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Standard
Peer Review

EPSRC Reference: EP/I020020/1

Document Status: With Council

Applicant Details

Applicant	Dr Thorsten Altenkirch	Organisation	University of Nottingham

Title of Research Project

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

Review Information

Response Due Date	29/11/2010	Reviewer Reference:	CFU8YX

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 proposed project is clearly within the mainstream of theoretical computer science and its applications to quantum computation, in that it proposes to apply the 'big guns' of functional programming, type theory, monads, and dependent types to quantum computation. This is a complementary approach to other UK and worldwide institutions and their focus on logical and categorical methods - however, the tools proposed are novel, and rely on preliminary work of the principle investigator and his colleagues.

This methodology is appropriate, in that monads are the standard way of dealing with side-effects in functional programming, and both the proposal and prior work of the PI make a good case that measurement in quantum computation should be thought of in exactly these terms. The proposed extension to this, via the introduction of dependent types, appears essential in order to make a clear type-theoretic split between (irreversible) measurement and (reversible) unitary evolution. This follows the broad picture of how one might expect type theory / functional programming to be applied to quantum computation, and a good case is made that the proposers are able to make this concrete.

The project appears to be ambitious, but eminently achievable. The theoretical computer science required is certainly high-level, with corresponding potential pay-offs, and the overall aims of the project are such that either total or partial success would certainly be of interest. Crucially, the proposers talk about both potential programming languages for quantum computers, and verifying existing quantum algorithms and protocols. Given that many quantum computing researchers are now expressing skepticism that many new algorithms remain to be discovered, this dual emphasis is both important and timely.

The excellence of this proposal has been demonstrated

□ Not at all	□ Adequately	☒ 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 immediate beneficiaries of this project will be workers in the very active research community in quantum computation - both in the UK and worldwide. Impact in terms of actual physical quantum computation must be seen as a long-term benefit; however verification of quantum communication protocols is something that is needed immediately, for very practical purposes.

The routes to dissemination of results are entirely suitable for such a project, with the proposed workshop providing additional benefit.

The track record of the researchers on this project demonstrates that dissemination and knowledge exchange will take certainly place within the academic community, and it is work noting the wider links of the collaborators on this project. In particular, the links to both Oxford and Edinburgh suggests that outcomes of his project will be disseminated widely.

Potential impact has been demonstrated

□ Not at all	□ Adequately	☒ 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

I am certainly familiar with the work of Thorsten Altenkirch and the other project members, in both quantum computation and other fields. Given that most progress in this particular approach to quantum computation has been made by the proposers themselves, it is doubtful that this project could be carried out by any other team. The proposed RA is also entirely suitable for this project, given his background - including his PhD thesis - in this precise area.

The academic collaborators are also first-class, and are a substantial benefit to the projec

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

□ Not appropriate	□ Adequate	☒ Appropriate

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.

he timeline, division into work-packages, and overall management of this project is appropriate. Management is strongly based around a single institution, under the principle investigator. The resources requested are suitable for such a project, and the amount of time the PI proposes to dedicate to the project is probably required for its success.

In general, the resources requested per year seem modest. Thee 4 year length of the project is unusual, but seems appropriate. Given the division of work between the PI, RA and PHD student, it seems that training of future academics is a non-trivial part of this proposal, and 4 years seems reasonable for such a high-level PhD project.

The level of planning and justification of resources is

□ Unacceptable	□ Adequate	☒ Good

Overall Assessment

Please summarise your view of this proposal

My summary view is that this proposal is both interesting and achievable, and is one of the best proposals I have seen for some time. I look forward to seeing the outcomes of this project, and also expect that investigation of quantum computing along the lines proposed may also lead to entirely unexpected interesting results.

I think the decision to frame the project more widely than simply creating a quantum programming language for quantum computers is entirely appropriate, given the continuing lack of novel quantum algorithms - this project suggests a way in which to tools of theoretical computer science may nonetheless provide significant benefit.

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

My confidence level in assessing this is:

☐	☐	☐	☐	☐	☒
1	2	3	4	5	6

☐	☐	☒
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.

Quantum Computation
Category theory
Type Theory
Logic