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EPSRC Reference: EP/I020020/1

Standard Peer Review

Document Status: With Council

none

Applicant Details

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|-----------|------------------------|--------------|--------------------------|
| Applicant | Dr Thorsten Altenkirch | Organisation | University of Nottingham |
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Title of Research Project

Quantum Computing Meets Type Theory: A Framework for Certified Quantum Information Processing

Review Information

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|-------------------|------------|---------------------|--------|
| Response Due Date | 06/12/2010 | Reviewer Reference: | 94A25H |
|-------------------|------------|---------------------|--------|

Research Council Contact Details

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Quality

Please comment on the degree of excellence of the proposal, making reference to:

- (1) The novelty, relationship to the context, and timeliness;
- (2) The ambition, adventure, and transformative aspects identified;
- (3) The appropriateness of the proposed methodology.

(For multi-disciplinary proposals please state which aspects of the proposal you feel qualified to assess)

The proposal builds on PhD work of Alexander Green, in which, together with the PI, he introduces preliminary ideas for a framework for certified quantum computation based on the Quantum IO monad. The work proposed here aims to develop and extend this framework and apply it to the design and validation of quantum algorithms and protocols. A dependently typed system such as Agda, Coq or Epigram 2 will be chosen for the implementation and a certified compiler will provide a common platform for translations to different formalisms and architectures. The research will also leverage work by others on high level structures for quantum computation. The work proposed will offer further insights into quantum programming, leading to both theoretical and practical contributions. Since the applicants have worked in this area for a few years, the methodology is a natural continuation of their ongoing work. In this sense, perhaps the project is not that adventurous and does not involve a high risk element. But it also means that the project is likely to produce good results without too much lead time.

The excellence of this proposal has been demonstrated

| | | |
|-------------------------------------|-------------------------------------|---|
| <input type="checkbox"/> Not at all | <input type="checkbox"/> Adequately | <input checked="" type="checkbox"/> Fully |
|-------------------------------------|-------------------------------------|---|

Impact

Please comment on the extent to which the proposal shows the potential impact of the project, making reference to:

- (1) The relevance and appropriateness of any beneficiaries or collaborators;
- (2) Whether appropriate routes and resources have been identified for dissemination and knowledge exchange.

The beneficiaries are mainly academic. Other researchers in the area will benefit from new and improved techniques for design and verification of quantum algorithms and protocols. Designers of quantum systems, especially for cryptography,

are good targets for this kind of work. This is mentioned; however, a more detailed plan with a concrete route towards working with a manufacturer would have strengthened the proposal. The PI has participated in QNET, a recently concluded EPSRC network and has good links with universities in the UK. The routes for dissemination and knowledge exchange are standard and appropriate. The work package WP5, which proposes the organisation of a workshop on Formal Methods in Quantum Computing, would be a valuable contribution to sustain and build the community in this area.

Potential impact has been demonstrated

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|-------------------------------------|--|--------------------------------|
| <input type="checkbox"/> Not at all | <input checked="" type="checkbox"/> Adequately | <input type="checkbox"/> Fully |
|-------------------------------------|--|--------------------------------|

Applicant

Please comment on the applicant's ability to deliver the proposed project, making reference to:

- (1) Appropriateness of the track record of the applicant(s);
- (2) Balance of skills of the project team, including academic collaborators

The PI is a respected researcher in the UK and abroad, with a good track-record of publishing in reputable journals and conferences. He has led or participated in various research projects. The co-applicant is a recent Ph.D. who has already demonstrated a good working knowledge in areas relevant to the project, and seems to possess the required skills for directing the implementation.

The applicant's track record and ability to deliver this project is

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|--|-----------------------------------|---|
| <input type="checkbox"/> Not appropriate | <input type="checkbox"/> Adequate | <input checked="" type="checkbox"/> Appropriate |
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Resources and Management

Please comment on the effectiveness of the proposed planning and management and on whether the requested resources are appropriate and have been fully justified.

The general planning and management seems appropriate for a project of its kind. The work plan is detailed, and resources are justified. The resources requested are standard, the main components being the salary for a postdoctoral researcher and funding for a PhD student. If I am not mistaken, there is a mismatch between the sum requested for PCs and that specified in the JoR, but this is not important. Given that the background of the named researcher is directly relevant to the project, work can begin immediately and progress could be made at a good pace.

The level of planning and justification of resources is

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| <input type="checkbox"/> Unacceptable | <input checked="" type="checkbox"/> Adequate | <input type="checkbox"/> Good |
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Overall Assessment

Please summarise your view of this proposal

The proposal continues an interesting line of work pursued by the proposers over the last few years. It is timely and potentially valuable. The work has a good theoretical basis and has interesting applications. However, the proposal as it stands, lacks details which would have made the case more convincing. The work packages are high level descriptions of the direction the project is likely to follow rather than a more concrete outline of planned work. Applications are mentioned only briefly and not considered in much depth, which leaves some doubt as to whether the proposed framework is suitable for handling issues which arise in practical systems. The proposal also needed to be written more carefully with further attention to details. Overall, I think it is a good proposal by capable researchers but the components could have been specified more precisely.

My judgement is that:

- 1) This proposal is scientifically or technically flawed
- 2) This proposal does not meet one or more of the assessment criteria
- 3) This proposal meets all assessment criteria but with clear weaknesses
- 4) This is a good proposal that meets all assessment criteria but with minor weaknesses
- 5) This is a strong proposal that broadly meets all assessment criteria
- 6) This is a very strong proposal that fully meets all assessment criteria

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| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1 | 2 | 3 | 4 | 5 | 6 |

My confidence level in assessing this is:

| | | |
|--------------------------|--------------------------|-------------------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| Low | Medium | High |

Reviewer Expertise

Please indicate your areas of expertise that are relevant to your assessment. Take care not to reveal your identity to the applicant.

Theoretical Computer Science, in particular, Foundations of Programming Languages, Formal Methods, and Information Security.

