



Decree of the Rector n. 1145 of 08/11/2023
Competition for awarding 1 research grant at the University of Udine

DISCLAIMER:

The official and legally binding call for applications is in Italian only.
This document cannot be used for legal purposes and is only meant to provide information in English on the call for applications (Decree of the Rector n. 1145 of 08/11/2023). Please refer to the official call published on: <https://www.uniud.it/it/albo-ufficiale>

Any change and integration will be made available on the above mentioned web page. Therefore, no personal written communication regarding the examination date and/or competition results shall be provided to applicants.

Annex 1

Competition announcement for the assignment of 1 research grant at the University of Udine, entitled "Spatiotemporal logics: extensions with nominal quantification operators and for hierarchical structures" SSD: INF/01 (principal investigator, Marino Miculan)

Research grant co-funded by the resources of the project PRIN 2022 - Prot. n. 20228KXFN2

Art. 1

A selection procedure is hereby launched for the award of 1 research grant at the University of Udine, as identified in Attachment A which constitutes an integral part of the present announcement.

The research grant is linked to the research project and is subject and conditioned upon the relative funding.

The fellowship may be renewed, in compliance with Art. 22, Law No. 240 of 30 December 2010 (as in the text in force before the implementation of the Conversion Law of the D.L. 36/2022, L. 79/2022), Law No. 11 of 27 February 2015, and the current regulations of the University of Udine for awarding research grants, issued with the Rector's Decree No. 182 of 31 March 2021. The renewal is subject to the scientific coordinator's positive assessment of the researcher's activities, an adequate scientific rationale, and a corresponding financial covering.

The research fellowship does not give rise to any right with regards to accessing University posts.

Any personal communication to candidates related to this selection will be sent exclusively to the email address indicated when registering for the selection, as mentioned in Art. 5.

Art. 2

The research grant described in this competition announcement and the required qualifications to apply for the position are identified in Attachment A. The lack of the admission requirements leads to the automatic exclusion from the competition procedure.

Possession of a PhD or equivalent degree obtained abroad or, only for the interested areas, of a medical specialization accompanied by an adequate scientific production, constitutes a preferential qualification for awarding the research fellowship of this selection, if it has not been provided as a mandatory requirement.



For the only purpose of the admission to the competition, the Examining Board (Art. 7) shall assess the equivalence of the qualification obtained abroad, except for the evaluation of the medical specialization qualification to which Article 38 of the Legislative Decree 165/2001 and subsequent modifications and additions, and EU regulations on the matter, shall be applied.

The Examining Board will proceed to the evaluation of the qualification obtained abroad according to the documentation attached to the application form. The Examining Board may exclude the candidate if the submitted documentation does not provide sufficient information for the assessment.

Therefore, applicants must enclose all the documentation in their possession relating to their qualification in order to provide the Examining Board with sufficient information for assessment.

Candidates holding a qualification issued by a **European Research Area country**, if successful, must submit, if not already attached to the application form one of the following options:

- Supplement Diploma in English issued by the competent University.
- CIMEA Certificate of comparability of the foreign qualification, issued by CIMEA (Information Centre on Academic Mobility and Equivalence) via the "diplome" service at <https://cimea.diplo-me.eu/udine/#/auth/login>

Candidates holding a qualification issued by a **non-European Research Area country**, if successful, must submit, if not already attached to the application form one of the following options:

- Declaration of the on-site value of the qualification and the certificate relating to the degree with examinations and grades. A certificate in a language other than Italian or English must be accompanied by an official translation into one of these languages (certified by the competent diplomatic-consular authority or certified by a court in Italy).
- CIMEA Certificate of comparability of the foreign qualification, issued by CIMEA (Information Centre on Academic Mobility and Equivalence) via the "diplome" service at <https://cimea.diplo-me.eu/udine/#/auth/login>

If the Supplement Diploma or the statement/attestation of comparability are not available when signing the contract, the applicant must demonstrate that he/she has requested the documentation and submit it as soon as possible.

