Allegato 1

MODELLO PER LA PRESENTAZIONE DEL PROGETTO DI RICERCA

a) **Project title**: An ISEQL-based Framework to support Doctors and Patients in Monitoring Diabetes through an Interactive Web Application.
b) Proposer (PI): Prof. Fabio Persia.
c) **Proposer's Academic Position:** Associate Professor in the scientific-disciplinary sector *INFO/01*.
d) **Curriculum vitae of the proposer (max 5000 characters) with ASN 2024/26 indicators at the deadline of the call (only for research projects):** Fabio Persia is (since November 2023) an associate professor at DISIM, University of L'Aquila, after having been an RTD/B at the same department. Previously, he was RTD/A at the Faculty of Computer Science of the Free University of Bolzano, from May 2015 to October 2020. He obtained his master's degree and PhD in Computer Engineering from the University of Naples Federico II in 2009 and 2013, respectively. During his PhD, he was a visiting scholar at the University of Maryland, College Park (USA) for six months, under the supervision of Prof. V.S. Subrahmanian. He was also a Postdoctoral Research Fellow at DIETI at the University of Naples Federico II from July 2013 to April 2015.

He obtained his ASN as Associate Professor in ING-INF/05 and INF/01 in November 2020. His citation data are listed below:

- **Scopus Citation Report**: Total Citations: 930 – H-index: 17.
- **Google Scholar Report**: Total Citations: 1301 – H-index: 21.
- **ASN indicators: Number of articles in the last 10 years:** 12 (First Tier Candidates: 9); **Numero di citazioni negli ultimi 15 anni**: 930 (Candidati Prima Fascia: 304); **H-index ultimi 15 anni**: 17 (Candidati Prima Fascia: 10).

His research interests include the fields of event detection and analysis in large-scale databases applied to multimedia data, semantic analysis, and security, as demonstrated by numerous articles published in high-level journals (such as TKDE, TOIT, and VLDBJ) and conferences

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(IJCAI, EDBT, CIKM, ECAI). During his PhD, he focused primarily on identifying unexplained activities in a sequence of time-stamped observation data.

Since arriving in Bolzano (May 2015), he has been working on a highly interactive event detection system in the context of video surveillance. Specifically, the system is based on an extension of relational algebra, ISEQL, enriched with powerful temporal operators and supported by an intelligent graphical interface. These temporal operators were implemented by defining some very efficient join algorithms [1]. In addition, he has worked on an innovative route planning systems to improve the user experience in orienteering [4, 5, 6].

Subsequently, since arriving in L'Aquila (November 2020), he has been working with the DISIM artificial intelligence research group; in particular, he has focused on the application of complex event processing techniques to the field of e-health, with the aim of improving patient monitoring [2, 3, 7, 8, 9, 10].

In addition, he has so far managed to attract (as PI) approximately € 50,000 in funding to finance part of his research work, and since 2016 he has been an officer of the IEEE Computer Society Technical Committee on Semantic Computing (TCSEM) with responsibility for conference activities.

Selected Publications from 2021 to 2025

[1] D. Piatov, S. Helmer, A. Dignös, *F. Persia, Cache-Efficient Sweeping-Based Interval Joins for Extended Allen Relation Predicates*, The VLDB Journal 30, 2021.

[2] G. Viozzi, *F. Persia, D. D'Auria* (2025). *Automated recognition of humerus anomalies with convolutional neural networks*. Image and Vision Computing, 2025.

[3] L. Tucceri, *F. Persia*, *A Complex Event Processing Framework for Patients with Diabetes*, 2024 IEEE AIxDKE, 2024.

[4] A. Pio, *F. Persia*, G. Pilato, D. D'Auria, M. Ge, *SPARK: Semantic Planning with Augmented Retrieval and Knowledge – An LLM-Based Orienteering System*, ECAI, 2025.

[5] G. Pilato, *F. Persia*, M. Ge and D. D'Auria, *Social Sensing for Personalized Orienteering Mediating the Need for Sociality and the Risk of COVID-19*, in IEEE Transactions on Technology and Society, 2022.

[6] G. Pilato, *F. Persia*, M. Ge, T. Chondrogiannis, D. D'Auria, *A Modular Social Sensing System for Personalized Orienteering in the COVID-19 Era*, ACM Trans. Manage. Inf. Syst., 2023.

