I wish to extend my gratitude to the Royal Netherlands Air Force, and in particular to Rich and the 312, 313, and 322 squadrons. I sincerely hope that your support of my research will double the expected pay back in the near future. Also, in my research, only a few things have been more inspiring than preparing my experiments while listening to the roars of F-16s taking off into the skies. Furthermore, I thank the members of the NATO IST-121 panel for the many interesting discussions we have had, and for helping me place my research in an international context.

My roommate Esther Kuindersma deserves special mention. For me, it was invaluable to share the fantastic ups and the devastating downs that come while writing a thesis, with someone going through the same roller coaster. Thanks, Esther.

Finally, this thesis would not have been possible without the unconditional support of the people closest to me: pa, ma, Omri, Tanna, Iet, Hans, and most of all, Marit. Thank you all.

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32 Eelco Vriezekolk (UT), Assessing Telecommunication Service Availability Risks for Crisis Organisations

33 Peter Bloem (UvA), Single Sample Statistics, exercises in learning from just one example

34 Dennis Schunselaar (TU/e), Configurable Process Trees: Elicitation, Analysis, and Enactment

35 Zhaochun Ren (UvA), Monitoring Social Media: Summarization, Classification and Recommendation

36 Daphne Karreman (UT), Beyond R2D2: The design of nonverbal interaction behavior optimized for robot-specific morphologies

37 Giovanni Sileno (UvA), Aligning Law and Action - a conceptual and computational inquiry

38 Andrea Minuto (UT), Materials that Matter - Smart Materials meet Art & Interaction Design

39 Merijn Bruijnes (UT), Believable Suspect Agents; Response and Interpersonal Style Selection for an Artificial Suspect

40 Christian Detweiler (TUD), Accounting for Values in Design

41 Thomas King (TUD), Governing Governance: A Formal Framework for Analysing Institutional Design and Enactment Governance

42 Spyros Martzoukos (UvA), Combinatorial and Compositional Aspects of Bilingual Aligned Corpora

43 Saskia Koldijk (RUN), Context-Aware Support for Stress Self-Management: From Theory to Practice

44 Thibault Sellam (UvA), Automatic Assistants for Database Exploration

45 Bram van de Laar (UT), Experiencing Brain-Computer Interface Control

46 Jorge Gallego Perez (UT), Robots to Make you Happy

47 Christina Weber (UL), Real-time foresight - Preparedness for dynamic innovation networks

48 Tanja Buttler (TUD), Collecting Lessons Learned

49 Gleb Polevoy (TUD), Participation and Interaction in Projects. A Game-Theoretic Analysis

50 Yan Wang (TiU), The Bridge of Dreams: Towards a Method for Operational Performance Alignment in IT-enabled Service Supply Chains

2017

01 Jan-Jaap Oerlemans (UL), Investigating Cybercrime

02 Sjoerd Timmer (UU), Designing and Understanding Forensic Bayesian Networks using Argumentation

03 Daniël Harold Telgen (UU), Grid Manufacturing; A Cyber-Physical Approach with Autonomous Products and Reconfigurable Manufacturing Machines

04 Mrunal Gawade (CWI), Multi-core Parallelism in a Column-store

05 Mahdieh Shadi (UvA), Collaboration Behavior

06 Damir Vandic (EUR), Intelligent Information Systems for Web Product Search

07 Roel Bertens (UU), Insight in Information: from Abstract to Anomaly

08 Rob Konijn (VU), Detecting Interesting Differences:Data Mining in Health Insurance Data using Outlier Detection and Subgroup Discovery

09 Dong Nguyen (UT), Text as Social and Cultural Data: A Computational Perspective on Variation in Text

10 Robby van Delden (UT), (Steering) Interactive Play Behavior

11 Florian Kunneman (RUN), Modelling patterns of time and emotion in Twitter #anticipointment

12 Sander Leemans (TU/e), Robust Process Mining with Guarantees

13 Gijs Huisman (UT), Social Touch Technology - Extending the reach of social touch through haptic technology

14 Shoshannah Tekofsky (TiU), You Are Who You Play You Are: Modelling Player Traits from Video Game Behavior

15 Peter Berck (RUN), Memory-Based Text Correction

16 Aleksandr Chuklin (UvA), Understanding and Modeling Users of Modern Search Engines

17 Daniel Dimov (UL), Crowdsourced Online Dispute Resolution

18 Ridho Reinanda (UvA), Entity Associations for Search

19 Jeroen Vuurens (UT), Proximity of Terms, Texts and Semantic Vectors in Information Retrieval

20 Mohammadbashir Sedighi (TUD), Fostering Engagement in Knowledge Sharing: The Role of Perceived Benefits, Costs and Visibility

