Two perspectives on information processing

Dan C. Marinescu
Computer Science Division
Department of Electrical Engineering and Computer Science
University of Central Florida, Orlando, FL 32816, USA
Email: dcm@cs.ucf.edu

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Abstract

During the next four weeks I will discuss two very different topics related to information processing. The term information processing has a broader scope than computing, it refers not only to the transformation of information, but also to information storage and communication. It also addresses a larger audience, while computing seems targeted only at scientists and engineers, all of us are deeply involved in some form of information processing, be it downloading and playing music, using the Web to search for new recipes for our favorite dish, searching for extraterrestrial life, designing airplanes, or playing games.

The two topics are very different from one another; the first, cloud computing is very down to earth, it addresses the question on how we can compute more effectively and cheaply today. The second topics deals with how we may be able to compute, store the information, and communicate tomorrow; I cannot tell you precisely when this “tomorrow” will be, all I can say is that it has already started today, but it may take years to become a reality affecting our daily life.

Cloud computing supports network-centric computing and network-centric content; in other words instead of using your laptop for the next engineering class you could sign in to a distant place where a farm of computers and storage devices is located and do your calculations there. In fact you can do more than that, store all your data including class work, digitally recorded music, photos, movies, even your love letters on the “cloud” and access this information whenever you have an Internet connection. Thus network-centric computing means that you compute “there” rather than “here” and network-centric content means that you store all your data “there” rather than “here.” Several logical questions pop up to our minds immediately: Why? How? What is the catch?

Why? Because it is much cheaper and more convenient to do so. First, you do not need to buy an expensive laptop or a powerful desktop, you need only a very primitive tablet running only a browser. If your project involves a lot of data you may not be able carry out the computations “here” (on your laptop), but there are lots of computing cycles and storage “there” (on the cloud). Moreover, you do not need to install and maintain the software needed for these computations on your own
computer, deal with failing disks, backup files, or copy favorite songs from the smart phone to the tablet, desktop, and laptop; all songs will be “there” ready to be played when you wish. Now, you simply buy the computing cycles and the disk space when you need and as much as you need and pay only for what you use. If this sounds like the way we get the electricity and the water in our homes, that’s precisely what this new model is all about and, incidentally, that’s why it is also called utility computing.

We shall discuss these topics in more detail in Cloud 1, our first seminar.

How? Well, this is a more complicated question. You have first to create an account “there” then spend some time learning how to use the “cloud”. This is more difficult than people who would want you to use the “cloud” may say, but it is manageable, the learning curve is not that steep. We’ll talk about this in Cloud 2, 3, 4.

What is the catch? Well, remember what the mouse told Alice “I have a very long and sad tale.” Alice looked puzzled: “I see that your tale is very long, but why do you say it is sad?” So, seriously, first you have to pay, it does not cost much, but the use of the “cloud” is not free. Then there is the question of what to do when the service is not available, either your network connection, or the “cloud” are down. Another tricky question is how secure is the data stored “there” and if you still own the data, or the “cloud” owns it.

As you can see, things get complicated fast, so now is the time to switch to the next topic.

Quantum information processing. Though we may not have paid too much attention to this essential fact, we all can probably agree that information is physical, it has a physical support. In other words, information is stored, transported, and transformed by devices that obey the laws of physics. The question is what physics do we have in mind, the classical physics or the quantum physics?

While we can enjoy a very happy life on earth if we deal with objects that behave normally (whatever that means!) and are large enough and we never dream of moving close to the speed of light, then classical physics is a very good model of the world we live in. In the world of classical physics we deal with classical information, one bit can be either 0 or 1 and stays in the same state regardless how many of us examine it (of course provided that no external forces change it).

But there is another world, the world of atomic and subatomic particles which obey different laws, they are described by quantum physics. In this brave, but nondeterministic new world, we talk about qubits, strange creatures that are in a superposition state, some combination of 0 and 1. Looking at the same qubit I could draw the conclusion that it is 0, while you may say that it is 1, and none of us could be either dreaming or lying. This sounds very funny, it is as if a “cat can be in a superposition state, dead and alive at the same time.”

Welcome to this very funny new world in which we try to compute using qubits rather than bits! It sounds delusional but it works! This is what I am going to discuss in four lectures, Quantum 1, 2, 3 and 4.

Cloud computing seminars. The material covered is available online; the textbook will be published in 2013 by Morgan Kaufmann “Cloud computing: theory and practice,” Chapters 1 - 6 see http://www.cs.ucf.edu/~dcm/LectureNotes.pdf

1. Cloud 1- Tuesday May 22: Network-centric computing and network-centric content; the good, the bad, and the ugly
   - Utility and cloud computing
Cloud computing paradigms and services
Cloud diversity and vendor lock in
Energy use and ecological impact of large-scale data centers
Ethical issues in cloud computing

2. Cloud 2 - Tuesday May 29: *Cloud infrastructure and applications*

- AWS - the Amazon Web Services
- Google’s view of cloud computing
- Microsoft’s Azure
- Open-source platforms for cloud computing
- How to use the AWS
- Case study 1 - a cloud service for trust management in cognitive radio networks
- Case study 2 - adaptive data streaming from a cloud

3. Cloud 3 - Tuesday June 5: *Cloud computing*

- Challenges
- Existing and new applications
- Coordination and the *Zookeeper*
- The Map-Reduce programming model
- The GrepTheWeb application
- Clouds in science and engineering
- Benchmarks

4. Cloud 4 - Tuesday June 12: *Virtualization*

- Layering and virtualization
- Virtual machines
- Virtual machine monitors
- Performance isolation; security isolation
- Full and paravirtualization
- *Xen*
- *vBlades*

Quantum information processing seminars. The material is available online. It is covered in the book *Classical and Quantum Information* by D. C. Marinescu and Gabriela M. Marinescu, Academic Press, 2011.

1. Quantum 1 - Thursday May 24: *Introduction to quantum computing*

- The limitations of solid state technology
- Bits and qubits
- States and observables; eigenvectors and eigenvalues of quantum operators

2. Quantum 2 - Thursday May 31: *Physical implementation of qubits*

- Quantum gates and quantum circuits
- One qubit gates: X, Y, Z, Hadamard, and phase-shift
• Two qubit gates: CNOT
• Three qubit gates: Fredkin and Toffoli
• Universality of quantum gates

3. Quantum 3 - Thursday June 7: Quantum computational models; quantum algorithms
   • The quantum circuit model
   • Deutsch and Deutsch-Josza algorithm
   • Bernstein-Vazirani algorithm
   • Amplitude amplification
   • Grover’s quantum search algorithm

4. Quantum - Thursday June 14: Quantum information
   • Density matrix
   • Pure and mixed states
   • Entanglement, monogamy of entanglement
   • The no-cloning theorem
   • Accessible information in a quantum measurement

Note: This is a tentative list of topics and may change to reflect the reaction of the audience.