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## Research Interests

Artificial Intelligence (AI) is currently one of the fastest growing areas of computer science. In the past few years the interest in this field has transcended academic development, achieving a variety of applications, potentially influencing every modern economic activity. Much of this development is due to the recent availability of large data sets, as well as of computational resources, and is linked to a single field of AI, namely Machine Learning (ML). This fast development brought notoriety to the field, however, being confined to a single subarea of AI, it is deemed to achieve a standpoint, since the outputs of ML systems do not have explicit justifications that allow them to be audited. Therefore, machine learning algorithms cannot be fully trusted when dealing with human (sensitive) data. The key reason for the lack of justification for the ML outputs is that these algorithms have been largely developed independently from the AI subfield of Knowledge Representation and Reasoning. The future development of AI should consider the development of machine learning systems with knowledge representation capabilities allowing them to provide an explanation to their computed decisions. A large part of my current research has been devoted exactly at developing feasible and efficient combinations of machine learning algorithms (specially convolutional neural networks and reinforcement learning) with high-level ontologies capable of describing the outputs of ML algorithms. This facilitates reasoning about ML decisions and the inference of new facts about the underlying domain. In particular, I have been investigating how the output of a convolutional neural network, that associates visual scenes to English sentences, could be explained by means of a spatial ontology representing the domain objects and their attributes.

## Qualifications

PhD, Imperial College London  
Award Date: 20 Nov 2003

Master of Science, University of Amsterdam  
Award Date: 8 Oct 1998

Master of Science, Universidade de Sao Paulo  
Award Date: 10 Jul 1995

Bachelor (Honours), Universidade de Sao Paulo  
Award Date: 30 Nov 1993

## Employment

### Associate Professor in Artificial Intelligence and Robotics

College of Science and Engineering  
Flinders University  
8 Oct 2019 → 28 Jan 2023

### Associate Professor in Artificial Intelligence and Robotics

College of Science and Engineering  
Flinders University  
8 Oct 2019 → 31 Dec 2009

## Research outputs

### An investigation of preprocessing filters and deep learning methods for vessel type classification with underwater acoustic data

Domingos, L. C. F., Santos, P. E., Skelton, P. S. M., Brinkworth, R. S. A. & Sammut, K., 7 Nov 2022, In: IEEE Access. 10, p. 117582-117596 15 p.

### CAPTION: Caption Analysis with Proposed Terms, Image of Objects, and Natural Language Processing

Ferreira, L. A., De Rizzo Meneghetti, D., Lopes, M. & Santos, P. E., 23 Jul 2022, In: SN Computer Science. 3, 16 p., 390.

**A Survey of Underwater Acoustic Data Classification Methods Using Deep Learning for Shoreline Surveillance**

Domingos, L. C. F., Santos, P. E., Skelton, P. S. M., Brinkworth, R. S. A. & Sammut, K., 2 Mar 2022, In: *Sensors*. 22, 6, 30 p., 2181.

**Commonsense Reasoning for Identifying and Understanding the Implicit Need of Help and Synthesizing Assistive Actions**

Neau, M., Santos, P., Bossier, A. G., Beu, N. & Buche, C., Mar 2022, In: *CEUR Workshop Proceedings*. 3121, 9 p.

**Contrastive Visual and Language Translational Embeddings for Visual Relationship Detection**

Tran, T., Santos, P. E. & Powers, D., Mar 2022, In: *CEUR Workshop Proceedings*. 3121, 12 p.

**Heuristics, Answer Set Programming and Markov Decision Process for Solving a Set of Spatial Puzzles\***

dos Santos, T. F., Santos, P. E., Ferreira, L. A., Bianchi, R. A. C. & Cabalar, P., Mar 2022, In: *Applied Intelligence*. 52, 4, p. 4488-4510 23 p.

**Monitoring electrical systems data-network equipment by means of Fuzzy and Paraconsistent Annotated Logic**

Côrtes, H. M., Santos, P. E. & da Silva Filho, J. I., Jan 2022, In: *Expert Systems with Applications*. 187, 21 p., 115865.

**Guided navigation from multiple viewpoints using qualitative spatial reasoning**

Perico, D. H., Santos, P. E. & Bianchi, R. A. C., 2021, In: *Spatial Cognition and Computation*. 21, 2, p. 143-172 30 p.

**Qualitative case-based reasoning and learning**

Homem, T. P. D., Santos, P. E., Reali Costa, A. H., da Costa Bianchi, R. A. & Lopez de Mantaras, R., Jun 2020, In: *Artificial Intelligence*. 283, 23 p., 103258.

