Call for Exploratory Projects in All Scientific Domains 2023
2023.15110.PEX

Status
Draft

Closes in
01.03.202

Application Global View

General data

Principal investigator

Francisco Manuel Gonçalves Coelho

Project title in portuguese

Indução de Stochastic Answer Set Programs por Meios Algébricos

Project title in english

Induction of Stochastic Answer Set Programs by Algebraic Means

Project acronym

IAM

Keywords in portuguese

Indução de Programas Lógicos Programação Lógico-Probabilística Programação de Conjunto de Resposta

Keywords in english

Inductive Logic Programming Probabilistic Logic Programming Answer Set Programming

Main scientific area

Scientific domain

Exact Sciences

Scientific area

Computer and Information Sciences

Scientific subarea

Computer Sciences

Evaluation panel

Computer and Information Sciences and Informatics

Timetable

Start date

01.09.2024

Duration (months)

18

Institutions

Principal contractor

Institution

Universidade de Évora

Research Unit

→ NOVA Laboratory for Computer Science and Informatics
→ Cátedra High Performance Computing

Institution description and its competencies for the development of the project

The University of Évora is a public University organized in 5 Schools: Arts, Sciences and Technology, Social Sciences, Health and human development, Nursing and the Institute for Advanced Studies and Research. Research and Development covers several areas through 18 Research Units, all of them submitted to international evaluation. The University of Évora has established 10 Chairs in Aerospace, Agriculture, Biodiversity, Heritage, Health, High Performance Computer, Iberian studies, UNESCO and Renewable Energies, participates in the National Roadmap of Strategic Research Infrastructures and has several research infrastructures in biodiversity, computer sciences, aerospace engineering, solar energy and heritage. The University fosters a close link with the community, enhanced through the creation of networks, the participation in the Science and Technology Park and by establishing protocols and co-promotion research projects. The main R&D areas are: Applied Mathematics; Chemistry; Culture; Education and Psychology; Healthcare; Geophysics; History; Environment and Sea; Linguistics and Literature; Materials and Surface Science; Social and Political Sciences and Science. The 300 running R&D projects are developed through national and international partnerships, under Horizon Europe, PRIMA, ERASMUS +, LIFE, Creative Europe, Digital Europe Programme, Cost Actions, EIT Health, EIT Urban Mobility, EEA Grants, INTERREG, PT2020, Alentejo2020, COMPETE2020, PRR, FCT or private funding.

Collaborative institutions

Country	Institution
PORTUGAL	Cátedra High Performance Computing

Institution description and its competencies for the development of the project

The High Performance Computing Chair (HPC) presents itself as a research and development (R&D) infrastructure dedicated to high performance computing that seeks to follow developments towards the digital transition, which enables a more efficient approach to national and European IT strategies, digital innovation for academia, companies and other public-private organizations.

This new research infrastructure, in partnership with the universities of Algarve, Nova de Lisboa and Porto, has as its main objective to promote professional training between academia and industry, enhancing the development and adoption of HPC, HPDA (High Performance Data Analytics) and AI (Artificial Intelligence) by different actors in the region and at national and international levels. At the same time, it enhances the use of local advanced computing infrastructures managed by the HPC-UÉ Center, such as the OBLIVION supercomputer

Research team

Principal investigator

Francisco Manuel Gonçalves Coelho Core PI

Ciência ID
AF10-03F3-E074

Institution to which you are associated in the scope of the research project
Universidade de Évora

CV
Obtained in 25-02-2024 at 15:48:59 GMT

PI Narrative CV

Carreer profile

1993 Degree in Mathematics, ECU

1993 Degree in Mathematics, FCUL.

1997 MSc in Mathematics (Algebra), FCUL. About Hilbert's tenth problem and a computational model based on geometric constructions with ruler and compass.

1997 Teaching Assistant, Mathematics Department, UÉ.

2006 PhD in Informatics (Computer Science), UL. About deliberation by autonomous agents.

2006 Assistant Professor, Mathematics Department, UÉ.

2006-2021, Period of minor visible activity, dedicated to learn statistical AI. Here I started to think about the limitations and advantages of the statistical vs. logic AI approaches and how they can contribute to each other.

2006 Assistant Professor, Computer Science Department, UÉ.

2008 Article "The euclid abstract machine: Trisection of the angle and the halting problem". Develops the ideas about computing and geometry, started in the master's dissertation.

2010 Book "Teoria da Computação, Computabilidade e Complexidade" (Escolar Editora). For graduate students.

2015 Article "Probabilistic perception revision in AgentSpeak(L)". Initial study on the integration of logic and statistical AI.

2016 Book "Introdução à Matemática - Álgebra, Análise e Otimização" (LIDEL). For undergraduate students.

2017 Article "A method for regularization of evolutionary polynomial regression" (Applied Soft Computing). Proposes a method for learning polynomial models using genetic algorithms.

2021 Researcher at the chair "High Performance Computing" at UÉ. Organized and taught an introduction course to the Julia language, aimed at the digital humanities and social sciences.

2021 Integrated member of the NOVALINCS center. I have been researching the extension of the ASP language with probabilistic annotations.

2022 CPCA/A0 Project "JuPy". Small FCT founded project exploring the use of "high-level" languages (Julia, Python) in distributed computing and HPC systems.

2023 Work on the extension of ASP with probabilistic annotations, and respective induction by a set of data and background knowledge.

Contributions to Science and Society

Contributions to the generation of new ideas, tools, methodologies or knowledge

- 2021, Mentor of i-Days: Student competition to tackle health challenges, organized by EIT-Health and StartUB!C (Universidad de Barcelona), that took place in PACT, Évora. i-Days promote health innovation among university students through dozens of one-day and two-day programmes held in academic institutions around Europe.
- Co-author of "Lattice-Maker", a set of tools to present lattices of combinatorial games in LaTeX, used on the PhD thesis "Lattices related to Conway's construction", where I was member of the juri, and two papers where I'm co-author: DOI:10.1016/j.tcs.2014.01.025 (2014) and DOI:10.1007/s00182-020-00715-3 (2021).
- Author of "TeseUE", a LaTeX class to MSc dissertations and PhD thesis in Universidade de Évora, is currently used by many students.
- Co-author of "Genetic Algorithms for Polynomial Regression", R code to find the best polynomial regression using genetic algorithms, used in the journal paper DOI:10.1016/j.asoc.2017.05.047 (2017).
- Author of "Galaxity", a Java system to assess the correction of perceptions of AgentSpeak(L) agents using probabilistic methods, used in the conference paper DOI:10.1007/978-3-319-25524-8_44 (2015).