Any exclusion from the selection procedure due to lack of eligibility requirements, absence of required documents, failure to sign the selection application or submission of the selection application in a manner different from what is provided for in this call for applications will be communicated to applicants exclusively at the email address indicated in the application form.

Art. 3

The research grant referred to in this call for applications cannot be awarded:

- a. to employees of Universities and the entities referred to in Article 22, section 1, of Italian Law no. 240 of 30 December 2010 (in the text prior to the reform introduced by Law no. 79 of 29 June 2022);
- b. to those who have already been awarded research grants pursuant to Italian Law no. 240 of 30 December 2010 (prior to the reform introduced by Law no. 79 of 29 June 2022) for the maximum period provided by law, even if not continuously, excluding the period in which the grant was used in conjunction with the doctorate, up to the legal term of the relative course;
- c. to those who have already benefited from research grants and fixed-term researcher contracts provided for, respectively, in Articles 22 and 24 of Italian Law no. 240 of 30 December 2010 (in the



text prior to the reform introduced by Law no. 79 of 29 June 2022), for a total of 12 years, even if not consecutive;

- d. to anyone who has a degree of kinship or affinity, up to and including the fourth degree, with:
- the Rector, the Director General or a member of the Board of Directors of the University of Udine;
 - the scientific supervisor or a professor/researcher belonging to the department or organisation hosting the research grant in question.

The research grant provided for in this call for applications cannot be combined:

- a) with scholarships of any kind, except for those granted by Italian or foreign institutions to supplement, by means of stays abroad, the fellow's training or research activities;
- b) with other research grants;
- c) with an employment relationship, even if part-time, without prejudice to the relevant provisions for employees of public administrations.

The grant awarded under this call for applications is also incompatible with simultaneous attendance at university degree courses, either Bachelor's degree or Master's degree courses, research Doctorates with scholarships and medical specializations, in Italy or abroad.

Art. 4

Applicants must enclose with their application, under penalty of exclusion, the following documents:

- a) their professional scientific CV, highlighting the candidate's aptitude for carrying out and implementing the research project (Attachment A);
- b) their identity card, their passport or any other identification document¹;
- c) (for candidates with a foreign qualification only) certification or self-certification of both the academic qualification required for the admission to the selection, and of the exams (with evaluation) took during the period of study abroad, and of any other document that can be useful to the evaluation of the degree by the Examining Board.

Applicants can attach to the application, publications and any other certification considered useful to demonstrate the qualification based on the research program (Attachment A) and to certify any research activity accomplished at public or private institutes (indicating the starting and ending date and the duration).

The documents and qualifications mentioned above must be submitted in Italian or English. Those that are not as requested will not be evaluated. Documents originally written in a language other than Italian or English must come with a translation in Italian or English, that the candidate will do on its own responsibility. The translation can be an abstract concerning the thesis.

Italian and Community candidates wishing to submit qualifications referring to conditions and facts attested by Public Administrations must proceed exclusively with self-certification.

Non-EU citizens legally residing in Italy may self-certify only data that can be verified or certified by Italian public bodies. They may also use declarations in lieu when provided for by an international convention between Italy and the declarant's country of origin.

Non-EU citizens not residing in Italy cannot self-certify.

Only the qualifications possessed by the candidate on the date the application form is submitted and submitted in accordance with the procedures set out in Article 5 will be assessed.

¹ Please be aware that the residence permit is not an identification document.



Failure to submit mandatory documents provided for in this article will constitute grounds for exclusion from the selection.

Art. 5

The submission of the applications for the present call starts on November 16, 2023 at 2:00 pm (Italian time) and ends on January 12, 2024 at 2:00 pm (Italian time).

The application to take part in the selection must be completed, under penalty of exclusion, using the appropriate online procedure, available at the link <https://pica.cineca.it/>. The procedure involves an applicant registration step, for those who do not already have an account, and then an application completion step.

Once completed, the online application must be signed in the manner described in the online procedure (manual signature with attached identity document or digital signature), under penalty of exclusion from selection. The application does not have to be signed if you access the above-mentioned online procedure using your SPID ID.