**Standpoint semantics for polysemy in spatial prepositions**

Rodrigues, E. J., Santos, P. E., Lopes, M., Bennett, B. & Oppenheimer, P. E., Mar 2020, In: *Journal of Logic and Computation*. 30, 2, p. 635-661 27 p.

**Spatial reasoning about string loops and holes in temporal asp**

Cabalar, P. & Santos, P. E., 2020, *17th International Conference on Principles of Knowledge Representation and Reasoning, KR 2020*. Calvanese, D., Erdem, E. & Thielscher, M. (eds.). International Joint Conference on Artificial Intelligence (IJCAI), p. 181-191 11 p. (17th International Conference on Principles of Knowledge Representation and Reasoning, KR 2020; vol. 1).

**The knowledge of knots: an interdisciplinary literature review**

Santos, P. E., Cabalar, P. & Casati, R., 30 Sep 2019, In: *Spatial Cognition and Computation*. 19, 4, p. 334-358 25 p.

**Representation and retrieval of images by means of spatial relations between objects**

Nunes, D., Ferreira, L. A., Santos, P. E. & Pease, A., 1 Jan 2019, In: *CEUR Workshop Proceedings*. 2350

**Solving Safety Problems with Ensemble Reinforcement Learning**

Ferreira, L. A., dos Santos, T. F., Bianchi, R. A. C. & Santos, P. E., 2019, *AI 2019: Advances in Artificial Intelligence - 32nd Australasian Joint Conference, 2019, Proceedings*. Liu, J. & Bailey, J. (eds.). Cham, Switzerland: Springer , p. 203-214 12 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 11919 LNAI).

**Solving a spatial puzzle using answer set programming integrated with Markov decision process**

Freitas Dos Santos, T., Santos, P., Ferreira, L., Bianchi, R. & Cabalar, P., 17 Dec 2018, *Proceedings - 2018 Brazilian Conference on Intelligent Systems, BRACIS 2018*. Institute of Electrical and Electronics Engineers Inc., p. 528-533 6 p. 8575668. (Proceedings - 2018 Brazilian Conference on Intelligent Systems, BRACIS 2018).

**Heuristically Accelerated Reinforcement Learning by Means of Case-Based Reasoning and Transfer Learning**

Bianchi, R. A. C., Santos, P. E., da Silva, I. J., Celiberto, L. A. & Lopez de Mantaras, R., Aug 2018, In: *Journal of Intelligent and Robotic Systems: Theory and Applications*. 91, 2, p. 301-312 12 p.

**A method for the online construction of the set of states of a Markov decision process using answer set programming**  
Ferreira, L. A., Bianchi, R. A. C., Santos, P. E. & de Mantaras, R. L., 30 May 2018, *Recent Trends and Future Technology in Applied Intelligence - 31st International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems, IEA/AIE 2018, Proceedings*. Ait Mohamed, O., Mouhoub, M., Sadaoui, S. & Ali, M. (eds.). Springer-Verlag, p. 3-15 13 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 10868 LNAI).

**Perception, cognition and reasoning about shadows**

Santos, P. E., Casati, R. & Cavanagh, P., 3 Apr 2018, In: *Spatial Cognition and Computation*. 18, 2, p. 78-85 8 p.

**Qualitative Model of Location Relations Learned from Human Data**

Cardoso Truchlaeff, T. C., Santos, P. E. & Lopes, M., Mar 2018, In: *IEEE Latin America Transactions*. 16, 3, p. 764-769 6 p.

**A hybrid approach to learn, retrieve and reuse qualitative cases**

Homem, T. P. D., Perico, D. H., Santos, P. E., Costa, A. H. R., Bianchi, R. A. C. & Lopez de Mantaras, R., 15 Dec 2017, *Proceedings - 2017 LARS 14th Latin American Robotics Symposium and 2017 5th SBR Brazilian Symposium on Robotics, LARS-SBR 2017 - Part of the Robotics Conference 2017*. Tonidandel, F. & Todt, E. (eds.). Institute of Electrical and Electronics Engineers Inc., p. 1-6 6 p. (Proceedings - 2017 LARS 14th Latin American Robotics Symposium and 2017 5th SBR Brazilian Symposium on Robotics, LARS-SBR 2017 - Part of the Robotics Conference 2017; vol. 2017-December).

**Answer set programming for non-stationary Markov decision processes**

Ferreira, L. A., Reinaldo, R. A., Santos, P. E. & Lopez de Mantaras, R., Dec 2017, In: *Applied Intelligence*. 47, 4, p. 993-1007 15 p.