Contributions to the development of individuals and/or research teams

- 2023, 2024, coordinator and teacher of the online course "Programming in Julia for Digital Humanities", aimed to digital humanities and social sciences researchers, part of the training and dissemination activities of the HPC Centre and the HPC Chair.
- 2024, mentor of the mini-project "Automatic Differentiation", aimed at MSc and PhD students, at the Birla Institute of Technology and Science, Pilani, India, within the Asian and European Schools in Mathematics. Travel was supported by a CIMPA scholarship.
- 2024, teacher of the course "An Introduction to Julia for Scholars", aimed at MSc and PhD students and researchers, at the Birla Institute of Technology and Science, Pilani, India, within the Asian and European Schools in Mathematics. Travel was supported by a CIMPA scholarship.
- Since 2016, course director and teacher of "Introdução ao LaTeX" (Introduction to LaTeX), directed at students and

researchers, at U. Évora.
- 2016, Co-author of the book "Introdução à Matemática - Álgebra, Análise e Otimização"(LIDEL), ISBN:978-989-752-209-3, addressing core mathematical subjects (algebra, calculus and optimization) for social sciences university courses. Used in the course "Matemática Aplicada à Economia e Gestão", Universidade de Évora.
- 2010, co-author of the book "Teoria da Computação, Computabilidade e Complexidade", ISBN:978-972-592-281-1, where computation is explained starting with simple machines, addressing the computation limits such as the Halting Problem, polynomial equivalence and complexity. A draft version of this book was used in the course "Teoria da Computabilidade e Complexidade", Universidade de Évora.
- Since 2023, mentor of one BII Scholarship within the scope of the multi-annual financing of the R&D unit with reference UIDP/04516/2020, financed by national funds through the FCT/MCTES.
- Since 2022, supervisor of three ongoing PhD thesis on computer science.
- Since 2010, supervisor of six completed and three ongoing MSc dissertations about topics such as e-learning, virtual reality, serious games or game design.
- Since 2010, member of the juri in 13 academic examinations, including three as examiner.
- Since 2006, assistant professor at UÉ. Within this role I coordinated more than 26 courses, including mathematics and computer science, for graduation or MSc grades.

Contributions to the research community and the broader society

- Since 2022, reviewer for the "Applied Soft Computing" journal (Q1).
- Since 2021, participation in the "High Performance Computing Chair" of U. Évora, as member of the scientific team, technical-scientific board, coordinator of the "Programming in Digital Humanities" task and member of five work packages.
- Since 2011, member of several organizing and scientific committees of international scientific events. In the most recent, the international conference "Programming and Data Infrastructure in Digital Humanities", I was member of both the scientific and organizing committee.
- Since 1997, fifteen communications at scientific dissemination events, either at international conferences or invited to scientific lectures.
- 2024, 2023, 2010, visited higher education institutions in India, the Czech Republic and Timor-Lorosa'e to disseminate knowledge and to establish or reinforce cooperation between U. Évora and local HEI.
- 2010, 2016, Co-author of two pedagogical books, about Mathematics and Computer Science, aimed at higher education students, contributions to the dissemination of knowledge.
- Since 2016, course director and teacher of "Introdução ao LaTeX" (Introduction to LaTeX), directed at students and researchers, at U. Évora.
- 2023, 2024, An introduction course to the Julia language, for researchers in the areas of digital humanities and social sciences.
- 2023, Invited Talk, "Fronteiras da Inteligência Artificial", Festival da Ciência'23, U. Évora, aimed at societal engagement with science.
- 2024, An introduction course to the Julia language, for students on technical courses and researchers.
- 2024, A mini-project/introduction course to automatic derivation with Python, for students of technical courses.

Selected outputs and/or activities

Activity "Combinatorial Games Theory" and results

- Contributed to the development of "Lattice-Maker", a set of tools to present lattices of combinatorial games in LaTeX, available in the public repository <https://github.com/fmgc/Lattice-Maker>.
- Lattice-Maker was used by Cátia Dias on her PhD thesis "Lattices related to Conway's construction" where I was member of the juri, and in two international, indexed, jornal papers:
  - 2021, Carvalho, Dias, Coelho, Neto, Nowakowski, Vinagre, "On lattices from combinatorial game theory: infinite case", DOI:10.1007/s00182-020-00715-3
  - 2014, Carvalho, Santos, Dias, Coelho, Neto, Nowakowski, Vinagre, "On lattices from combinatorial game theory. Modularity and a representation theorem: Finite case", DOI:10.1016/j.tcs.2014.01.025

Activity "Polynomial Regression" and results

- Contributed to "Genetic Algorithms for Polynomial Regression", R code to find the best polynomial regression using genetic algorithms, available in the public repository <https://github.com/jpneto/GenAlgPoly>.
- This program was used in the international, indexed, journal paper
  - 2017, Coelho e Neto, "A method for regularization of evolutionary polynomial regression", DOI:10.1016/j.asoc.2017.05.047
- This is my most cited work, some of which two in 2023, six years after publishing.

Activity "Perception Correction" and results

- Implemented "Galaxity", a Java system to assess the correction of perceptions of AgentSpeak(L) agents using probabilistic methods, and "jpgm", a small Java library to support simple probabilistic graphical models (pgm) computations used in Galaxity. These are available in the public repositories <https://bitbucket.org/mangon/galaxity> and <https://github.com/fmgc/jpgm>.
- "Galaxity" (and "jpgm") where used in the conference paper

- 2015, Coelho e Nogueira, "Probabilistic perception revision in AgentSpeak(L)", DOI:10.1007/978-3-319-25524-8_44

Activity "Stochastic Answer Set Programs" and results

- Started in 2023 and is currently my main research activity, a continuation of "Perception Correction" towards the combination of statistical ans logic AI. At this moment the outcomes of this activity are
  - BII scholarship, supported by "Financiamento Plurianual da unidade de I&D UIDP/04516/2020", co-supported by FCT, Portugal.
  - Draft programs, available in a public repository.
  - A paper, "An Algebraic Approach to Stochastic ASP", in co-authorship, recently submitted to a international conference.

Why would this grant be timely for me at this point in my career path and/or in my research?

2006, PhD thesis about deliberation.

Deliberation, selecting an action from perceptions and internal state, embodies the key challenges of AI, from computer vision to planning, learning, complexity or the frame problem. Each can be stated as a statistical problem (eg POMDP) or as a logical one (eg "plans" as formal expressions processed by symbolic rules).

Each has strengths and weaknesses. Statistical models require large amounts of data to train while inductive logic programs often result from background knowledge and small sets of examples but the former are robust to noise while the latter are fragile.

