

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY (PCT Rule 43bis.1)

To:

see form PCT/ISA/220

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference see form PCT/ISA/220	FOR FURTHER ACTION See paragraph 2 below
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International application No. PCT/EP2019/080689	International filing date (day/month/year) 08.11.2019	Priority date (day/month/year) 29.11.2018
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International Patent Classification (IPC) or both national classification and IPC
INV. G06N10/00

Applicant
INTERNATIONAL BUSINESS MACHINES CORPORATION

1. This opinion contains indications relating to the following items:


- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the international application
- Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA:  European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Fax: +31 70 340 - 3016	Date of completion of this opinion see form PCT/ISA/210	Authorized Officer Cilia, Elisa Telephone No. +31 70 340-0
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Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 - the international application in the language in which it was filed.
 - a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).
2. This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
 - a. forming part of the international application as filed:
 - in the form of an Annex C/ST.25 text file.
 - on paper or in the form of an image file.
 - b. furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
 - c. furnished subsequent to the international filing date for the purposes of international search only:
 - in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).
 - on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
4. In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>2, 7, 8, 10-12, 17, 18, 20</u>
	No: Claims	<u>1, 3-6, 9, 13-16, 19</u>
Inventive step (IS)	Yes: Claims	
	No: Claims	<u>1-20</u>
Industrial applicability (IA)	Yes: Claims	<u>1-20</u>
	No: Claims	

2. Citations and explanations

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

D1 SWAMIT TANNU ET AL: "Not All Qubits Are Created Equal", ARCHITECTURAL SUPPORT FOR PROGRAMMING LANGUAGES AND OPERATING SYSTEMS, vol. 1805.10224, no. v1, 25 May 2018 (2018-05-25), pages 1-12, XP055665644, 2 Penn Plaza, Suite 701 New York NY 10121-0701 USA ISBN: 978-1-4503-6240-5

D2 WILL FINIGAN ET AL: "Qubit Allocation for Noisy Intermediate-Scale Quantum Computers", ARXIV.ORG, CORNELL UNIVERSITY LIBRARY, 201 OLIN LIBRARY CORNELL UNIVERSITY ITHACA, NY 14853, 19 October 2018 (2018-10-19), XP081067707,

2 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claims 1, 3-6, 9, 13-16, and 19 is not new in the sense of Article 33(2) PCT and the subject-matter of claims 2, 7-8, 10-12, 17-18, and 20 does not involve an inventive step in the sense of Article 33(3) PCT.

2.1 Independent claims

2.1.1 In so far as the subject-matter of claim 1 can be understood, it is not new. D1 discloses:

A computer-implemented method (*subtitle, §V.C lines 1-3, 6-11, §VI.C*) comprising:
executing a calibration operation on a set of qubits, in a first iteration, to produce a set of parameters, a first subset of the set of parameters corresponding to a first qubit of the set of qubits, and a second subset of the set of parameters corresponding to a second qubit of the set of qubits (*page 2 left-hand column lines 22-23; §III lines 10-12*); and selecting the first qubit, responsive to a parameter of the first subset meeting an acceptability criterion; and forming a quantum gate, responsive to a second parameter of the second subset failing to meet a second acceptability criterion, using the

first qubit and a third qubit (*abstract lines 21-25; page 2 right-hand column lines 2-5; §V.A-B; §VI.A-B; page 10 right-hand column lines 10-11; §X lines 14-16, 25-30*).

- 2.1.2 An equivalent novelty objection may apply to claim 1 based on the disclosure of D2 (it is also observed that D2 directly refer to D1, hence the teachings of D1 are incorporated into those of D2):

A computer-implemented method (*page 1 right-hand column lines 7-8, 21-22*) comprising:
executing a calibration operation on a set of qubits, in a first iteration, to produce a set of parameters, a first subset of the set of parameters corresponding to a first qubit of the set of qubits, and a second subset of the set of parameters corresponding to a second qubit of the set of qubits (*page 2 left-hand column lines 1-12; Fig. 1(a)*); and selecting the first qubit, responsive to a parameter of the first subset meeting an acceptability criterion; and
forming a quantum gate, responsive to a second parameter of the second subset failing to meet a second acceptability criterion, using the first qubit and a third qubit (*page 2 right-hand column lines 39-42, 50-51; page 3 left-hand column lines 1-3, 6-9, right-hand column last three lines; page 4 left-hand column lines 1-5, 20-24, 53-55; Fig. 1(d); page 4 left-hand column lines Fig. 3*).