[7] C. M. Bertoncelli, S. Costantini, *F. Persia*, D. Bertoncelli, D. D'Auria, *PredictMed-epilepsy: A multi-agent based system for epilepsy detection and prediction in neuropediatrics*, Computer Methods and Programs in Biomedicine, 2023.

[8] L. De Lauretis, *F. Persia*, S. Costantini, D. D'Auria, *How to leverage intelligent agents and complex event processing to improve patient monitoring*, Journal of Logic and Computation, 2023.

[9] L. De Lauretis, *F. Persia*, S. Costantini, *A Smart Ecosystem to improve Patient Monitoring using Wearables, Intelligent Agents, Complex Event Processing and Image Processing*, 2022 IEEE ISCC, 2022.

[10] *F. Persia*, S. Costantini, C. Ferri, L. De Lauretis, D. D'Auria, *A Smart Framework for Automatically Analyzing Electrocardiograms*, IEEE TransAI 2021, 2021.

e) Any members of the research team

a. Dr. Daniela D'Auria, Universitas Mercatorum, Italy.
b. Prof. Raffaele Russo, Pineta Grande Hospital, Caserta, Italy.
c. Dr. Alfonso Fedele, Pineta Grande Hospital, Caserta, Italy.

f) ERC research area of reference for the proposal

a. Artificial intelligence, intelligent systems, multi agent systems (50 %).
b. Web and information systems, database systems, information retrieval and digital libraries, data fusion (25 %).
c. Diagnostic Tools, Therapies and Public Health (25 %).

g) Abstract

Blood glucose levels must be continuously monitored in order to manage diabetes and avoid complications. To this end, this project focuses on proposing a complete framework, supported by an interactive web application that also works effectively on mobile devices,

capable of analyzing glucose time series data to model different glycemic conditions, from normal to abnormal or extremely abnormal. More specifically, our proposed architecture will include a Data Crawler for raw data extraction, an Interval Action Detector for event annotation, and a High-Level Event Detector leveraging the ISEQL language for complex event identification. In summary, the system will enable doctor–patient interaction through a web application, including sharing of raw data and automatically detected short-term events, and also support effective long-term modeling and detection of innovative high-level events that improve understanding of glucose behavior for personalized therapeutic strategies.

h) Project Description (max 8,000 characters, including any bibliographic references)

a. State of the Art

Vital sign monitoring plays a critical role in modern telemedicine, enabling remote healthcare and continuous patient supervision [11, 12]. More specifically, continuous glucose monitoring (CGM) systems have become a valuable tool in diabetes care, enabling real-time collection of glucose data and allowing both patients and doctors to respond more effectively to fluctuations in blood glucose levels.

Relevant works in the literature, such as Speracino et al. [13], analyze the use of CGM devices to collect real-time glycemic data, enabling more accurate predictions. Additionally, Georga et al. propose the METABO system [14], which is an innovative solution for diabetes management that integrates advanced technologies to collect and analyze patient data in real time. Moreover, Asad et al. [15] apply Feedforward Neural Networks (FNNs) for predicting blood glucose levels using historical data from CGM systems. These models are designed to process sequences of past glucose measurements. This study could provide a deeper understanding of high-level events by predicting glucose levels and the possible events that follow.

However, such related work is only capable of detecting short-term events in a timely manner, but none of them provides an accurate long-term analysis of events that doctors may overlook.

References

[11] V. Chauhan, S. Galwankar, B. Arquilla, M. Garg, S. Somma, A. El-Menyar, V. Krishnan, J. Gerber, R. Holland, and S. Stawicki, "Novel coronavirus (COVID-19): Leveraging telemedicine to

optimize care while minimizing exposures and viral transmission," J. Emergencies, Trauma, and Shock, 2020.

[12] J. E. Hollander and B. G. Carr, "Virtually Perfect? b711 for Covid-19," N. Engl. J. Med., vol. 382, no. 18, pp. 1679–1681, 2020.

[13] G. Sparacino, F. Zanderigo, S. Corazza, A. Maran, A. Facchinetti, and C. Cobelli, "Glucose Concentration can be Predicted Ahead in Time From Continuous Glucose Monitoring Sensor Time-Series," IEEE Trans. Biomed. Eng., 2007.