**Retrieving and reusing qualitative cases: An application in humanoid-robot soccer**

Homem, T. P. D., Perico, D. H., Santos, P. E., Bianchi, R. A. D. C. & De Mantaras, R. L., 12 Jul 2017, In: *AI Communications*. 30, 3-4, p. 251-265 15 p.

**Improving reinforcement learning results with qualitative spatial representation**

Homem, T. P. D., Perico, D. H., Santos, P. E., Costa, A. H. R. & Da Costa Bianchi, R. A., 28 Jun 2017, *Proceedings - 2017 Brazilian Conference on Intelligent Systems, BRACIS 2017*. Institute of Electrical and Electronics Engineers Inc., p. 151-156 6 p. (Proceedings - 2017 Brazilian Conference on Intelligent Systems, BRACIS 2017; vol. 2018-January).

**Consistency check in a multiple viewpoint system for reasoning about occlusion**

Martin, A. P., Santos, P. E. & Safi-Samghabadi, M., 4 Jun 2017, (E-pub ahead of print) *Advances in Artificial Intelligence: From Theory to Practice - 30th International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems, IEA/AIE 2017, Proceedings*. Ali, M., Benferhat, S. & Tabia, K. (eds.). Springer-Verlag, Vol. 10350. p. 523-532 10 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 10350 LNCS).

**Pinning down polysemy: A formalisation for a Brazilian Portuguese preposition**

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**Information, context and structure in cognition**

João, K-J. & Santos, P. E., 2017, *Cognitive Science: : Recent Advances and Recurring Problems*. Adams, F., Pessoa Jr, O. & Kogler Jr, J. E. (eds.). United States of America: Vernon Press, p. 179-196 17 p.

**Transfer Learning Heuristically Accelerated Algorithm: A Case Study with Real Robots**

Celiberto, L. A., Bianchi, R. A. C. & Santos, P. E., 15 Dec 2016, *Proceedings - 13th Latin American Robotics Symposium and 4th Brazilian Symposium on Robotics, LARS/SBR 2016*. Cavalcante, S. V. & Tonidandel, F. (eds.). Institute of Electrical and Electronics Engineers Inc., p. 311-316 6 p. 7783545. (Proceedings - 13th Latin American Robotics Symposium and 4th Brazilian Symposium on Robotics, LARS/SBR 2016).

**Qualitative case-based reasoning for humanoid robot soccer: A new retrieval and reuse algorithm**

Homem, T. P. D., Perico, D. H., Santos, P. E., Bianchi, R. A. C. & de Mantaras, R. L., 29 Sep 2016, *Case-Based Reasoning Research and Development - 24th International Conference, ICCBR 2016, Proceedings*. Belen Diaz-Agudo, M., Roth-Berghofer, T. & Goel, A. (eds.). Springer-Verlag, p. 170-185 16 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 9969 LNAI).

**A qualitative spatial representation of string loops as holes**

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**Communication of spatial expressions on multi-agent systems using the qualitative Ego-Sphere**

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**An occlusion calculus based on an interval algebra**

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**To ban or regulate autonomous weapons: A Brazilian response**

Santos, P. E., 2 Mar 2016, In: *Bulletin of the Atomic Scientists*. 72, 2, p. 117-119 3 p.

**Vision-Based Monte Carlo Localization without Measurement: A Qualitative Approach during Update Phase**

Perico, D. H., Santos, P. E. & Bianchi, R. A. C., 11 Feb 2016, *Proceedings - 12th LARS Latin American Robotics Symposium and 3rd SBR Brazilian Robotics Symposium, LARS-SBR 2015 - Part of the Robotics Conferences 2015*. Goncalves, R. S., Macharet, D. G., Osorio, F. S., Campos, M. F. M. & Carvalho, J. C. M. (eds.). Institute of Electrical and Electronics Engineers Inc., p. 216-221 6 p. 7402168. (Proceedings - 12th LARS Latin American Robotics Symposium and 3rd SBR Brazilian Robotics Symposium, LARS-SBR 2015 - Part of the Robotics Conferences 2015).

**Framing holes within a loop hierarchy**

Santos, P. E. & Cabalar, P., 11 Jan 2016, In: *Spatial Cognition and Computation*. 16, 1, p. 54-95 42 p.

**Probabilistic self-localisation on a qualitative map based on occlusions**

Santos, P. E., Martins, M. F., Fenelon, V., Cozman, F. G. & Dee, H. M., 10 Jan 2016, In: *Journal of Experimental and Theoretical Artificial Intelligence*. 28, 5, p. 781-799 19 p.