21 Jeroen Linssen (UT), Meta Matters in Interactive Storytelling and Serious Gaming (A Play on Worlds)

22 Sara Magliacane (VU), Logics for causal inference under uncertainty

23 David Graus (UvA), Entities of Interest — Discovery in Digital Traces

24 Chang Wang (TUD), Use of Affordances for Efficient Robot Learning

25 Veruska Zamborlini (VU), Knowledge Representation for Clinical Guidelines, with applications to Multimorbidity Analysis and Literature Search

26 Merel Jung (UT), Socially intelligent robots that understand and respond to human touch

27 Michiel Joosse (UT), Investigating Positioning and Gaze Behaviors of Social Robots: People's Preferences, Perceptions and Behaviors

28 John Klein (VU), Architecture Practices for Complex Contexts

29 Adel Alhuraibi (TiU), From IT-BusinessStrategic Alignment to Performance: A Moderated Mediation Model of Social Innovation, and Enterprise Governance of IT"

30 Wilma Latuny (TiU), The Power of Facial Expressions

31 Ben Ruijl (UL), Advances in computational methods for QFT calculations

32 Thaer Samar (RUN), Access to and Retrievability of Content in Web Archives

33 Brigit van Loggem (OU), Towards a Design Rationale for Software Documentation: A Model of Computer-Mediated Activity

34 Maren Scheffel (OU), The Evaluation Framework for Learning Analytics

35 Martine de Vos (VU), Interpreting natural science spreadsheets

36 Yuanhao Guo (UL), Shape Analysis for Phenotype Characterisation from High-throughput Imaging

37 Alejandro Montes Garcia (TU/e), WiBAF: A Within Browser Adaptation Framework that Enables Control over Privacy

38 Alex Kayal (TUD), Normative Social Applications

39 Sara Ahmadi (RUN), Exploiting properties of the human auditory system and compressive sensing methods to increase noise robustness in ASR

40 Altaf Hussain Abro (VU), Steer your Mind: Computational Exploration of Human Control in Relation to Emotions, Desires and Social Support For applications in human-aware support systems

41 Adnan Manzoor (VU), Minding a Healthy Lifestyle: An Exploration of Mental Processes and a Smart Environment to Provide Support for a Healthy Lifestyle

42 Elena Sokolova (RUN), Causal discovery from mixed and missing data with applications on ADHD datasets

43 Maaike de Boer (RUN), Semantic Mapping in Video Retrieval

44 Garm Lucassen (UU), Understanding User Stories - Computational Linguistics in Agile Requirements Engineering

45 Bas Testerink (UU), Decentralized Runtime Norm Enforcement

46 Jan Schneider (OU), Sensor-based Learning Support

47 Jie Yang (TUD), Crowd Knowledge Creation Acceleration

48 Angel Suarez (OU), Collaborative inquiry-based learning

2018

01 Han van der Aa (VU), Comparing and Aligning Process Representations

02 Felix Mannhardt (TU/e), Multi-perspective Process Mining

03 Steven Bosems (UT), Causal Models For Well-Being: Knowledge Modeling, Model-Driven Development of Context-Aware Applications, and Behavior Prediction

04 Jordan Janeiro (TUD), Flexible Coordination Support for Diagnosis Teams in Data-Centric Engineering Tasks

05 Hugo Huurdeman (UvA), Supporting the Complex Dynamics of the Information Seeking Process

06 Dan Ionita (UT), Model-Driven Information Security Risk Assessment of Socio-Technical Systems

07 Jieting Luo (UU), A formal account of opportunism in multi-agent systems

08 Rick Smetsers (RUN), Advances in Model Learning for Software Systems

09 Xu Xie (TUD), Data Assimilation in Discrete Event Simulations

10 Julienka Mollee (VU), Moving forward: supporting physical activity behavior change through intelligent technology

11 Mahdi Sargolzaei (UvA), Enabling Framework for Service-oriented Collaborative Networks

12 Xixi Lu (TU/e), Using behavioral context in process mining

13 Seyed Amin Tabatabaei (VU), Computing a Sustainable Future

14 Bart Joosten (TiU), Detecting Social Signals with Spatiotemporal Gabor Filters

15 Naser Davarzani (UM), Biomarker discovery in heart failure

16 Jaebok Kim (UT), Automatic recognition of engagement and emotion in a group of children

17 Jianpeng Zhang (TU/e), On Graph Sample Clustering

18 Henriette Nakad (UL), De Notaris en Private Rechtspraak

19 Minh Duc Pham (VU), Emergent relational schemas for RDF

20 Manxia Liu (RUN), Time and Bayesian Networks

21 Aad Slootmaker (OU), EMERGO: a generic platform for authoring and playing scenario-based serious games

22 Eric Fernandes de Mello Araujo (VU), Contagious: Modeling the Spread of Behaviours, Perceptions and Emotions in Social Networks