By then my research main interest become how to combine the strengths of statistical and logic AI.

2015, author of Galaxity, a system to play with correction of perceptions of logic agents using probabilistic methods; Described in **DOI:10.1007/978-3-319-25524-8_44**, a initial study on combining logic and statistical AI.

BDI agents often win planning competitions where, unlike real scenarios, perception is perfect. The Galaxity system introduces noise in the agent's perception and uses a HMM to estimate the probability of the real state. This is then tested in simulations, outperforming other agents also subject to noisy perceptions.

Despite the positive result, this is a shallow approach with no substantial theoretical base to support further work.

By then I have learned about probabilistic logic programming, the Sato semantics and Markov logic.

Also, my participation in the NOVALINCS research unit opened new opportunities.

Since 2023, mentor of a BII Scholarship about Stochastic Answer Set Programs (SASP), financed by national funds through FCT/MCTES: UIDP/04516/2020; NOVALINCS (UIDB/04516/2020).

Answer Set Programming (ASP) is a pure declarative logic language with excellent tool support and theoretical foundations (Gelfond and Lifschitz stable models). Semantics for probabilistic versions of ASP have been proposed but the problem is still very much open.

My, Bruno Dinis and Salvador Abreu approach is described in "An Algebraic Approach to Stochastic ASP", recently submitted to an international conference.

We address the problem of extending probability from total choices to stable models, and from there to general events. Possible applications include assigning a score to a logic program with respect to the empiric distribution of a dataset, which can be used by evolutionary algorithms searching optimal models of that dataset. From there we have induction of stochastic ASP.

This paper is the root to the research proposed with this project:

1. Investigate the structure and composition of SASP and transformation rules to **support program space search by evolutionary algorithms**.
2. Implement a library to **support SASP evaluation** using existing ASP systems.
3. Explore how distributed HPC systems can be used to **scale-up and speed-up the evaluation of SASP**.
4. Investigate the **application of SASP to theoretical and real-world problems**.

Members

Bruno Miguel Antunes Dinis Core Member

Association
Accepted

Ciência ID
3E1F-A94E-D147

Institution to which you are associated in the scope of the research project
Universidade de Évora

CV
Obtained in 23-02-2024 at 15:10:13 GMT

Miguel Ângelo Pignatelli de Avillez Nunes Pereira Core Member

Association
Waiting

Ciência ID
4110-30FC-E46E

Institution to which you are associated in the scope of the research project
Cátedra High Performance Computing

CV
-

SALVADOR LUÍS DE BETHENCOURT PINTO DE ABREU Core Member

Association
Accepted

Ciência ID
C617-7ED4-8326

Institution to which you are associated in the scope of the research project
Universidade de Évora

CV
Obtained in 28-02-2024 at 14:19:53 GMT

Hirings

(BIPD - 01) Post doctoral Research Grant

Institution
Universidade de Évora

Tasks
Integration with existing ASP and ILP software frameworks (INT) · 12 person * month

Consultants

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Research team CV synopsis

- **Francisco Coelho** completed his PhD in Informatics in 2006 at Universidade de Lisboa under the supervision of Helder Coelho

on Artificial Intelligence. Is previous formation is on Mathematics, where he has a Master degree in Mathematics, specialty Algebra, with a dissertation about Hilbert's tenth problem and about geometric computation, advised by Prof. Augusto Franco de Oliveira and Prof. José Félix Costa. Currently he is Assistant Professor at the Computer Science department of Universidade de Évora, where he has coordinated more than twenty courses and restructured or proposed other six, to the graduation and master degrees. He is supervising three PhD thesis and two MSc dissertations and has supervised other six completed MSc dissertations. He contributed with software and writing to papers covering a wide range of subjects but mostly about logic and statistical AI. He is integrated member of the Intelligent Systems of the research unit NOVALINCS and member of the scientific team of the High Performance Computing Chair.

- **Bruno Dinis** completed his PhD in Maths in 2013 at the University of Évora under the supervision of Imme van den Berg on Nonstandard Analysis. After his doctoral studies, he was a postdoc at the Faculdade de Ciências under the supervision of Fernando Ferreira, working on Proof Theory. Bruno Dinis is currently an Assistant Professor at the Universidade de Évora. Co-supervised 1 master's dissertation. He has written over 20 papers on several aspects of logic, for the most part in proof interpretations and its applications (proof mining).

- **Salvador** is Full Professor at the University of Évora (UE) School of Science and Technology since 2013, Senior Researcher at NOVA LINCS and President of the Scientific Council at the UE Institute for Research and Advanced Training (IIFA). He currently directs the PhD Program in Informatics at UE.
  He holds a Habilitation in Informatics from the University of Évora (2009), a PhD in Informatics from Universidade NOVA de Lisboa (1994), and a BSc in Informatics Engineering from Universidade Nova de Lisboa (1987).
  Salvador successfully supervised 9 doctoral theses and is currently directing 3. He was granted an IBM SUR award in 2013 and a JSPS Invitation Fellowship in 2015. He participates or participated as a project member or Principal Investigator in nationally and European funded projects, including OAR, AJACS, STAMPA, JEDI, HORUS, VAPS, BIOECOSYS, AI4EU, EUGREEN and PaCoMoCo.

Work plan

Abstract

Abstract in portuguese

[DRAFT]

Esta pesquisa visa superar as restrições das representações lógicas em cenários do mundo real com elementos probabilísticos, expandindo a Programação Lógica Probabilística (PLP) com Programas Estocásticos de Conjunto de Respostas (SASP). Embora os sistemas PLP atuais, como o ProbLog, forneçam algumas soluções, persistem desafios na caracterização de distribuições de probabilidade para Programas de Conjunto de Respostas (ASP) com fatos probabilísticos. A abordagem SASP proposta introduz um método algébrico para representar a incerteza e integra algoritmos evolutivos para induzir modelos SASP. O plano de pesquisa envolve análise teórica, desenvolvimento de algoritmos, avaliação empírica e colaboração interdisciplinar. Os principais objetivos incluem investigar a estrutura e composição do programa na modelação SASP, desenvolver regras e algoritmos de transformação e avaliar modelos SASP codificados manualmente e induzidos em casos teóricos e do mundo real.

Estado da arte

- Sistemas PLP como o ProbLog abordam limitações de representações lógicas com distribuições de probabilidade.
- No entanto, caracterizar distribuições de probabilidade para ASP estendidos com fatos probabilísticos permanece um desafio.
- A abordagem SASP proposta estende ASP, representa a incerteza algebricamente e incorpora algoritmos evolutivos para indução de modelos.