[14] E. Georga, V. Protopappas, and D. I. Fotiadis, "Data mining for blood glucose prediction and knowledge discovery in diabetic patients: The METABO diabetes modeling and management system," in 2009 Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. (EMBC), Minneapolis, MN, USA, 2009,

[15] M. Asad, U. Qamar, B. Zeb, A. Khan, and Y. Khan, "Blood Glucose Level Prediction with Minimal Inputs Using Feedforward Neural Network for Diabetic Type 1 Patients," in Proc. 2019 11th Int. Conf. Machine Learning and Computing (ICMLC '19), New York, NY, USA, 2019.

b. Goals

In this context, the main goal of this project is to propose an interactive framework to support doctors and patients in monitoring diabetes, enabling modeling and identification of long-term events that current medical apps are unable to provide.

More specifically, the framework will be provided with:

- An efficient and effective back-end based on ISEQL [1];
- A smart front-end that will allow doctors and patients to interact effectively with each other.

Using Python tools, such as Pandas for data manipulation and NumPy for numerical analysis, we prepare the dataset for exploration. Then, we leverage ISEQL [1] (Interval-based Surveillance Event Query Language) to detect complex patterns within the glucose data. ISEQL is a language that originally extends the Allen's interval relationships, and is particularly well-suited for this task, as it allows to define complex events by combining simpler interval-based occurrences. Additionally, it is supported by very efficient algorithms [1]. More specifically, this project will focus on modeling and identifying high-level Simple Events and Aggregated Events; by

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distinguishing between simple and aggregated events, our approach allows for a deeper understanding of complex glycemic patterns, ultimately contributing to improved diabetes management and better clinical outcomes for patients.

The overall pipeline in which the proposed framework for glucose level monitoring is integrated is illustrated in Fig. 1. Specifically, the framework is organized into three main components (Fig. 2): the *Data Crawler*, the *Interval Action Detector*, and the *High-Level Event Detector*. On top of the back-end, an intuitive graphical user interface allows doctors and patients to share raw data, simple and aggregated high-level events; additionally, they can also interact with each other by commenting on the automatic analysis generated by the system.