**Transferring knowledge as heuristics in reinforcement learning: A case-based approach**

Bianchi, R. A. C., Celiberto, L. A., Santos, P. E., Matsuura, J. P. & Lopez De Mantaras, R., Sep 2015, In: *Artificial Intelligence*. 226, p. 102-121 20 p.

**Perceptual narratives of space and motion for semantic interpretation of visual data**

Suchan, J., Bhatt, M. & Santos, P. E., 20 Mar 2015, *Computer Vision - ECCV 2014 Workshops, Proceedings*. Rother, C., Bronstein, M. M. & Agapito, L. (eds.). Cham: Springer-Verlag, p. 339-354 16 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 8926).

**Spatial occlusion within an interval algebra**

Ligozat, G. & Santos, P. E., 1 Jan 2015, *Logical Formalizations of Commonsense Reasoning: Papers from the AAAI Spring Symposium, Technical Report*. AI Access Foundation, p. 103-106 4 p. (AAAI Spring Symposium - Technical Report; vol. SS-15-04).

**Message from program co-chairs**

Prudencio, R. B. C. & Santos, P. E., 12 Dec 2014, In: *Proceedings - 2014 Brazilian Conference on Intelligent Systems, BRACIS 2014*. p. xiii 6984792.

**Probabilistic logic for multi-robot event recognition**

Gurzoni, J. A., Santos, P. E., Martins, M. F. & Cozman, F. G., Mar 2014, *Qualitative Representations for Robots: Papers from the AAAI Spring Symposium, Technical Report*. AI Access Foundation, p. 50-56 7 p. (AAAI Spring Symposium - Technical Report; vol. SS-14-06).

**Logic-probabilistic model for event recognition in a robotic search and rescue scenario**

Gurzoni, J. A., Cozman, F. G., Martins, M. F. & Santos, P. E., 2014, In: *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics*. 2014, p. 1726-1731 6 p.

**An investigation of actions, change and space**

Santos, P. E. & Cabalar, P., 13 Dec 2013, *ICAPS 2013 - Proceedings of the 23rd International Conference on Automated Planning and Scheduling*. p. 484-485 2 p. (ICAPS 2013 - Proceedings of the 23rd International Conference on Automated Planning and Scheduling).

**Probabilistic logic for multi-robot event recognition**

Gurzoni, J. A., Santos, P. E., Martins, M. F. & Cozman, F. G., 1 Dec 2013, *2013 IEEE International Symposium on Safety, Security, and Rescue Robotics, SSRR 2013*. 2 p. 6719383. (2013 IEEE International Symposium on Safety, Security, and Rescue Robotics, SSRR 2013).

**PID, LQR and LQR-PID on a quadcopter platform**

Argentim, L. M., Rezende, W. C., Santos, P. E. & Aguiar, R. A., 1 Aug 2013, *2013 International Conference on Informatics, Electronics and Vision (ICIEV)*. Institute of Electrical and Electronics Engineers Inc., 6572698

**Reasoning about shadows in a mobile robot environment**

Fenelon, V., Santos, P. E., Dee, H. M. & Cozman, F. G., 1 Jun 2013, In: *Applied Intelligence*. 38, 4, p. 553-565 13 p.

**An investigation of actions, change, space within a hole-loop dichotomy**

Santos, P. E. & Cabalar, P., May 2013. 7 p.

**A Qualitative-Probabilistic Approach to Autonomous Mobile Robot Self Localisation and Self Vision Calibration**

Pereira, V. F., Cozman, F. G., Santos, P. E. & Martins, M. F., 2013, *2013 Brazilian Conference on Intelligent Systems*. Fortaleza: Institute of Electrical and Electronics Engineers Inc., p. 157-162 6 p. 6726442

**Holes, knots and shapes: A spatial ontology of a puzzle**

Santos, P. & Cabalar, P., 1 Dec 2011, In: *CEUR Workshop Proceedings*. 812, 10 p.

**Probabilistic Logic Reasoning about Traffic Scenes**

Souza, C. R. C. & Santos, P. E., 20 Sep 2011, *Towards Autonomous Robotic Systems: 12th Annual Conference, TAROS 2011, Sheffield, UK, August 31 – September 2, 2011. Proceedings*. Springer , p. 219-230 12 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 6856 LNAI).

**The Perception and Content of Cast Shadows: An Interdisciplinary Review**

Dee, H. M. & Santos, P. E., 17 Aug 2011, In: *Spatial Cognition and Computation*. 11, 3, p. 226-253 28 p.

**Formalising the fisherman's folly puzzle**

Cabalar, P. & Santos, P. E., Jan 2011, In: *Artificial Intelligence*. 175, 1, p. 346-377 32 p.