The qualifications referred to in Article 4 must be attached to the application in .pdf format. Individual .pdf files may not exceed 30MB.

The application for participation in the selection is automatically sent to the University of Udine with the definitive closing of the online procedure.

The University Administration:

- is not responsible if it is impossible to read the submitted documentation in electronic format due to damaged files;
- shall not accept or take into consideration qualifications or documents received in paper form or by any means other than what is specified in this article.

Reference to documents or publications already submitted in connection with other competitions is not allowed.

The Administration is not responsible for any missing document or communication because of inaccurate indication of residence and/or address submitted by the candidate during the application. Also, the Administration is not responsible if the candidate has not communicated changes in this information, or has communicated them too late. The Administration is also not responsible for any postal or telegraphic problems not attributable to the Administration itself.

Applicants are advised not to wait until the last few days before the closing date to submit their application. The University accepts no responsibility for any malfunctions due to technical problems and/or overloading of the communication line and/or application systems.

Art. 6

The selection procedure is held in accordance with the modality indicated in Attachment A.

The test will aim to assess the general preparation, experience and aptitude for research of the candidate. It will consist in the evaluation of the professional scientific curriculum, of the publications and qualifications presented, and of the interview, where foreseen.



Art. 7

The Examining board for the competition is identified in Attachment A of the present competition announcement, of which it is an integral part.

At its first meeting, the Examining board shall appoint its President and Secretary, and establish the criteria and methods for evaluating the qualifications and the interview, where foreseen.

The results of the qualifications assessment must be disclosed to applicants during the interview, where foreseen.

The Examining board can award a maximum of 100 points (one hundred out of one hundred) to the selection.

At the end of the evaluation procedure, the Examining board shall formulate the general merit list based on the overall score of each candidate, and draw up the minutes of the whole competition procedure.

Based on the ranking list, the assignment is awarded to candidates who have obtained a minimum overall score of 70/100 (seventy out of one hundred).

The Examining board's judgement is final.

The ranking list will be made public exclusively through publication on the University's official website.

Applicants will not be notified of the outcome of the evaluation.

Those who do not declare their acceptance of the research grant and do not present themselves at the research centre within the deadline communicated by the latter, even if not formally, shall lose the right to receive it. Exceptions to this term will only be granted in cases of documented force majeure.

Art. 8

The research activity cannot be started before signing the contract defining the terms and conditions of the collaboration.

The activity covered by the research grant must have the following characteristics:

- a) it must be carried out as part of the research programme covered by the grant and not be a merely technical support to it;
- b) it must have a close connection with the realization of the research program for which the winner of the grant has been awarded the contract;
- c) it must be continuous and, in any case, temporally defined, not merely occasional, and in coordination with the overall activity of the University;
- d) it must be carried out autonomously, solely within the limits of the programme prepared by the programme supervisor, without predetermined working hours.

The researcher is required to submit a detailed written report on the work carried out and the results achieved, accompanied by the opinion of the scientific supervisor, to the reference organisation at the intervals set out in the contract. The researcher must also submit interim reports and timesheets, if requested by the reference organisation.

Either the fellow or the reference organisation may withdraw from the contract.



The reference organisation may terminate the contract not only in the cases referred to in Article 9, sections 2 and 3, of the "Internal rules for awarding research grants pursuant to law 240 of 30 December 2010" of the University of Udine, but also in the event the research project and therefore the financial coverage on which the research grant is based cease to exist.

Art. 9

The following legal dispositions shall apply to the grant referred to in this call for applications:

- for tax matters, the provisions of Article 4 of Italian Law no. 476 of 13 August 1984, as subsequently amended and supplemented;
- for social security matters, the provisions of Article 2(26) *et seq.* of Italian Law no. 335 of 8 August 1995, as subsequently amended and supplemented;
- for mandatory maternity leave, the provisions of the Italian Ministerial Decree of 12 July 2007;
- with regard to sick leave, the provisions of Article 1(788) of Italian Law no. 296 of 27 December 2006 and subsequent amendments.