Objetivos principais

- Investigar o papel da estrutura dos programa na utilização de SASP na modelação de fenómenos probabilísticos.
- Investigar a aplicação de algoritmos evolutivos para indução de modelos SASP com base em conhecimento e evidências adicionais.
- Avaliar modelos SASP codificados manualmente ou induzidos, em casos teóricos e do mundo real.

Conhecimento e competências

- O grupo tem experiência em lógica, programação lógica e sistemas distribuídos.
- Trabalhos anteriores demonstram a viabilidade e a capacidade representativa dos SASP.
- A colaboração com uma equipe interdisciplinar garante diversas perspetivas.

Estratégia e Metodologias

- A análise teórica explorará os efeitos da estrutura dos programas SASP na modelação de fenómenos probabilísticos.

- O desenvolvimento de algoritmos será focado on uso de SASP para a modelação de fenómenos probabilísticos e indução indução de modelos SASP.
- A avaliação empírica irá apurar o desempenho dos modelos em vários casos.
- A colaboração interdisciplinar promove a inovação e garante pesquisas abrangentes.

Novidade e resultados esperados

- A novidade está na semântica probabilística do SASP, na pontuação resultante baseada em evidências e na utilização dessa pontuação para induzir SASP a partir de conhecimento anterior e evidência.
- Os resultados esperados incluem melhor compreensão da modelação SASP, algoritmos eficientes e modelos SASP validados.

A pesquisa proposta aborda limitações críticas na programação lógica probabilística com ASP e visa avançar através de metodologias inovadoras e colaboração interdisciplinar. O plano de investigação abrangente, apoiado pelos conhecimentos e recursos existentes, demonstra um forte potencial para contribuições significativas para esse problema.

Abstract in english

[DRAFT]

This research aims to overcome the constraints of logical representations in real-world scenarios with probabilistic elements by expanding Probabilistic Logic Programming (PLP) with Stochastic Answer Set Programs (SASP). While current PLP systems like ProbLog provide some solutions, challenges persist in characterizing probability distributions for Answer Set Programs (ASP) with probabilistic facts. The proposed SASP approach introduces an algebraic method to represent uncertainty and integrates evolutionary algorithms for inducing SASP models. The research plan involves theoretical analysis, algorithm development, empirical evaluation, and interdisciplinary collaboration. Key objectives include investigating program structure and composition in SASP modeling, developing transformation rules and algorithms, and evaluating hand-coded and induced SASP models on theoretical and real-world cases.

State of the Art

- PLP systems like ProbLog address limitations of logical representations with probability distributions.
- However, characterizing probability distributions for Answer Set Programs extended with probabilistic facts remains challenging.
- The proposed SASP approach extends ASP, represents uncertainty algebraically, and incorporates evolutionary algorithms for model induction.

Main Goals

- Investigate the role of program structure in the utilization of PASP for modeling probabilistic phenomena.
- Investigate the application of evolutionary algorithms for induction of SASP models based on additional background knowledge and evidence.
- Evaluate hand-coded or induced SASP models, on theoretical and real-world cases.

Knowledge and Skills

- The group possesses expertise in logic, logic programming, and distributed systems.
- Previous work demonstrates the feasibility and representational power of SASP.
- Collaboration with an interdisciplinary team ensures diverse perspectives.

Strategy and Methodologies

- Theoretical analysis will explore SASP program structure effects on modeling probabilistic phenomena.
- Algorithm development will focus on transformation rules and efficient exploration of SASP space.
- Empirical evaluation will assess model performance on various cases.
- Interdisciplinary collaboration fosters innovation and ensures comprehensive research.

Novelty and Expected Results

- The novelty lies in the probabilist semantics of SASP, the resulting score based in evidence and the utilization of that score to induce SASP from background knowledge and evidence.
- Expected results include improved understanding of SASP modeling, efficient algorithms, and validated SASP models.

Overall, the proposed research addresses critical limitations in probabilistic logic programming with ASP and aims to advance the field through innovative methodologies and interdisciplinary collaboration. The comprehensive research plan, supported by existing expertise and resources, demonstrates a strong potential for significant contributions to the field.

Abstract for publication

Abstract for publication in portuguese

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Abstract for publication in english

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State of the art and objectives

[DRAFT]

A major limitation of logical representations in real world applications is the implicit assumption that the background knowledge (BK) is perfect. This assumption is problematic if data is noisy, which is often the case. Probabilistic Logic Programming (PLP) is one ongoing effort to address this problem by extending the syntax and semantics of logic programs in order to have them represent and operate probability distributions (see [11]).

Current systems for PLP, such as ProbLog [5], P-log [3], LP^MLN [6], or cplint [7], derive a probability distribution from a program. However, for Answer Set Programs (ASP) [12] with probabilistic facts, the characterization of a probability distribution on the program's domain is not straightforward (see [1, 2, 3, 4]).

In [8] we address the problem of extending probability from the total choices of an ASP program to its stable models and, from there, to general events. Our approach is algebraic in the sense that it relies on an equivalence relation over the set of events and uncertainty is expressed with variables and polynomial expressions. In that work we show how SASP can represent arbitrary bayesian networks and therefore express any probability distribution of discrete random variables.

This representation of arbitrary bayesian networks conferes to SASP the capability to deal with a very large collection of probability problems and tasks. However, the problem of obtaining such SASP, besides hand-coded, remains open.

In our system some unknowns are represented by numeric parameters that can be estimated later from further information, e.g., evidence. This approach, delaying the assignment of certain parameters, enables later refinement and scoring a partial program from additional evidence.

In turn, scoring of SASP (i.e., models of a probabilistic phenomenon) is a key feature required to the application of evolutionary algorithms. From here we can explore how to induce SASP from BK and evidence.

The calculus of the score of an SASP with respect to evidence was already introduced and illustrated in [8]. It remains to investigate the application of this process to induction of SASP from BK and evidence.

Ideas of this paper have a partial, limited, implementation, available in a public repository, that results from the work of a BII scholarship, supported by NOVALINCS "Financiamento Plurianual da unidade de I&D UIDP/04516/2020" and co-supported by Fundação para a Ciência e a Tecnologia (FCT), Portugal.