2.2 Dependent claims

- 2.2.1 Dependent claims 2-8, 10-18, and 20 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, as detailed in the following.
- 2.2.1.1 The subject-matter of claim 2 is not inventive. D1, which may be regarded as being the prior art closest to the subject-matter of this claim, fails to disclose the subject-matter of claim 2. However, D1 discloses re-calibration and periodical characterization of the qubit devices (*§III.D; Figure 9; §III.E lines 12-17*) and an iterative algorithm for qubit allocation and movement in which qubits are selected and deselected responsive to parameters meeting an acceptability criterion (*abstract lines 21-25; page 2 right-hand column lines 2-5; §V.A-B; §VI.A-B; page 10 right-hand column lines 10-11; §X lines 14-16, 25-30*).

- 2.2.1.1.1 Claim 2 does not specify, neither which kind of calibration operation is performed nor the kind of parameters produced and not even whether the second calibration aims at capturing, for instance, a parameter variation over time or different kind of parameters in two different calibration operations. A further technical effect of the distinguishing feature cannot be derived from the claim in the present language. Hence, the subject-matter of claim 2 cannot involve an inventive step. Please refer also to the clarity objections on independent claim 1 in Item VIII below. It is not clearly defined in the claim what is the final technical aim of the method.
- 2.2.1.1.2 Nevertheless, starting from D1, the mere of idea of deselecting a qubit based on parameters of a second calibration, appears as one of the several straightforward possibilities the person skilled in art would select, in accordance with the circumstances, without exercising inventive skill.
- 2.2.1.2 The same reasoning above applies *mutatis mutandis* to the subject-matter of corresponding claims 12 and 20, which are also considered as not involving an inventive step.
- 2.2.1.3 The subject-matter of claims 3 and 4 is considered to be implicitly disclosed in D1. D1 discloses, for instance, characterization of devices via error-rates during device calibration, which require executing a pre-determined operation and comparing an output of the pre-determined operation to an expected output (*page 2 left-hand column lines 22-33, §III lines 7-9*). Hence, the subject-matter of these claims is not new.
- 2.2.1.4 The same reasoning above applies *mutatis mutandis* to the subject-matter of corresponding claims 13 and 14, which is also considered not new.
- 2.2.1.5 In so far as it can be understood the subject-matter of claims 5 and 6 is disclosed in D1 (*subtitle, §V.C lines 1-3, 6-11, §V.A-C, §VI.A-C*). Hence, the subject-matter of these claims is not new.
- 2.2.1.6 The same reasoning above applies *mutatis mutandis* to the subject-matter of corresponding claims 15 and 16, which is also considered not new.
- 2.2.1.7 The subject-matter of claims 7 and 8 is not inventive. D1, which may be regarded as the prior art closest to the subject-matter of these claims, fails to disclose a lower/upper bound fixed on measurement error and coherence time (i.e. 4% and 50µs). The claimed thresholds have values that the person skilled in the art would consider and may empirically derive, in accordance with the circumstances (for instance the technology of the underlying quantum processor), without exercising inventive skill. The subject-matter of these claims

is not considered as involving an inventive step. Furthermore, D1 discloses a calibration for characterization of measurement errors and coherence times and shows an analysis of this characterization (§III.A-C; Figs. 6-8).