During the period of mandatory maternity leave, the allowance paid by INPS according to Art. 5 of the Italian Ministerial Decree of 12 July 2007 is supplemented by the University up to the full amount of the research grant.

The grant will be paid in monthly instalments.

Art. 10

The data collected as part of the procedure referred to in Art. 5 are necessary to properly manage the selection procedure, for any subsequent management of the research grant and for purposes related to managing services provided by the University. The University of Udine is the Data Controller. At any time, the data subject may request access, rectification and, depending on the University's institutional purposes, cancellation and restriction of processing or oppose the processing of their data. The data subject can always lodge a complaint with the Italian Data Protection Authority. The complete disclosure is available on the University of Udine website in the "Privacy" section, accessible from the home page www.uniud.it Direct Link: <https://www.uniud.it/it/it/pagine-speciali/guida/privacy>

Art. 11

For all matters not expressly mentioned in this call for applications, refer to the regulations in force on the subject cited in the introduction and to the "Internal rules for awarding research grants pursuant to Italian Law no. 240 of 30 December 2010" of the University of Udine, issued by Rector's Decree no. 182 of 31 March 2021.

Art. 12

The procedure supervisor is Dr Sandra Salvador, Head of the Research Services Area of the University of Udine.

The Responsible office at the University of Udine is "Area Servizi per la Ricerca - Ufficio Formazione per la Ricerca", via Mantica n. 31 - 33100 Udine, Italia.

To request information about the call for applications, please complete the following form available on the University of Udine website:

https://helpdesk.uniud.it/SubmitSR.jsp?type=req&accountId=universityofudine&populateSR_id=42105



Attachment A

Responsabile scientifico della ricerca / Principal investigator:

Nome e cognome / Name and surname: Marino Miculan
Qualifica / Position: Professore Associato / Associate Professor
Dipartimento / Department: Scienze Matematiche, Informatiche e Fisiche (DMIF) / Mathematics, Computer Science and Physics
Area MUR / Research field: 01 – Scienze matematiche e informatiche
Settore concorsuale e Settore scientifico disciplinare / Scientific sector: 01/B1; INF/01 – Informatica

Titolo dell'assegno di ricerca / Topic of the research fellowship "assegno di ricerca":

I bandi sono consultabili dal sito dell'Ateneo, del MUR e di Euraxess / The calls are available on the University, MUR and Euraxess websites

Testo in italiano:

Logiche spazio-temporali: estensioni con operatori di quantificazione nominale e per strutture gerarchiche.

Text in English:

Spatiotemporal logics: extensions with nominal quantification operators and for hierarchical structures.

Obiettivi previsti e risultati attesi del programma di ricerca in cui si colloca l'attività dell'assegnista di ricerca / Foreseen objectives and results of the research programme performed by the research fellow "assegnista di ricerca":

I bandi sono consultabili dal sito dell'Ateneo, del MUR e di Euraxess / The calls are available on the University, MUR and Euraxess websites

Testo in italiano:

