Summary of Hyperion Research's First QC Expert Panel Survey Questions/Answers

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Hyperion's Quantum Computing Program

- **Global Coverage of R&D Efforts**
  - Government, academic, commercial
  - US, China, EU, others
  - Crypto, HPC-accelerator, Quantum Supremacy
- **Highlights of Major Commercial Efforts**
  - DWave, Google, IBM, Rigetti, Microsoft, ATOS/Bull, etc.
  - Characterization analysis of competing QC development/product/commercialization models
- **QC Market Description and Analysis:**
  - Size, QC product categories, Regions, Sectors, Trends, Opportunities and Challenges
- **Insights on the QC sector as a Market Space**
  - Hardware & software ecosystem development, algorithm development trends, standards, collaborations, open source efforts, etc.
- **Impact on HPC sector writ large**
  - The role of QC in near-term and post Moore's law HPC environment
    - AI/ML/DL
    - Modelling/Simulation
    - Others

Hyperion's Research Approach

1. **Identify the QC experts around the world**
   - Invite them to be on a QC Experts panel
2. **Collect as many real-world use case examples as possible**
   - With a focus on where and how its used
   - Including plans for the future
     → *Publish as case studies*
3. **Collect many technology examples and vendor approaches**
   - Software, hardware, services, new discoveries, new innovations
     → *Publish as research reports*
4. **Then create taxonomies of the different technologies and where its used**
   - Both from a usage perspective and a technology perspective
   - We work to separate out one-off examples from main stream examples
     → *Publish as our base taxonomy (market definitions)*
5. **Then we can size the market and create 5-year forecasts**
     → *Publish "the numbers" and trends*

The QC Experts Panel

- **We are contacting thought leaders throughout the global QC community to join the panel**
  - Invitations are being sent across the QC ecosystem including HW researchers, algorithm developers, QC solutions providers, and the growing QC user base
  - Positive returns are coming in
- **The panel will be used for developing and testing technology definitions, market use cases, etc.**
  - And for probing and exploring all different types of questions about QC and its future evolution

If interested in participating, let us know

First Survey for Experts Panel

We are seeking to establish the big picture for QC:

1. **Which organizations (government, academic, corporate) are conducting some of the most advanced QC activities today?**
2. **What are some of the key QC technology developments currently underway at these locations?**
   - Address any/all of the following QC subcategories:
   - QC hardware, simulators, architectures, and algorithms
3. **What are some of the key technical challenges/roadblocks facing QC developers today?**
4. **What are some of the most compelling quantum computing applications currently under development?**
5. **What kind of schedule do you see for the roll out of key quantum computing systems or application?**

Summary of Answers : Q1

Which organizations (government, academic, corporate) are conducting some of the most advanced QC activities today?

- **Government:**
  - NASA Ames, Office of Science in general (with a 100M budget plus up in FY19), LBL, SNL, LANL, ORNL, ANL
- **Academia:**
  - U of Maryland, Perimeter Institute, UCSB, MIT, Caltech, Oxford, University of Waterloo, University of Delft, University of Sydney, University of Bristol
- **Commercial:**
  - Intel, Google, IBM, Microsoft, Alibaba, DWave
  - Start-ups: IonQ, DWave, Rigetti

Summary of Answers :Q2

What are some of the key QC technology developments currently underway at these locations?

- Superconducting qubit quantum computing – Google, IBM, Intel, Rigetti, Yale, (Caltech)
- Topological quantum computing – Microsoft, Delft, UCSB
- Photonic quantum computing – University of Bristol
- QC theory and Quantum error correction – University of Waterloo
- Silicon spin donors – Silicon Quantum Computing and University of Sydney
- Trapped Ions – IonQ, Oxford

Summary of Answers : Q2 (cont.)

What are some of the key QC technology developments currently underway at these locations?

- **Architectures:**
  - Programming languages and frameworks (Microsoft Q#, Rigetti Forest, IBM Q)
- **Simulators:**
  - Ever more scalable through classical code and method optimization and “shortcut”-identification.
- **Algorithms:**
  - Quantum chemistry.
  - Hybrid classical-quantum algorithms,
  - Approximate optimization algorithms,
  - Quantum machine learning algorithms
  - Mostly old but some new ones popping up from time to time,
  - Some efforts to use the “old” algorithms on current QCs in a meaningful way

Summary of Answers : Q3

What are some of the key technical challenges/roadblocks facing QC developers today?

- Qubit quality still needs improvement: longer coherence times and more accurate gates
- Qubit connectivity is at least as much of an issue as sheer number of qubits
- Maturity of quantum frameworks (they are at assembler level)
- Patience : It will take time, both in development and return-on-investment)
- Access to quantum computers (there are some but it is not real time)
- Money

Summary of Answers : Q3 (cont.)

What are some of the key technical challenges/roadblocks facing QC developers today?

- Crosstalk between matter-based qubits
- Operation at sub-1K for most technologies
- Scalable interface architectures
- Enormous cooling power requirements
- Quantum Error Correction overhead
  - Even larger overhead for error corrected logical operations
- Lack of quantum algorithms that will run with small numbers of logical qubits
- Engaging domain experts to develop new quantum algorithms and applications
- People don't think in quantum algorithms
- **Demonstration of logical qubit with sufficiently good performance**

Summary of Answers : Q4

What are some of the most compelling quantum computing applications currently under development?

- Quantum chemistry.
- Simulation of condensed matter systems
- Interesting developments in sampling and matrix inversion.
- Quantum machine learning
- Quantum implementations of linear algebra problems
- Simulation of chemical reactions and analysis of novel material properties

Summary of Answers : Q5

What kind of schedule do you see for the roll out of key quantum computing systems or application?

- Still 10 years.
- In 2-4 years we will see more use of quantum simulations.
- In 3-5 years we will have an instance of relevant quantum supremacy. (There will be some quantum supremacy apps in 1-3 years but in a special non-practical use case)
- In 7-15 years there will be relevant size low noise QCs, even for breaking some public keys.
- 5+ years: On-demand cloud-based devices used for quantum simulation tasks
- 10+ years: Larger scale on-demand services for big data and ML applications
- First application in chemical reaction and material simulation within 5 years.

Some Additional Thoughts

- **Suggested Benchmarks**
  - Coherence time
  - Quantum gate error rates
  - Shor's Algorithm factoring rate
  - Quantum volume (qubits X gate coherence time X number of gates X connectivity X error rate (operation ^ read))
  - Use case-based
- **QC Hybrid Systems Needed for Processing, Memory, Interconnect**
  - There will not be a one size fits all architecture
- **The systems we see now are not camera-ready, but they are critically important quantum algorithm research tools**

HYPERION RESEARCH

QUESTIONS?

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