Amorphous Computing : Principles, Trends, Future Directions

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Abstract: Amorphous computing refers to systems capable of performing parallel processing using very large numbers of identical, parallel processors each having limited computational ability and local interactions. Examples of naturally occurring amorphous computations can be found in many fields, such as developmental biology , molecular biology , neural networks, and chemical engineering . The investigation of amorphous computation is hardware agnostic . It is not concerned with the physical substrate but rather with the characterization of amorphous algorithms as abstractions with the aim of both understanding existing natural examples and engineering novel systems. This paper presents the inherent research vision in planning and implementation of amorphous computing systems.

Keywords : Amorphous, Parallel, Cellular, microfabrication

1. INTRODUCTION

Amorphous computing emerged in anticipation of the fast developing disciplines of micro fabrication and cellular biology. These enable the construction of numerous identical information-processing units cooperating as a computational framework, which is precisely the basis of an amorphous computer. In addition to this, an amorphous computer has no geometrical arrangement nor an asynchronous updating of processors, as opposed to a cellular automaton. Also, communication between processors occurs only locally. Taking into account that processors are mass produced, any amorphous computer should be fault tolerant, since individual units as well as the communication between them might be nonfunctional. Being a relatively new domain, there as yet exist no general engineering techniques or languages to exploit and control behavior of such programmable multitudes – in other words, there is no amorphous computing paradigm. Achieving this is the actual issue of amorphous computing, such that one can program the particles to produce predefined global behavior , resulting from local interactions only. Due to obvious parallels with biology and physics, most work done until now has concentrated on metaphors from these sciences. This resulted in a series of applications, such as constructing a coordinate system, establishing a hierarchy, and the simulation of waves.

2. PRINCIPLES

This form of computing takes into base from molecular technology. In this type of computing, organizational principles are identified and programmed. Technologies are created for acquiring pre-specified behavior from irregular and unreliable parts. The main aim is information processing at unprecedentedly low-cost.

Model for Amorphous-Computing:

A collection of computational cells with modest memory, computing power. This cells are irregularly positioned on the surface. This cells are fabricated by same process thereby moving at same speed.

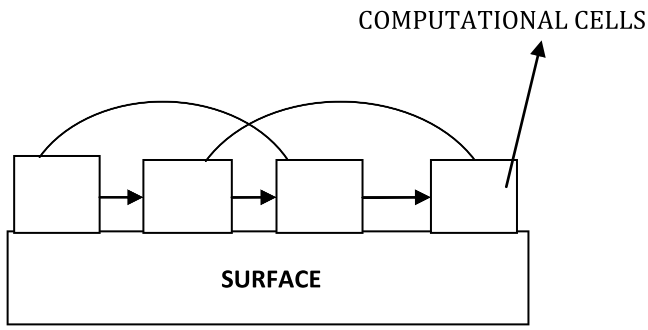

Fig.1. Model for Amorphous Computing

Each cell can communicate with few nearby cells. Communication messages are unreliable. Algorithms which run on amorphous computer should be independent of the count of computational cells.

The programming paradigm used is diffusion. One cell broadcasts a message to each of its neighbors, which pass onto their neighbors and so on. This creates a wave which spreads throughout the system. The message has a count and each cell stores the received count and increments it before rebroadcasting. This count-up wave indicates for a cell its approximate distance from original source.

Applications of Amorphous-Computing:

1. Smart paint that detects shadows on a wall.

2. Bridge surfaces that detect load.

3. Sensors that monitor chemical concentrations in the soil.

Communication in Amorphous-Computing:

If distance, time are important parameters, then its difficult to find network path-length. So, an all-to-all nothing-case is applied to gather extensive information in routing table. So that if fault-occurs, self-repair is possible. Need based communication is another approach but optimization in such cases is difficult. We can consider this approach where in search for destination, message is passed by source-router.

The search-message accumulates knowledge of its path as it travels. When destination receives the search message, it responds to the first search message by sending back a path setup message along the path setup message along the path the search message travelled. Each amorphous-computing processor acts as a potential-router. Reuse of a path by messages re-enforces a path. If table is full, the LRU entry is replaced. In this way, old paths get forgotten over time in favor of current paths. If paths are broken, then a limited range search for either processors that know the path to the destination, or for the destination.