<p>Abstract del progetto</p>	<p>Il ragionamento sullo spazio e sul tempo è fondamentale in tutte le scienze, tra cui la logica, l'informatica teorica e l'intelligenza artificiale. In quest'ultimo campo, gli approcci subsimbolici spesso superano quelli simbolici nell'analisi di modelli complessi, ma mancano di affidabilità nel processo decisionale basato su informazioni spaziali. Per risolvere questo problema sono nati formalismi come le logiche spaziali (SL). Progetti precedenti, QUANTICOL del 7° PQ dell'UE e il PRIN 2017 IT-MATTERS, hanno sviluppato la <i>Spatial Logic of Closure Spaces</i> (SLCS), che consente di ragionare in modo uniforme sulla vicinanza e sulla raggiungibilità in diversi domini. Le estensioni includono modelli spazio-temporali basati su bigrafie. Strumenti gratuiti come TopoChecker e VoxLogicA facilitano la verifica dei modelli, applicati al ragionamento sui trasporti intelligenti e sulle immagini mediche. SLCS migliora l'analisi affidabile e strumenti pratici come VoxLogicA soddisfano le esigenze di imaging digitale. Le logiche spaziali offrono soluzioni potenti per il ragionamento spazio-temporale nei sistemi intelligenti.</p> <p>Questo progetto mira a progredire la teoria e l'implementazione delle logiche spaziali, consentendo l'analisi spazio-temporale in sequenze di immagini (ad esempio, l'analisi di video o studi longitudinali in ambito sanitario) e integrando la verifica dei modelli spaziali con le reti neurali, combinando la precisione di queste ultime con il monitoraggio dei requisiti guidato da esperti. In particolare, l'obiettivo principale di questo progetto è</p>
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	<p>studiare e sviluppare estensioni delle logiche spaziali esistenti (in particolare SLCS), al fine di gestire gli aspetti temporali, vincolanti e gerarchici. Il nostro obiettivo è quello di raggiungere un buon compromesso tra espressività, usabilità e decidibilità.</p> <p>I risultati di questo progetto sono molteplici. In primo luogo, il progetto definirà la sintassi e la semantica di SLCSB, una nuova logica spaziotemporale con quantificatori vincolanti. In secondo luogo, sarà la base per una nuova architettura ibrida, che integrerà primitive logiche con una rete neurale all'avanguardia. In terzo luogo, il progetto produrrà nuovi metodi ibridi per la segmentazione di immagini mediche (come la stima dello spessore corticale e dei linfociti infiltranti il tumore nel cancro al seno).</p>
Obiettivi del progetto	<p>L'obiettivo principale di questo progetto è studiare e sviluppare estensioni delle logiche spaziali esistenti (in particolare, SLCS), per gestire gli aspetti temporali, vincolanti e gerarchici. Le scelte progettuali di questo progetto sono motivate da casi di studio reali, come l'imaging medico e i sistemi cyber-fisici, allo scopo di fornire input fondamentali e per ottenere un feedback durante la fase di implementazione.</p> <p>Il primo obiettivo è la definizione della sintassi e della semantica di una logica spaziotemporale degli spazi di chiusura con vincolo (STLCSB). Il progetto è di estendere la SLCS esistente con modalità e tecniche delle logiche temporali, ispirandosi agli spazi di chiusura in evoluzione. L'introduzione di un costrutto di "binding", come la quantificazione nominale, consentirà l'identificazione di oggetti astratti. La fattibilità di questo obiettivo è garantita dalla competenza del team nelle logiche nominali e nelle logiche modali quantificate, nonché dalla loro esperienza nello sviluppo della logica SLCS e nell'implementazione dello strumento TopoChecker.</p> <p>Il secondo obiettivo mira a incorporare modelli strutturati gerarchicamente in STLCSB, consentendo un'analisi completa di dati spaziali radi e sparsi. I bigrafi, strutture a grafo progettate per la modellazione di sistemi gerarchici distribuiti, rappresentano naturalmente queste strutture multilivello.</p> <p>Combinando i punti di forza del gruppo e sfruttando le precedenti ricerche sulle logiche spaziali e temporali, il progetto farà progredire il campo introducendo nuovi concetti e strumenti per ragionare su spazi di chiusura in evoluzione, specifiche multi-scala e analisi olistica di dati spaziali eterogenei.</p>
Stato dell'arte	<p>L'ultimo decennio ha visto una nuova attenzione per le logiche spaziali (SL) [1] nel campo dei metodi formali, spostando il paradigma dalla deduzione e dalla dimostrazione di teoremi a metodi completamente automatizzati come il model checking e il monitoraggio. A tal fine, la SL è stata al centro del progetto QUANTICOL del 7° PQ dell'UE e del PRIN 2017 IT-MATTERS, il cui obiettivo principale era lo sviluppo di tecniche per la specificazione, l'implementazione e la validazione di sistemi intelligenti affidabili. I sistemi intelligenti possono essere pensati come insiemi di entità spazialmente distribuite, collegate in un grafo, che si evolvono nel tempo; pertanto, i requisiti complessi di tali sistemi sono specificati da logiche che predicano sui domini spaziali e temporali.</p> <p>I risultati di questi progetti precedenti includono progressi nelle basi teoriche e nelle implementazioni di strumenti per la <i>Spatial Logic of Closure Spaces</i> (SLCS), un linguaggio logico in grado di ragionare uniformemente sulla vicinanza e sulla raggiungibilità [2], con domini</p>