- 2.2.1.7.1 Additionally, the application as whole does not provide any technical justification for the specific choice of the bounds values.
- 2.2.1.8 The same reasoning above applies *mutatis mutandis* to the subject-matter of corresponding claims 17 and 18, which is also considered as lacking an inventive step.
- 2.2.1.9 In so far as it can be understood, the subject-matter of claims 10 and 11 is not inventive. D1, which may be regarded as the prior art closest to the subject-matter of these claims fails to disclose the subject-matter of these claims. Nevertheless, this pertains to known technical means (data processing system, network transfer/download, remote system) and obvious distribution of functionalities in computer systems. Hence, it is not considered to involve an inventive step.

Re Item VIII

Certain observations on the international application

- 1 The application does not meet the requirements of Article 6 PCT, because claims 1, 5, 6, and 9-20 are not clear.
- 1.1 Claims 1, 9, and 19 are unclear because it is not clear nor defined whether the mentioned "qubits" are quantum devices (emphasis added) of a quantum processor and constitute the device under test for the calibration. The lack of clarity also renders unclear the step of "executing a calibration". It is noted that the defined "computer-implemented method" needs to be interfaced with a quantum processor and with the qubit devices for the claimed "calibration operation" to be performed. No technical features defining this interface are present in the independent claims.
- 1.1.1 Regarding the step of "executing a calibration operation" it is not clear nor defined in claim 1 (and corresponding claims 9 and 19), and ambiguous, whether the calibration is limited to a comparison or results in adjustments to of device(s) under test or control of its/their operation. Claims 3 and 4 further define the "calibration operation" to the comparison and the whole description does not seem to support the case in which calibration results in adjustment of

- the device(s) or control of operation. Hence, the scope of claim 1 (and corresponding claims 9 and 19) results broader than justified by description and drawings.
- 1.1.2 Furthermore, claims 1, 9 and 19 generally define "executing a calibration operation [...] to produce a set of parameters", nevertheless it is not specified which parameters are produced nor their type. As an example parameters of a calibration operation of a quantum device may include control parameters, nevertheless, the application as a whole does not support this case, hence the scope of the independent claims is broader than justified by description and drawings.
- 1.1.3 The scope of claims 1, 9, and 19 is further unclear because it is not understood how the subject-matter described on paragraphs [0069-85] and shown in figures 6-7 would fall within the scope of the claims. As an example, the application as a whole does not appear to provide a link between the first, second, and third qubit defined in the independent claims (as well as fourth and fifth qubits defined in claims 2, 12, and 20) and the qubits present in the above-mentioned embodiments. This inconsistency between the claims and the description leads to doubt concerning the matter for which protection is sought, thereby rendering the claims unclear, Article 6 PCT.
- 1.1.4 It is noted that the scope of the independent claims is broader than justified by description and drawings because as stated in [0001] of the description "the invention relates to a method for noise and calibration adaptive compilation of quantum programs", however, the claims do not define any technical features that would, at least hint to "noise", "adaptiveness", and/or "compilation of quantum programs".
- 1.1.5 The expression "forming a quantum gate" used in claims 1, 9, and 19 is vague and unclear because it does not allow to understand which technical features are involved in the "forming" of the quantum gate. As in above objections, the independent claims do not define the necessary technical features enabling the technical implementation of the method steps.
- 1.1.6 It is not clear nor defined in claims 5 and 15 the link between the step of "transforming a quantum algorithm into a set of quantum gates" and the "selecting of the first qubit".
- 1.1.7 In claims 6 and 16 it is ambiguous whether the expression "the first subset" refers to previously defined "subset of the set of qubits" or to the previously defined "first subset of the set of parameters". Furthermore the step of

"determining" is vague and unclear because it is not clear nor defined the link of the determining step with the rest of the steps for selecting the first qubit nor it is clear the meaning of "determining" in technical terms.

- 1.1.8 The scope of claims 9 and 19 (and dependent claims) is not clear because the independent claims are not limited to any execution of the program on a computer/processor. In claim 19 the expression "for execution" does not provide the above-mentioned limitation.
- 1.1.9 The expression "the computer usable code" used in claims 10 and 11 is unclear because it is not clear to which previously defined "computer usable code" it is referred.