23 Kim Schouten (EUR), Semantics-driven Aspect-Based Sentiment Analysis

24 Jered Vroon (UT), Responsive Social Positioning Behaviour for Semi-Autonomous Telepresence Robots

25 Riste Gligorov (VU), Serious Games in Audio-Visual Collections

26 Roelof Anne Jelle de Vries (UT),Theory-Based and Tailor-Made: Motivational Messages for Behavior Change Technology

27 Maikel Leemans (TU/e), Hierarchical Process Mining for Scalable Software Analysis

28 Christian Willemse (UT), Social Touch Technologies: How they feel and how they make you feel

29 Yu Gu (TiU), Emotion Recognition from Mandarin Speech

30 Wouter Beek (VU), The “K” in “semantic web” stands for “knowledge”: scaling semantics to the web

2019

01 Rob van Eijk (UL), Web privacy measurement in real-time bidding systems. A graph-based approach to RTB system classification

02 Emmanuelle Beauxis Aussalet (CWI, UU), Statistics and Visualizations for Assessing Class Size Uncertainty

03 Eduardo Gonzalez Lopez de Murillas (TU/e), Process Mining on Databases: Extracting Event Data from Real Life Data Sources

04 Ridho Rahmadi (RUN), Finding stable causal structures from clinical data

05 Sebastiaan van Zelst (TU/e), Process Mining with Streaming Data

06 Chris Dijkshoorn (VU), Nichesourcing for Improving Access to Linked Cultural Heritage Datasets

07 Soude Fazeli (TUD), Recommender Systems in Social Learning Platforms

08 Frits de Nijs (TUD), Resource-constrained Multi-agent Markov Decision Processes

09 Fahimeh Alizadeh Moghaddam (UvA), Self-adaptation for energy efficiency in software systems

10 Qing Chuan Ye (EUR), Multi-objective Optimization Methods for Allocation and Prediction

11 Yue Zhao (TUD), Learning Analytics Technology to Understand Learner Behavioral Engagement in MOOCs

12 Jacqueline Heinerman (VU), Better Together

13 Guanliang Chen (TUD), MOOC Analytics: Learner Modeling and Content Generation

14 Daniel Davis (TUD), Large-Scale Learning Analytics: Modeling Learner Behavior & Improving Learning Outcomes in Massive Open Online Courses

15 Erwin Walraven (TUD), Planning under Uncertainty in Constrained and Partially Observable Environments

16 Guangming Li (TU/e), Process Mining based on Object-Centric Behavioral Constraint (OCBC) Models

17 Ali Hurriyetoglu (RUN), Extracting actionable information from microtexts

18 Gerard Wagenaar (UU), Artefacts in Agile Team Communication

19 Vincent Koeman (TUD), Tools for Developing Cognitive Agents

20 Chide Groenouwe (UU), Fostering technically augmented human collective intelligence

21 Cong Liu (TU/e), Software Data Analytics: Architectural Model Discovery and Design Pattern Detection

22 Martin van den Berg (VU), Improving IT Decisions with Enterprise Architecture

23 Qin Liu (TUD), Intelligent Control Systems: Learning, Interpreting, Verification

24 Anca Dumitrache (VU), Truth in Disagreement - Crowdsourcing Labeled Data for Natural Language Processing

25 Emiel van Miltenburg (VU), Pragmatic factors in (automatic) image description

26 Prince Singh (UT), An Integration Platform for Synchromodal Transport

27 Alessandra Antonaci (OU), The Gamification Design Process applied to (Massive) Open Online Courses

28 Esther Kuindersma (UL), Cleared for take-off: Game-based learning to prepare airline pilots for critical situations

29 Daniel Formolo (VU), Using virtual agents for simulation and training of social skills in safety-critical circumstances

30 Vahid Yazdanpanah (UT), Multiagent Industrial Symbiosis Systems

31 Milan Jelisavcic (VU), Alive and Kicking: Baby Steps in Robotics

32 Chiara Sironi (UM), Monte-Carlo Tree Search for Artificial General Intelligence in Games

33 Anil Yaman (TU/e), Evolution of Biologically Inspired Learning in Artificial Neural Networks

34 Negar Ahmadi (TU/e), EEG Microstate and Functional Brain Network Features for Classification of Epilepsy and PNES

35 Lisa Facey-Shaw (OU), Gamification with digital badges in learning programming

36 Kevin Ackermans (OU), Designing Video-Enhanced Rubrics to Master Complex Skills

37 Jian Fang (TUD), Database Acceleration on FPGAs

38 Ákos Kádár (TiU), Learning visually grounded and multilingual representations

2020

01 Armon Toubman (UL), Calculated Moves: Generating Air Combat Behaviour