In the general Induction of Logic Programs (ILP) setting (see [11, 13]) the goal is to algorithmically obtain a (target) logic program. For that, (1) BK (e.g., obtained from experts) is provided in the form of a logic program, describing objects and (first-order) relations of a domain and (2) observations are organized as positive evidence, that should be inferred from the target program, and negative evidence, that should not be inferred from the target program. Moreover, the target program must be (logically) consistent with the BK. ILP is a form of Machine Learning (ML) that offers significant advantages over numeric based ML:

- For one, ILP address the problem of Explainable Artificial Intelligence (XAI) because, unlike the large-dimensional vector based models of numeric ML, logic programs are human-readable in the sense that their declarative nature describes what objects are in the domain, their structure, properties and relations.
- Second, ILP describes phenomena with related instances while numeric ML is limited to a single (tabulated) relation where different instances (lines) are independent given the model.
- Third, often a target program is generated from a small set of observations, while, in general, numeric ML models require large datasets to achieve significant accuracy.
- At last, expert knowledge, expressed in the BK, can be utilized to structure the target program, i.e., to model the observations. Again, this is a feature hard to achieve with numeric ML models.

Drawbacks of ILP include the computational complexity of inducing the target program and the general difficulty of logic programs to deal with noisy data. While the later is being addressed by PLP in general and SASP in particular, the computational complexity of induction remains an important challenge that we propose to investigate with this project.

In summary, with this project we aim to continue our exploration on how SASP represent probability distributions, how to use them to model probabilistic phenomena and how they can be induced from BK and evidence.

More specifically, this project's objectives are to investigate:

- The role of program structure and composition in the use of PASP to model probabilistic phenomena.
- Program transformation rules and space exploration algorithms for SASP.
- The performance of hand-coded and induced SASP models on selected theoretic and real-world cases.

- The performance of hand-coded and induced SASP models on selected theoretic and real world cases.

Research plan and methods

[DRAFT]

Feasibility and Originality

The outlined scientific approach leverages existing developments in Probabilistic Logic Programming (PLP) and Answer Set Programming (ASP) and extends it with the concept of Stochastic Answer Set Programs (SASP) to represent probability distributions in scenarios where traditional logical representations fall short due to probabilistic phenomena. The novelty lies in the application of algebraic methods to express uncertainty and the integration of evolutionary algorithms for inducing SASP models. Feasibility is supported by previous work demonstrating the representational power of SASP. Originality is derived from the interpretation of PLP and ASP concepts with an original approach to the association of probability annotated facts in logic programs to the probability of events, and the proposed investigation into program induction from background knowledge and evidence.

Research Methodology

1. **Theoretical Analysis.** Conduct a thorough analysis of the role of program structure and composition in the utilization of PASP for modeling probabilistic phenomena. This involves investigating how different program structures impact the representation and inference capabilities of SASP.
2. **Algorithm Development.** Develop program transformation rules and space exploration algorithms tailored for SASP. This includes devising methods to efficiently transform SASP representations and explore the space of possible SASP models.
3. **Empirical Evaluation.** Evaluate the performance of both hand-coded and induced SASP models on a range of theoretic and real-world cases. This involves designing experiments to assess the accuracy, scalability, and computational efficiency of SASP models in comparison to existing PLP systems.
4. **Integration of Evolutionary Algorithms.** Investigate the application of evolutionary algorithms for refining SASP models based on additional background knowledge or evidence. Develop algorithms to update SASP parameters and structure to improve model fit to observed data.

Working Arrangements

- Collaborative Environment. Foster collaboration between researchers with expertise in logic, logic programming, and distributed systems to ensure interdisciplinary perspectives are considered.
- Regular Meetings. Schedule regular meetings (e.g., every three/four months) to discuss progress, address challenges, and align research efforts towards the project objectives.
- Access to Resources. Ensure human and computational resources for theoretical research, algorithm development, experimentation, and data analysis.

Timeline

1. **Task Structure and Induction of SASP (SI) (Months 1-12)**
   - Theoretical research on program structure and transformation rules conducted by an interdisciplinary team of three members, including the PI.
   - Identifications of relevant program structure and transformation rules.
   - Regular meetings and discussions to ensure progress and collaboration within the team.
   - Publication of research findings in peer-reviewed international journals or presentations at international conferences.
2. **Task Integration with existing ASP and ILP software frameworks (INT) (Months 3-15)**
   - Implementation, testing, profiling, benchmark, and documentation conducted by a post-doctoral researcher.
   - Translation of theoretical findings into practical algorithms and software tools.
   - Rigorous testing of implemented solutions to ensure correctness and efficiency.
   - Profiling to identify computation intensive points for improvement.
   - Benchmark against existing methods to evaluate performance and identify areas for improvement.
   - Comprehensive documentation of the developed methodologies, including user guides and technical reports.
   - Continuous refinement based on feedback from internal testing and validation.
   - Publication of research findings in peer-reviewed international journals or presentations at international conferences.
   - Dissemination of outcomes through seminars, and open-source repositories.
3. **Task Applications of SASP (APP) (Months 6-18)**
   - Application of developed methodologies and software tools to theoretical and real-world problems.
   - Case studies and experiments conducted to assess the effectiveness and scalability of the proposed approaches.
   - Analysis of results and comparison with existing state-of-the-art methods.
   - Publication of research findings in peer-reviewed international journals or presentations at international conferences.
   - Dissemination of outcomes through seminars, and open-source repositories.

Resources

- **Personnel**
  - PI: Leads and coordinates all tasks, providing guidance and oversight throughout the project duration.
  - Interdisciplinary team (4 members, including the PI): Comprising experts in logic, logic programming, and distributed systems, responsible for theoretical research, development and case exploration.
  - Post-doctoral researcher: Leads the implementation, testing, profiling, benchmark, and documentation efforts.
- **Equipment and Infrastructure**
  - High-performance computing resources for conducting complex simulations and experiments.
  - Software and hardware development tools and platforms for coding, testing, and version control.
  - Access to relevant databases, datasets, and computational libraries for validation and benchmark.
- **Funding**
  - Budget allocation for equipment procurement, travel expenses, publication fees, and other project-related costs.
  - Grant funding to sustain the research and software tools development activities over the designated timeline.

PI Commitment

As the Principal Investigator (PI), I am fully committed to overseeing and ensuring the success of each phase of the research project. My responsibilities include:

- Providing strategic direction and vision for the research activities.
- Facilitating interdisciplinary collaboration among team members.
- Securing necessary resources and funding to support the project goals.
- Monitoring progress and addressing any challenges or setbacks that may arise.
- Ensuring compliance with ethical guidelines and research protocols.
- Contributing to the dissemination of research outcomes through publications, presentations, and knowledge sharing initiatives.
- Mentoring and supporting team members to foster their professional development and growth.

Throughout the project duration, I will maintain open communication channels with all stakeholders, including team members, funding agencies, and collaborators, to ensure transparency and alignment with project objectives. My dedication to the project's success is unwavering, and I am committed to achieving impactful results that advance the field of probabilistic logic programming and inductive logic programming.