	<p>applicativi che vanno dall'imaging medico ai sistemi cyber-fisici e, più recentemente, ai complessi simpliciali e alle mesh 3D [4]. Inoltre, SLCS è stato esteso a una classe di modelli spazio-temporali basati su bigrafi in [6]. Un lavoro più recente include modelli categoriali di logiche su spazi di chiusura [3]. Il problema della verifica dei modelli per SLCS è stato affrontato con strumenti gratuiti e open-source. Il primo prototipo TopoChecker opera su grafi ed è stato utilizzato per applicazioni nei trasporti intelligenti e per i primi esperimenti di imaging medico [5]. Lo strumento di seconda generazione VoxLogicA è stato progettato specificamente per l'imaging digitale 2D e 3D [7].</p> <p>Questi risultati ci incoraggiano ad arricchire le logiche con operatori temporali e di legame, e a migliorarne gli strumenti di verifica, oltre a esplorare nuovi domini applicativi. A tal fine, prenderemo in considerazione i progressi teorici e di implementazione delle logiche temporali quantificate [8], delle logiche nominali [9], dei modelli gerarchicamente strutturati come i grafi gerarchici e i bigrafi [10,11].</p>
<p>Descrizione del progetto</p>	<p>Basandosi sui risultati dei progetti QUANTICOL del 7° PQ e IT-MATTERS del PRIN 2017, STENDHAL proseguirà la ricerca sulle logiche spaziali introducendo operatori temporali e quantificatori vincolanti, che predicano su oggetti spaziali strutturati (gerarchici).</p> <p>La maggiore espressività consentirà di specificare e verificare le proprietà degli oggetti strutturati, compreso il monitoraggio della loro evoluzione nel tempo. Inoltre, STENDHAL propone un'analisi spaziale profonda in cui una rete neurale viene addestrata su verità di base aumentate attraverso le logiche e, viceversa, le previsioni della rete vengono combinate con la conoscenza degli esperti attraverso le specifiche logiche. Ci baseremo su una combinazione del verificatore di modelli VoxLogicA e di NN-UNET, un metodo di segmentazione autoconfigurante basato sull'apprendimento profondo che ha avuto successo in un'ampia gamma di problemi di segmentazione di immagini mediche. Nel settore sanitario, saranno sviluppati e convalidati nuovi metodi ibridi per la segmentazione dei tumori cerebrali, la stima dello spessore corticale e dei linfociti infiltranti il tumore nelle immagini di microscopia. Nel dominio dei sistemi cyber-fisici, l'attenzione si concentrerà sul tracciamento degli oggetti e sull'analisi multiscala.</p>
<p>Possibili potenzialità applicative</p>	<p>Prevediamo una pluralità di risultati.</p> <ol style="list-style-type: none"> 1) Teoria: il progetto definirà la sintassi e la semantica di SLCSB, una nuova logica spazio-temporale con quantificatori con binders, con una semantica "piatta", basata su modelli istantanei, e una semantica "gerarchica", basata su bigrafi. La semantica gerarchica indurrà ulteriori operatori logici legati al cambiamento del livello di astrazione. 2) Metodi formali e intelligenza artificiale: il progetto introdurrà una nuova architettura ibrida, integrando primitive logiche con almeno una rete neurale all'avanguardia. 3) Sanità: il progetto prevede la ricerca di nuovi metodi ibridi per la segmentazione del glioblastoma, la stima dello spessore corticale e la valutazione dei linfociti infiltranti nel tumore nel cancro al seno.
<p>Bibliografia</p>	<p>[1] M. Aiello et alii. Handbook of Spatial Logics. Springer (2007). [2] V. Ciancia et alii. Model Checking Spatial Logics for Closure Spaces. LMCS 12(4) (2016). [3] D.Castelnovo, M. Miculan. Closure Hyperdoctrines. CALCO 2021, LIPIcs 211: 12:1-12:21. [4] N. Bezhanishvili et alii. Geometric Model Checking of Continuous Space.</p>



