**PhD Position Offer**

**Formal Verification of Contextuality in Quantum Programs**

Supervisor: A. Giorgetti\(^1,2\)
Co-Supervisor: Frédéric Holweck\(^1,3\)

\(^1\) Université Bourgogne Franche-Comté
\(^2\) Université de Franche-Comté
Institut FEMTO-ST (UMR CNRS 6174)
Département d’Informatique des Systèmes Complexes (DISC)
25030 Besançon cedex
alain.giorgetti@femto-st.fr

\(^3\) Université de Technologie de Belfort-Montbéliard (UTBM)
Laboratoire Interdisciplinaire Carnot de Bourgogne (ICB UMR 6303)
90000 Belfort
frederic.holweck@utbm.fr

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<th>Laboratory</th>
<th>FEMTO-ST Institute, DISC (Département d’Informatique des Systèmes Complexes)</th>
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<tr>
<td>Institution</td>
<td>UBFC, Université de Bourgogne Franche-Comté</td>
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<tr>
<td>Time span</td>
<td>3 years starting from October 2022</td>
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<td>Funding</td>
<td>36 months doctoral contract at UBFC</td>
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<tr>
<td>Contact</td>
<td><a href="mailto:alain.giorgetti@femto-st.fr">alain.giorgetti@femto-st.fr</a></td>
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## 1 Scientific Context

Contextuality is a quantum phenomenon that contributes significantly to the superiority of quantum programs, compared to their classical counterparts. However, there is still much to discover, understand and explain about how this benefit works. Formal program verification brings together various techniques of computer-assisted static or dynamic analysis, which not only increases confidence in the software, but may also deeply and rigorously explain how it works. These techniques and the corresponding tools are gradually adapted to quantum programs, but much remains to be done.

This thesis subject proposes to take up the challenge of the specification and formal verification of properties of quantum programs, and of automation of the latter, focusing on properties related to the
phenomenon of quantum contextuality. These programs and their optimizations are complex enough to raise questions about their good properties, including correctness, completeness and algorithmic complexity, which require rigorous justifications.

Regarding contextuality, some properties are known, but they have often been obtained either by manual mathematical calculations or by automated calculations for a small number of quantum bits. We propose to assist the verification of these properties, and the discovery of other analogous properties, in particular with the aid of proof assistants, such as Why3 [1] or Coq [3], to establish these properties with certainty and regardless of the number of quantum bits.

This challenge will be met through adaptations of formal proof and automatic test techniques, based on the current research results in verification of quantum programs. Particular attention will be paid to characterizations of contextuality based on contextual geometries [8, 4, 5, 7].

2 PhD Objectives

The PhD is expected to achieve the following objectives.

• An extended state of the art about techniques and tools for the formal specification and verification of quantum programs, including Qbricks [2] and VOQC [6].

• In the input languages of these tools, formalization of qualitative and quantitative characterizations of contextuality.

• In these languages, formalization of quantum programs, and formal specification of the evolution of contextuality in these programs.

• Formal proofs of existing but yet unproved quantum algorithms, by means of existing quantum proof tools, or their adaptation.

• Dissemination of this work in the international scientific community.

3 Work Environment and Framework

The research will take place at the premises of the DISC department at the FEMTO-ST institute, located in Besançon, France. The PhD student will settle in the VESONTIO research team, whose research domains are the formal specification and verification of programs by test or by proof, based on program models. The work will partly be realized in relation with other members of the ANR project EPiQ.

4 Candidates Profile and Application

The candidates should have a master degree in computer science, with proved skills in the general area of formal methods, formal specification, verification and validation. Skills in Why3 or Coq proof environments will be appreciated. Proficiency in English is important, and the candidates shall master writing and presenting scientific work.

The application consists of one PDF file comprising:

• a CV,

• a letter of motivation justifying the interest for this particular PhD subject,

• a recommendation letter from the supervisor of the master’s thesis, with contact details,

• a short summary of the master’s thesis,

• the transcript of records of the license and master degree (or equivalent), with rank and size of the promotion,

• if possible, a certificate of language level in French and English.
The application should be sent by e-mail to alain.giorgetti@femto-st.fr.
Applications will be reviewed upon receipt. Short-listed candidates may be contacted for an online interview. The recruitment process ends when a sufficient number of adequate applications has been processed. The targeted start of the thesis is at the earliest between September and November 2022.

References