Justification

The proposed research methodology aligns with the project's objectives by combining theoretical analysis, algorithm development, empirical evaluation, and interdisciplinary collaboration. The utilization of existing PLP frameworks as a foundation and the integration of evolutionary algorithms introduce innovative elements to address the challenges of data with random perturbations and computational complexity in logic-based probabilistic reasoning. The allocated timelines, resources, and PI's commitment are justified by the ambitious nature of the research objectives and the potential impact of the proposed advancements in probabilistic logic programming.

Identify whether the work plan requires advanced computer resources to be provided by FCT

Yes

Identify whether the work plan requires space in a research data repository to be provided by the FCT

Yes

Bibliographic references

1. Cozman, F. G., & Mauá, D. D. (2020). The joy of probabilistic answer set programming: Semantics, complexity, expressivity, inference. International Journal of Approximate Reasoning, 125, 218-239.
2. Verreet, V., Derkinderen, V., Dos Martires, P. Z., & De Raedt, L. (2022, June). Inference and learning with model uncertainty in probabilistic logic programs. In Proceedings of the AAAI Conference on Artificial Intelligence (Vol. 36, No. 9, pp. 10060-10069).
3. Baral, C., Gelfond, M., & Rushton, N. (2009). Probabilistic reasoning with answer sets. Theory and Practice of Logic Programming, 9(1), 57-144.
4. Pajunen, J., & Janhunen, T. (2021). Solution enumeration by optimality in answer set programming. Theory and Practice of Logic Programming, 21(6), 750-767.
5. De Raedt, L., Kimmig, A., & Toivonen, H. (2007). ProbLog: A probabilistic Prolog and its application in link discovery. In IJCAI

2007, Proceedings of the 20th international joint conference on artificial intelligence (pp. 2462-2467). IJCAI-INT JOINT CONF ARTIF INTELL.

6. Lee, J., & Wang, Y. (2016, March). Weighted rules under the stable model semantics. In Fifteenth international conference on the principles of knowledge representation and reasoning.
7. Alberti, M., Bellodi, E., Cota, G., Riguzzi, F., & Zese, R. (2017). cplint on SWISH: Probabilistic logical inference with a web browser. Intelligenza Artificiale, 11(1), 47-64.
8. Coelho, F., Dinis, B., & Abreu, S. (2024). An Algebraic Approach to Stochastic ASP. Submitted.
9. Körner, P., Leuschel, M., Barbosa, J., Costa, V.S., Dahl, V., Hermenegildo, M.V., Morales, J.F., Wielemaker, J., Diaz, D., Abreu, S. and Ciatto, G. (2022). Fifty years of Prolog and beyond. Theory and Practice of Logic Programming, 22(6), 776-858.
10. López, J., Múnera, D., Diaz, D., & Abreu, S. (2018). Weaving of metaheuristics with cooperative parallelism. In Parallel Problem Solving from Nature-PPSN XV: 15th International Conference, Coimbra, Portugal, September 8-12, 2018, Proceedings, Part I 15 (pp. 436-448). Springer International Publishing.
11. Riguzzi, F. (2022). Foundations of probabilistic logic programming: Languages, semantics, inference and learning. River Publishers.
12. Lifschitz, V. (2002). Answer set programming and plan generation. Artificial Intelligence, 138(1-2), 39-54.
13. Russell, S. J., & Norvig, P. (2010). Artificial intelligence a modern approach. London.

Past publications

Coelho, F., & Nogueira, V. (2015). Probabilistic perception revision in AgentSpeak (L). In PRIMA 2015: Principles and Practice of Multi-Agent Systems: 18th International Conference, Bertinoro, Italy, October 26-30, 2015, Proceedings 13 (pp. 613-621). Springer International Publishing.
https://doi.org/10.1007/978-3-319-25524-8_44

Körner, P., Leuschel, M., Barbosa, J., Costa, V.S., Dahl, V., Hermenegildo, M.V., Morales, J.F., Wielemaker, J., Diaz, D., Abreu, S. and Ciatto, G. (2022). Fifty years of Prolog and beyond. Theory and Practice of Logic Programming, 22(6), 776-858.
https://doi.org/10.1017/S1471068422000102

Dinis, B., & Miquey, É. (2023). Stateful Realizers for Nonstandard Analysis. Logical Methods in Computer Science, 19.
https://doi.org/10.46298/lmcs-19(2:7)2023

Codognet, P., Diaz, D., & Abreu, S. (2022, July). Quantum and Digital Annealing for the Quadratic Assignment Problem. In 2022 IEEE International Conference on Quantum Software (QSW) (pp. 1-8). IEEE.
https://doi.org/10.1109/QSW55613.2022.00016

Tasks

SUMMARY OF COSTS BY INSTITUTION

Universidade de Évora	
1. Structure and Induction of SASP (SI)	4 440,00 €
2. Integration with existing ASP and ILP software frameworks (INT)	34 735,00 €
3. Applications of SASPs (APP)	2 220,00 €
Total	**41 395,00 €**

1	**Structure and Induction of SASP (SI)**	12 months	From 01.09.2024 to 31.08.2025

Members

Persons / Month	Allocated
2	Bruno Miguel Antunes Dinis Universidade de Évora
2	Francisco Manuel Gonçalves Coelho Universidade de Évora
1	SALVADOR LUÍS DE BETHENCOURT PINTO DE ABREU Universidade de Évora

Task description and expected results

Objectives

Understand the role of Stochastic Answer Set Programs (SASP) structure and composition elements (e.g., stratified or recursive programs, functional symbols) on the stable models, event classes, respective probability and SASP scoring with respect to evidence (i.e., a dataset).

Understand what are the best choices for program transformation and combination rules for induction of SASP from Background Knowledge (BK) and evidence using evolutionary program space exploration algorithms (e.g., genetic algorithms).

Methodologies and approaches

List structure elements (e.g., stratified programs, recursive rules, functional symbols) and explore the respective effects on the stable models and event classes.

Modify the definition of event classes and study the effect on event probability and score function in modeling probabilistic processes

Define SASP transformation and combination rules to study and characterize the resulting properties of evolutionary program space exploration algorithms for the induction of SASP from BK and evidence.

Expected results

Assessment on the effects of SASP structures and composition elements on stable models, event classes, respective probability and SASP scoring with respect to evidence for the use of SASP in modeling probabilistic processes.

Assessment of SASP transformation and combination rules and the resulting properties of evolutionary program space exploration algorithms for the induction of SASP from BK and evidence.

Preconditions from other tasks

None. This is an initial task, a continuation of already done research.