	<p>arXiv:2105.06194 (2021).</p> <p>[5] V. Ciancia et alii. Spatio-Temporal Model Checking of Vehicular Movement in Public Transport Systems. STTT 20(3): 289-311 (2018).</p> <p>[6] C. Tsigkanos et alii. Modeling and Verification of Evolving Cyber-physical Spaces. FSE 2017: 38-48.</p> <p>[7] G. Belmonte et alii. VoxLogicA: A Spatial Model Checker for Declarative Image Analysis. TACAS 2019, LNCS 11427: 281-298 [16bis] VoxLogica. https://vincenzoml.github.io/VoxLogicA/</p> <p>[8] F. Gadducci, D. Trotta. A Presheaf Semantics for Quantified Temporal Logics. arXiv:2111.03855 (2022).</p> <p>[9] A.M. Pitts. Nominal Sets. Cambridge University Press (2013).</p> <p>[10] D. Castelnovo, F. Gadducci, M. Miculan. A New Criterion for M,N-adhesivity, with an Application to Hierarchical Graphs. FoSSaCS 2022, LNCS, to appear.</p> <p>[11] D. Grohmann, M. Miculan. Reactive Systems over Directed Bigraphs. CONCUR 2007, LNCS 4703: 380-394.</p>
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Text in English:

Abstract	<p>Reasoning about space and time is crucial across sciences, including logics, theoretical computer science, and artificial intelligence. In the latter field, sub-symbolic approaches often outperform symbolic ones in complex pattern analysis but lack reliability in decision-making based on spatial information. Formalisms like Spatial Logics (SL), have emerged to address this. Previous projects, EU FP7 QUANTICOL and PRIN 2017 IT-MATTERS, advanced the <i>Spatial Logic of Closure Spaces</i> (SLCS), enabling uniform reasoning on nearness and reachability in diverse domains. Extensions include spatio-temporal models based on bigraphs. Free tools like TopoChecker and VoxLogicA facilitate model checking, applied to reasoning about smart transportation and medical imaging. SLCS enhances reliable analysis, and practical tools like VoxLogicA cater to digital imaging needs. Spatial Logics offer powerful solutions for space-time reasoning in smart systems.</p> <p>This project aims to advance the theory and implementation of spatial logics, by enabling spatio-temporal analysis in sequences of images (e.g., analysis of videos or longitudinal studies in healthcare) and by integrating spatial model checking with neural networks, combining the precision of the latter with the expert-driven monitoring of requirements. In particular, the main aim of this project is to study and develop extensions of existing spatial logics (in particular SLCS), in order to deal with temporal, binding and hierarchical aspects. We aim at a good tradeoff between expressivity, usability, and decidability issues.</p> <p>The outcomes of this project are multifold. First, the project will define the syntax and semantics of SLCSB, a novel spatio-temporal logic with binding quantifiers. Secondly, this will be the basis for a novel hybrid architecture, integrating logical primitives with a state-of-the-art neural network. Third, the project will yield novel hybrid methods for image segmentation in medical images (such as in the estimation of cortical thickness and tumor-infiltrating lymphocytes in breast cancer).</p>
Objectives of the project	<p>The main aim of this project is to study and develop extensions of existing spatial logics (in particular, SLCS), to deal with temporal, binding and hierarchical aspects. The design choices in this project are motivated by real-world case studies, such as medical imaging and cyber-physical</p>