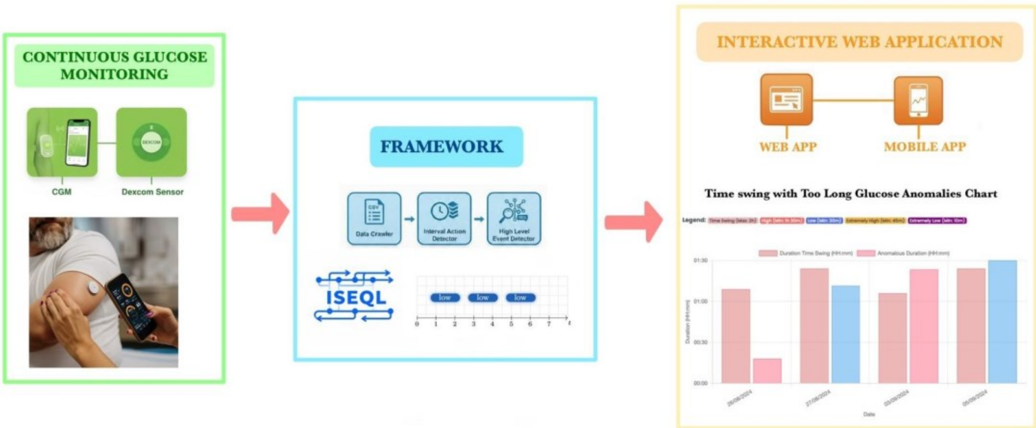

Fig. 1 – Overall Pipeline

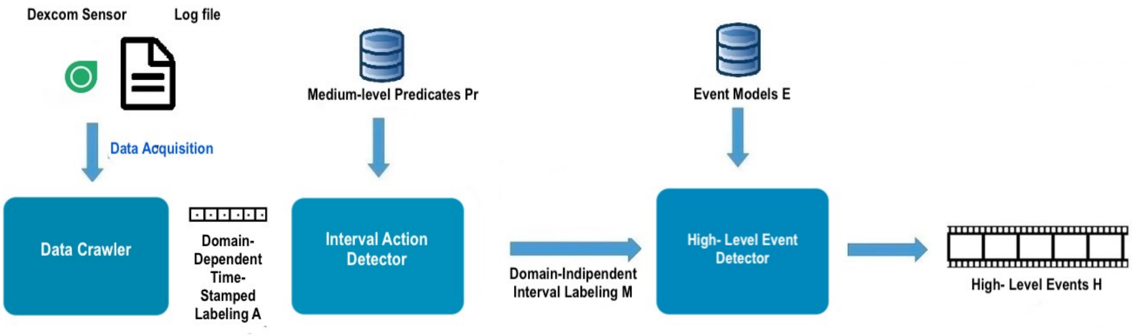

Fig. 2 – Overall Architecture

- **Data Crawler**: The *Data Crawler* extracts data from a continuous glucose monitoring sensor, specifically *Dexcom* (https://www.dexcom.com/it-EN/dexcom-g7). The raw events correspond to these periodic glucose level measurements. Consequently, this level depends heavily on the application domain and allows to obtain data with specific timestamps.
  Thus, the Data Crawler must include all the components necessary to extract and process this time-stamped data, such as a library for collecting and managing data from Dexcom.

- **Interval Action Detector**: Then, the *Interval Action Detector* transforms the raw events into simple events with a format that is mainly unaffected by the application domain (Fig. 3). This separates High-Level Event Detection from the technical details of raw events.
  Consequently, this level produces a set *M* of medium-level annotations that refer to intervals of glucose level readings, with timestamps, corresponding to the medium-level predicates *Pr* stored in the knowledge base. The events generated by this level already contain some aggregated data, thus simplifying the detection of high-level events.

- **High-Level Event Detector**: Ultimately, at the highest level, a user can build complex events of real interest using medium-level events and simpler high-level events as building blocks. Consequently, the *High-Level Event Detector* takes a set *E* of event patterns and determines whether any of these events occur in *M* (Fig. 4). We focus on analyzing time intervals associated with abnormal blood glucose events, and classify these events into *Simple High-Level Events* (Fig. 6) and *Aggregated High-Level Events* (Fig. 7). In order to build our knowledge base *E* on both categories of high-level events, we use ISEQL (Fig. 5).

INTERVAL LABELING FOR A PATIENT

Predicate	Patient	Start Time	End Time
Normal	Diego	13/02/2024 00:01:32	13/02/2024 10:46:33
High	Diego	13/02/2024 10:51:33	13/02/2024 11:06:32
Normal	Diego	13/02/2024 11:11:33	13/02/2024 12:11:33

Fig. 3 – Interval Labeling for a Patient

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First Event	*Second Event*	*Duration*	*Event Interval*
High	Low	00:50:00	2024-04-17 08:00:00–08:50:00
Low	High	01:20:00	2024-03-01 11:40:00–13:00:00

Fig. 4 – Time Swings for a Patient

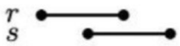
Relation	Doodle	Formal definition
START PRECEDING		$r.T_s \leqslant s.T_s < r.T_e$ $s.T_s - r.T_s \leqslant \delta$
END FOLLOWING		$r.T_s < s.T_e \leqslant r.T_e$ $r.T_e - s.T_e \leqslant \varepsilon$
BEFORE		$r.T_e \leqslant s.T_s$ $s.T_s - r.T_e \leqslant \delta$
LEFT OVERLAP		$r.T_s \leqslant s.T_s < r.T_e \leqslant s.T_e$ $s.T_s - r.T_s \leqslant \delta$ $s.T_e - r.T_e \leqslant \varepsilon$
DURING		$s.T_s \leqslant r.T_s \wedge r.T_e \leqslant s.T_e$ $r.T_s - s.T_s \leqslant \delta$ $s.T_e - r.T_e \leqslant \varepsilon$

Fig. 5 – ISEQL interval relations

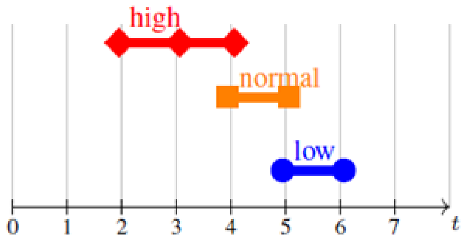


Fig. 6 – Time Swing from high to low in one hour

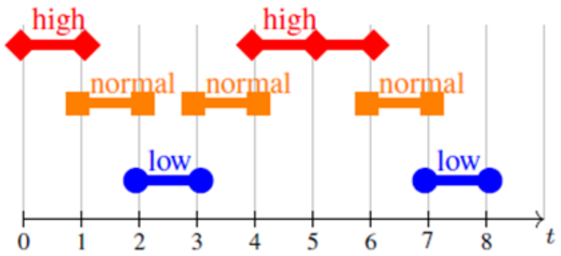


Fig. 7 – Rapid Time Swings between high and low glucose events within a few hours