Results to other tasks

The use of SASP in modeling probabilistic processes, because it studies the elements utilized in the computation of the event classes and respective probabilities.

The induction of SASP from BK and evidence, because it studies program transformation and combination rules utilized in evolutionary program space exploration algorithms.

Role of each partner and institution

Universidade de Évora: Principal contractor.

Justification for the resources

For deliverable "SI Paper 1": A member should present the results of this task in an international conference or journal.

For deliverable "SI Paper 2": A member should present the results of this task in an international conference or journal.

Deliverables and delivery dates

Paper accepted in international conference or journal, by 2025-03-01

Paper accepted in international conference or journal, by 2025-09-01

Overall cost justification of the task

Registration in international conference (x2)....1400.00€

Travel to international conference (x2).....1000.00€

Per diem international conference (x3x2).....1152.00€

Budgets

Institution	Amount requested
Universidade de Évora	4 440,00 €

2 Integration with existing ASP and ILP software frameworks (INT)

12 months | From 01.12.2024 to 30.11.2025

Members

Persons / Month	Allocated
2	Francisco Manuel Gonçalves Coelho Universidade de Évora
12	BIPD - 01 Post doctoral Research Grant Universidade de Évora

Task description and expected results

Objectives

Support the application of SASP for modeling probabilistic processes and induce SASP from Background Knowledge (BK) and evidence.

Methodologies and approaches

Implement, test, benchmark and document:

- SASP intermediate representation and a parser.
- Integration with existing, state of the art, Answer Set Program (ASP) tools such as Potassco and cplint for the computation of the stable models.
- Instrumental functions such as: event belongs to class, class probability, event probability.
- Support for SASP combination and transformation.
- Integration with existing, state of the art, evolutionary explorations tools (e.g. genetic algorithms).
- Command-line programs to support basic usage such as: list classes, query the probability of an event or class, induce SASP.

Expected results

A basic set of tools, including a library and command-line programs, to use Stochastic Answer Set Programs (SASP) for modeling probabilistic processes and induce SASP from Background Knowledge (BK) and evidence.

Preconditions from other tasks

From task SI:

- Insights on the relation of SASP structure and composition elements and the computation of classes, and element and class probability.
- Insights on the effects of SASP transformation and combination rules on evolutionary program space exploration algorithms.

Results for other tasks

The software tools required by task APP to use and/or induce SASP on large problems.

Role of each partner and institution

Universidade de Évora, Principal contractor.

Justification for resources

The implementation volume and complexity requires a full-time post-doc student working over a year, using a suitable laptop.

The student should present the results of this task in an international conference or journal.

Deliverables and delivery dates

A report on progress, documenting the implementation, testing, benchmarking and documentation of the tools, by 2025-06-01.

Paper accepted in international conference or journal, by 2025-12-01.

Overall cost justification of the task

Registration in international conference.....700.00€

Travel to international conference.....500.00€

Per diem international conference (x3).....576.00€

Laptop (i7, 32GB ram, 1TB SSD, 15").....2660.00€

Post-doc scholarship (BPD) (12 x (1801,00€ + 145,00€))...23352.00€ (Scholarship + SSV + Insurance per month)

Budgets

Institution	Amount requested
Universidade de Évora	34 735,00 €

3 Applications of SASPs (APP) — 12 months — From 01.03.2025 to 28.02.2026

Members

Persons / Month	Allocated
2	Francisco Manuel Gonçalves Coelho Universidade de Évora
1	Miguel Ângelo Pignatelli de Avillez Nunes Pereira Cátedra High Performance Computing
1	SALVADOR LUÍS DE BETHENCOURT PINTO DE ABREU Universidade de Évora

Task description and expected results

Objectives

Use Stochastic Answer Set Programs (SASP) for modeling probabilistic processes and induce SASP from Background Knowledge (BK) and evidence in the context of theoretic scenarios (toy problems) described in the relevant literature (e.g., Stochastic Plan Generation, Logic/Statistic Puzzles) as well as to a selected real world cases (e.g., virtual machine migration and server consolidation in data-centers).

Methodologies and approaches

Compile a set of theoretic and real-world problems.

Gather information in the form of background knowledge (e.g., from experts) and data (positive and negative examples) on selected problems.

Evaluate the performance of hand-coded and induced SASPs on that set of problems.

Compare with state-of-the-art results.

Expected results

Assessment of the performance of hard-coded and induced SASPs on selected theoretical and real-world problems.

A list of advantages and problems in the application of SASP.

Preconditions from other tasks

From task SI:

- Insights on the relation of SASP structure and composition elements and the computation of classes, and element and class probability.

- Insights on the effects of SASP transformation and combination rules on evolutionary program space exploration algorithms.

From task INT:

- Libraries, programs, and respective documentation.

Results for other tasks

None. This is a final task.

Role of each partner and institution

Universidade de Évora: Principal contractor.

High Performance Computing Chair: Research unit.

Justification for the needed resources:

A member should present the results of this task in an international conference.

Deliverables and delivery dates

A report on progress, documenting the performance of the hand-coded and induced PASP models on the selected problems, by 2025-09-01.

A paper accepted in an international conference or journal, by 2026-03-01.

Overall cost justification of the task

Registration in international conference.....700.00€

Travel to international conference.....500.00€

Per diem international conference (x3).....720.00€

Budgets

Institution	Amount requested
Universidade de Évora	2 220,00 €

Project timeline and management

Milestone list

Date	Designation	Description	Tasks
01.03.2025	SI Paper 1	A paper accepted in an international conferences or journals, describing the effects of structures and composition elements on SASP on stable models, event classes, and respective probability.	1. Structure and Induction of SASP (SI)
01.06.2025	INT Report	A report on progress, documenting the implementation, testing, benchmarking and documentation of the tools.	2. Integration with existing ASP and ILP software frameworks (INT)
01.09.2025	SI Paper 2	A paper accepted in an international conference or journal, describing program transformation rules and space exploration algorithms for SASP.	1. Structure and Induction of SASP (SI)
01.09.2025	APP Report	A report on progress, documenting the performance of the hand-coded and induced PASP models on selected problems.	3. Applications of SASPs (APP)
01.12.2025	INT Paper	A paper accepted in an international conference or journal, describing the performance of the implemented tools on	2. Integration with existing ASP and ILP software frameworks (INT)

		performance of the implemented tools on hand-coded and induced SASP.	frameworks (INT)
01.03.2026	APP Paper	A paper accepted in an international conference or journal, documenting the performance of the hand-coded and induced PASP models on selected problems.	3. Applications of SASPs (APP)

Timeline

timeline.pdf

Obtained on 27-02-2024 at 21:55:52

Description of the management structure

[DRAFT]

Coordination Between Participants

- **Principal Investigator (PI)**
  - Leads the overall project and ensures alignment with objectives.
  - Facilitates communication between participants from different research units.
  - Provides guidance and support to team members.
- **Researchers**
  - Collaborate closely with the PI to execute project tasks.
  - Coordinate with each other to ensure seamless progress on individual and collaborative activities.
  - Contribute expertise from their respective research units to enhance project outcomes.
- **Postdoctoral Student**
  - Works closely with the PI and researchers to implement project tasks.
  - Collaborates with other team members to integrate research findings into software tools and algorithms.