**Probabilistic logic encoding of spatial domains**

Santos, P., Hummel, B., Fenelon, V. & Cozman, F. G., 1 Dec 2010, In: *CEUR Workshop Proceedings*. 613, 10 p.

**Exploring the knowledge contained in neuroimages: Statistical discriminant analysis and automatic segmentation of the most significant changes**

Santos, P. E., Thomaz, C. E., dos Santos, D., Freire, R., Sato, J. R., Louzã, M., Sallet, P., Busatto, G. & Gattaz, W. F., Jun 2010, In: *Artificial Intelligence in Medicine*. 49, 2, p. 105-115 11 p.

#### **Knowledge-based adaptive thresholding from shadows**

Santos, P., Dee, H. M. & Fenelon, V., 1 Jan 2010, *ECAI 2010: 19th European Conference on Artificial Intelligence*. IOS PRESS, p. 1089-1090 2 p. (Frontiers in Artificial Intelligence and Applications; vol. 215).

#### **Qualitative robot localisation using information from cast shadows**

Santos, P., Dee, H. M. & Fenelon, V., 2 Nov 2009, *2009 IEEE International Conference on Robotics and Automation, ICRA '09*. p. 220-225 6 p. 5152199. (Proceedings - IEEE International Conference on Robotics and Automation).

#### **The space within fisherman's folly: Playing with a puzzle in mereotopology**

Santos, P. E. & Cabalar, P., 1 Dec 2008, In: *Spatial Cognition and Computation*. 8, 1-2, p. 47-64 18 p.

#### **Reasoning about dynamic depth profiles**

Soutchanski, M. & Santos, P., Jun 2008, *Frontiers in Artificial Intelligence and Applications*. IOS PRESS, Vol. 178. p. 30-34 5 p. (Frontiers in Artificial Intelligence and Applications; vol. 178).

#### **Logic-based interpretation of geometrically observable changes occurring in dynamic scenes**

Dos Santos, M. V., De Brito, R. C., Park, H. H. & Santos, P., 23 Feb 2008, In: *Applied Intelligence*. 31, 2, p. 161-179 19 p.

#### **Inductive learning spatial attention**

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#### **Off Board diagnosis using analytical system for Diesel powered vehicles**

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#### **Computational methods for management of hybrid vehicles**

Gomes, C. W., Colossetti, A. P., Imperatore, A. R., Oliveira De Aguiar, N. A., Abraham, E. R., Santos, P. E. & Da Silva, W. M., 2008, In: *SAE Technical Papers*. 8 p.

#### **Holes, knots and shapes: A spatial ontology of a puzzle**

Santos, P. & Cabalar, P., 28 Dec 2007, *Logical Formalizations of Commonsense Reasoning - Papers from the 2007 AAAI Spring Symposium, Technical Report*. p. 144-149 6 p. (AAAI Spring Symposium - Technical Report; vol. SS-07-05).

#### **Reasoning about depth and motion from an observer's viewpoint**

Santos, P. E., 1 Dec 2007, In: *Spatial Cognition and Computation*. 7, 2, p. 133-178 46 p.

#### **Net Bayesian applied on vehicle diagnostic with FMEA**

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#### **Cognitive vision: Integrating symbolic qualitative representations with computer vision**

Cohn, A. G., Hogg, D. C., Bennett, B., Devin, V., Galata, A., Magee, D. R., Needham, C. & Santos, P., 1 Dec 2006, *Cognitive Vision Systems: Sampling the Spectrum of Approaches*. Christensen, H. & Nagel, H-H. (eds.). Germany: Springer-Verlag, p. 221-246 26 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 3948 LNCS).

#### **Predictive and descriptive approaches to learning game rules from vision data**

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**Strings and holes: An exercise on spatial reasoning**

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**Protocols from perceptual observations**

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**Supervaluation semantics for an inland water feature ontology**

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**Autonomous learning for a cognitive agent using continuous models and inductive logic programming from audio-visual input**

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**Combining multiple answers for learning mathematical structures from visual observation**

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**A logic-based algorithm for image sequence interpretation and anchoring**

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**The Nature of Knowledge in an Abductive Event Calculus Planner**

De Barros, L. N. & Santos, P. E., 1 Jan 2000, *Knowledge Engineering and Knowledge Management Methods, Models, and Tools: 12th International Conference, EKAW 2000 Juan-les-Pins, France, October 2-6, 2000 Proceedings*. Dieng, R. & Corby, O. (eds.). Springer-Verlag, p. 328-343 16 p. (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); vol. 1937).