c. Methodology

The interdisciplinary project will involve diverse but perfectly complementary profiles; specifically, Dr. Daniela D'Auria will provide her valuable perspective as a biomedical engineer; in addition, Prof. Raffaele Russo, a world-renowned orthopedic surgeon, supported by Dr. Alfonso Fedele, will conduct his own medical assessment of various aspects of the framework and facilitate interaction with the Endocrinology and Diabetology Department of Pineta Grande Hospital in Castelvolturno. Therefore, the heterogeneity of the research group will help to cover all aspects of the proposal, while also allowing multiple tasks to be managed in parallel. In fact, while part of the team could focus on back-end development and testing (WP1), the other part could focus on the front-end (WP2). Subsequently, the entire team will devote itself to WP3.

d. Work Plan

Overall, the project is divided into three work packages. Each of these is associated with a deliverable, and we have two milestones in total.

- **WP1**: front-end implementation (4 months).
- **WP2**: back-end implementation (4 months).

  Milestone 1: first prototype developed.

- **WP3**: development and testing of the entire system using real data (3 months).

  Milestone 2: efficient and effective prototype developed.

The project will last ten months. The Gantt chart in Fig. 8 illustrates the breakdown into individual WPs.

Months	1	2	3	4	5	6	7	8	9	10
WP1										
WP2 (Milestone 1)							M1			
WP3 (Milestone 2)										M2

Fig. 8 – Gantt chart

i) Originality and innovation of the proposal and impact in terms of the significance of the progress made in basic research for the relevant scientific community

The interdisciplinary project was defined in collaboration with the research group described in the previous sections. Specifically, the team includes Dr. Daniela D'Auria from Universitas Mercatorum, a biomedical engineer and telemedicine expert, Prof. Raffaele Russo from Pineta Grande Hospital in Caserta, a world-renowned orthopedic surgeon, supported by Dr. Alfonso Fedele. The doctors will certainly be of great help, first of all for an initial technical opinion, and then to enable us to liaise effectively with the endocrinology and diabetology department at Pineta Grande Hospital in Castelvolturno. As highlighted in the previous sections, the project proposal presents both significant elements of originality and innovation, and a strong impact in terms of the relevance of the advancement of basic research for the scientific community in the scientific discipline INFO/01.

Specifically, the main elements of originality and innovation in the proposal are linked to its application in the medical context, where the adoption of complex event processing tools can optimize diagnosis times and therefore be of great support to healthcare personnel. In fact, the objective of this project is to propose a model that not only improves diagnostic efficiency but also ensures that its long-term findings are effective and verifiable by medical professionals.

To sum up, compared to the mentioned related work, our system will present the following advantages:

- generalizable to heterogeneous domains;

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- flexible in defining new event patterns, thanks to the robust support of an intelligent graphical user interface;
- combinable with machine learning techniques to predict short and long-term glucose levels and to automatically learn other complex event patterns that can be modeled and identified using ISEQL;
- effective and efficient in detecting the occurrences of events of interest;
- significantly improves glucose level analysis;
- introduces novel high-level event types that are not commonly available in other applications. For example, we will define events such as "Time Swing" and its variants, which identify specific patterns in glucose level fluctuations over time.

As regards the project relevance in terms of advancement in basic research, it will exploit and further refine the functionalities of a language – ISEQL [1] - previously defined for complex event processing. Specifically, we plan to formally define and add further constraints to the language, which will be very helpful for effectively modeling complex events. Additionally, the detection of complex events will be significantly improved by exploiting the very efficient implementation of the new interval operators proposed in [1]; this will be allowed by mapping the cardinality and the overlap percentage constraints as a function of the interval-timestamp join, which is the core algorithm for interval predicates defined in [1].

Approximate Budget (Table 1)

The total requested budget for this proposal is 15,000 €, broken down as follows:

Voce di spesa	*Importo (Euro)*
Borse di ricerca (art.2 del Regolamento per il conferimento di borse di ricerca attualmente in vigore)	8,000 €
Rinnovo assegni di ricerca	
Materiali di consumo	
Attrezzature, strumentazioni, software	
Missioni	5,000 €
Acquisto prodotti ritenuti necessari per la realizzazione del progetto (es. materiale	

librario, licenze per l'accesso a banche dati, ecc.)	
Pubblicazioni, organizzazione di convegni e workshop	2,000 €

Table 1 – Approximate budget

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