Planned Meetings

- **Quarterly Team Meetings**
  - Purpose: Discuss progress, challenges, and next steps for the quarter; Provide a comprehensive overview of progress across all project tasks.
  - Agenda: Review individual tasks, share updates, address any issues or roadblocks; Review achievements, challenges, and goals for the upcoming month.
- **Semiannual Review Meetings**
  - Purpose: Conduct a detailed review of project milestones and objectives.
  - Agenda: Evaluate progress, identify any necessary adjustments to the research plan, discuss potential collaborations or partnerships.

Reporting Structure

- **Progress Reports**
  - Format: Written reports submitted every three months by each team member.
  - Content: Summarize achievements, challenges, and goals for the upcoming month.
- **Semiannual Review Reports**
  - Format: Comprehensive reports submitted by the PI summarizing progress and outcomes over the past six months.
  - Content: Review achievements, challenges, adjustments to the research plan, and any recommendations for the future.

Financial and Administrative Management

The Administrative Services of the University of Évora are responsible for project's financial and administrative management, through its Projects Management Division (DGP).

DGP's main task is to fulfill all the necessary operations, provide administrative support and reassure the good execution of R&D Units budgets and respective Projects. It is accountable for the execution of all legal and required financial reports.

Each project is the responsibility of a project officer that acts as a link between the PI and the rest of the financial team. Is also responsible to process all expenses fulfilling all the current national and European legislations.

The project officer is also in charge of the liaison with FCT (Science and Technology National Agency), European Commission and other donors by elaborating and delivering the financial reports and respective requests for payments, including reassuring all necessary procedures to the validation of expenditures.

The University of Évora owns an information system that allows the researcher to follow the project's financial implementation on a permanent basis.

a permanent basis.

Ethical issues

Are there Ethics Issues identified in this project?

No

Ethical declarations you consider appropriate

-

Justification

-

2030 Agenda

Framework of the application for the United Nations SDG 2030 Agenda

SDG Goal 9: Industry, Innovation and Infraestructures

Framework justification

Application of this project include the optimization in the use of existing infrastructure, therefore in accordance to **Target 9.b:** *Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.* **Indicator 9.b.1:** *Proportion of medium and high-tech industry value added in total value added.*

Other projects

CPCA/A0/427668/2021 Fundação para a Ciência e a Tecnologia - FCT, I.P.

PI

Francisco Coelho (PI)

Project status

Completed

Project title (in English)

JuPy | High Level Languages on HPC

Principal contractor

High Performance Computing Chair

Total funding

185,00 €

Start date

21.01.2022

Duration (months)

3

Main objectives of the project that you consider relevant for this application

- Knowledge and experience acquired about implementing and executing programs in a distributed HPC system.
- Technical and scientific cooperation relationships established between the PI and the management team of the "Oblivion | HPCUE" cluster.

Attachments

Attachments

-

Indicators

Expected output indicators

Description	2024	2025	2026	Total
A · Publications	0	0	0	
Books	0	0	0	**0**
Book chapters	0	0	0	**0**
Papers in international journals	0	0	0	**0**
Papers in national journals	0	0	0	**0**
B · Communications	0	0	0	
Communications in national meetings	0	0	0	**0**
Communications in international meetings	0	3	1	**4**
C · Reports	0	2	0	**2**
D · Organization of seminars and conferences	0	0	0	**0**
E · Advanced training	0	0	0	
PhD theses	0	0	0	**0**
Master´s theses	0	0	0	**0**
Others	0	1	0	**1**
F · Models	0	0	0	**0**
G · Software	0	0	0	**0**
H · Pilot plants	0	0	0	**0**
I · Prototypes	0	1	1	**2**
J · Patents	0	0	0	**0**
K · Others	0	0	0	
API documentation	0	1	1	**2**
Library documentation	0	1	1	**2**
	0	0	0	**0**

Release

Promotion actions of the scientific activity planned in the project

- Publication in international peer-review conferences or journals.
- Public repositories with software and documentation, datasets and models.

Budget

Principal contractor

Universidade de Évora

Item	2024	2025	2026	Total
Human Resources	1 946,00 €	21 406,00 €	0,00 €	**23 352,00 €**
Missions	0,00 €	0,00 €	0,00 €	**0,00 €**
Scientific and technical instruments and equipment	2 660,00 €	0,00 €	0,00 €	**2 660,00 €**
Subcontracts	0,00 €	0,00 €	0,00 €	**0,00 €**
Patents registration	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstration, Promotion and Dissemination	0,00 €	5 328,00 €	1 776,00 €	**7 104,00 €**
Adaptation of buildings and facilities	0,00 €	0,00 €	0,00 €	**0,00 €**
Purchase of goods and services	0,00 €	0,00 €	0,00 €	**0,00 €**
Overheads	1 151,50 €	6 683,50 €	444,00 €	**8 279,00 €**
Total	**5 757,50 €**	**33 417,50 €**	**2 220,00 €**	**41 395,00 €**

Global budget

Item	2024	2025	2026	Total
Human Resources	1 946,00 €	21 406,00 €	0,00 €	**23 352,00 €**
Missions	0,00 €	0,00 €	0,00 €	**0,00 €**
Scientific and technical instruments and equipment	2 660,00 €	0,00 €	0,00 €	**2 660,00 €**
Subcontracts	0,00 €	0,00 €	0,00 €	**0,00 €**
Patents registration	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstration, Promotion and Dissemination	0,00 €	5 328,00 €	1 776,00 €	**7 104,00 €**
Adaptation of buildings and facilities	0,00 €	0,00 €	0,00 €	**0,00 €**
Purchase of goods and services	0,00 €	0,00 €	0,00 €	**0,00 €**
Overheads	1 151,50 €	6 683,50 €	444,00 €	**8 279,00 €**
Total	**5 757,50 €**	**33 417,50 €**	**2 220,00 €**	**41 395,00 €**

Funding plan

Item	2024	2025	2026	Total