	<p>systems. They will provide fundamental inputs as well as get feedback during the implementation phase.</p> <p>The first objective is defining the syntax and semantics for a Spatio-Temporal Logic of Closure Spaces with Binding (STLCSB). The plan is to extend the existing SLCS with modalities and techniques from temporal logics, drawing inspiration from evolving closure spaces. The introduction of a "binding" construct, like nominal quantification, will allow for abstract object identification. The feasibility of this objective is ensured by the team's expertise in nominal logics and quantified modal logics, as well as their experience in developing the SLCS logic and implementing the TopoChecker tool.</p> <p>The second objective aims to incorporate hierarchically structured models into STLCSB, enabling comprehensive analysis of sparse and scattered spatial data. Bigraphs, which are graph-like structures designed for modeling hierarchical distributed systems, naturally represent these multi-level structures.</p> <p>By combining the strengths of the team and leveraging previous research in spatial and temporal logics, the project will advance the field by introducing novel concepts and tools for reasoning about evolving closure spaces, multi-scale specifications, and holistic analysis of heterogeneous spatial data.</p>
<p>State of the art</p>	<p>The last decade has seen a novel focus for Spatial Logics (SL) [1] in the field of formal methods, shifting the paradigm from deduction and theorem proving to fully automated methods such as model checking and monitoring. To this end, SL took the central stage of the EU FP7 Project QUANTICOL and of the PRIN 2017 IT-MATTERS, whose main goal was the development of techniques for the specification, implementation, and validation of trustworthy smart systems. Smart systems can be thought of as sets of spatially distributed entities, connected in a graph, that evolve over time; thus, complex requirements of such systems are specified by logics that predicate over the spatial and the temporal domains.</p> <p>The outcome of these previous projects includes advances in the theoretical foundations and in tool implementations for the <i>Spatial Logic of Closure Spaces</i> (SLCS), a logical language capable of reasoning uniformly on nearness and reachability [2], with application domains ranging from medical imaging to cyber-physical systems and, more recently, simplicial complexes and 3D meshes [4]. Furthermore, SLCS was extended to a class of spatio-temporal models based on bigraphs in [6]. More recent work includes categorical models of logics over closure spaces [3]. The problem of model checking for SLCS has been addressed in free and open-source tools. The first prototype TopoChecker operates on graphs and was used for applications in smart transportation and early experiments in medical imaging [5]. The second-generation tool VoxLogicA was specifically designed for 2D and 3D digital imaging [7].</p> <p>These results encourage us to enrich the logics with temporal and binding operators and to improve its verification tools, as well as exploring novel application domains. To this end, we will consider both theoretical and implementation advances in quantified temporal logics [8], nominal logics [9], hierarchically structured models such as hierarchical graphs and bigraphs [10,11].</p>





Project description	First (months 1-6), we will consider logical primitives for temporal aspects, aiming at a good tradeoff between expressivity, usability, and decidability issues. To this end, we will adapt the experience from TopoChecker but customised to the applications we are considering, i.e., medical imaging and cyber-physical systems. Then (months 7-12), we will integrate the logics with primitives for bindings, inspired by nominal and quantified logics. From a theoretical point of view, we expect these primitives to arise from a SLCS model in suitable categories, extending recent work (e.g. [3,8]).
Possible application potentialities	We envision a plurality of outcomes. 1) Theory: the project will define the syntax and semantics of SLCSB, a novel spatio-temporal logic with binding quantifiers, with both a "flat" semantics, based on snapshot models, and a "hierarchical" semantics, based on bigraphs. The hierarchical semantics will induce further logical operators related to changing the abstraction level. 2) Formal methods and Artificial Intelligence: the project will introduce a novel hybrid architecture, integrating logical primitives with at least one state-of-the-art neural network. 3) Healthcare: the project will research novel hybrid methods for glioblastoma segmentation, estimation of cortical thickness, and evaluation of tumor-infiltrating lymphocytes in breast cancer.
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- Progetto/fondi: PRIN 2022 – "Spatio-Temporal Enhancement of Neural nets for Deeply Hierarchical Automatised Logic (STENDHAL)"; Prot. n. 20228KXFN2. Decreto di finanziamento n. 959 del 30/06/2023 - Settore PE6. Codice CUP G53D23002810006. Ministero dell'Università e della Ricerca (Finanziato dall'Unione Europea, NextGenerationEU).

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