3. CURRENT WORK IN THIS FIELD

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4. NOVEL RESEARCH PERSPECTIVES

Over the next few decades, two emerging technologies namely microfabrication and cellular engineering will make it possible to assemble systems that includes huge amount of information-processing units at negligible cost, provided:

1) that all the units need not work correctly

2) that there is no need to manufacture precise geometrical arrangements of the units or precise interconnections among them.

This technology shift will precipitate fundamental changes in methods for constructing and programming computers, and in the view of computation itself. Microelectronic mechanical components are becoming so inexpensive to manufacture that we can anticipate combining logic circuits, microsensors, actuators, and communications devices integrated on the same chip to produce particles that could be mixed with bulk materials, such as paints, gels, and concrete. Imagine coating bridges or buildings with smart paint that can sense and report on wind loads and monitor structural integrity of the bridge. A smart-paint coating on a wall could sense vibrations, monitor the premises for intruders, or cancel noise. Even more striking, there has been such astounding progress in understanding the biochemical mechanisms in individual cells, that it appears we'll be able to harness these mechanisms to construct digital-logic circuits. Imagine a discipline of cellular engineering that could tailor-make biological cells to function as sensors and actuators, as programmable delivery vehicles for pharmaceuticals, or as chemical factories for the assembly of nanoscale structures. The ability to fabricate such systems seems to be within our reach, even if it is not yet within our grasp. Yet fabrication is only part of the story. Digital computers have always been constructed to behave as precise arrangements of reliable parts, and almost all techniques for organizing computations depend upon this precision and reliability.

These foundations should be sufficient to implement digital logic in cells. In practice, however, realizing cellular logic will require an ambitious research program. We do not have a library of the available DNA-binding proteins and their matching repressor patterns. We do not have good data about their kinetic constants. We do not know about potential interactions among these proteins outside of the genetic regulatory mechanisms. Most importantly, we do not have a sufficiently clear understanding of how cells reproduce and metabolize to enable us to insert new mechanisms in such a way that they interact with those functions in predictable and reliable ways. Our effort required for making progress in cellular computing is the creation of tool suites to support the design, analysis, and the construction of biological circuits.

Various tools that are developed in this phase are:

1)BioSpice takes as inputs the specification of a network of gene expression systems (including the relevant protein products) and a small layout of cells on some medium. The simulator computes the time-domain behavior of concentration of intracellular proteins and intercellular message-passing chemicals.

2) "Plasmid Compiler" that takes a logic diagram and constructs plasmids to implement the required logic in a way compatible with the metabolism of the target organism. In the future, biological systems could be our machine shops, with proteins as the machine tools and with DNA as the control tapes.

We can envision applying this technology to the construction of molecular-scale electronic structures. Deliberately assembled molecular-scale electronic structures are likely to replace lithographically patterned electronics in the next century. While lithographic technologies struggle to surmount difficulties imposed by the small scale and statistical nature of doping profiles, deliberately assembled molecular-scale systems are atomically precise and uniform, with identical atoms in well-defined localized slots.

Various technical achievements are:

1) development and characterization of molecular-scale conductors, diodes, and transistors

2) a technology for assembling compound structures from molecular-scale components

Also, Morphogen gradients and lateral inhibition are well-matched to the amorphous setting because the gross phenomena of diffusion and spacing are insensitive to the precise arrangement of the individual agents, so long as the distribution is reasonably dense. In addition, if individual agents do not function, or stop broadcasting, the result will not change very much, so long as there are sufficiently many agents. Many phenomena exist in multi cellular systems, from quorum sensing to programmed cell death, that can provide inspiration for robust multi-agent algorithms. At the same time, it is extremely important to be able to analyze the behavior of these algorithms, so that we have a solid ground to build on top of.

Other Examples are in Distributed data structures, like morphogen gradients, driving agent activities, are emerging in many disparate scenarios. The research projects use algorithms based on field-like data structures spread in the network by mobile software agents to enable file sharing in Internet-scale.

peer-to-peer (P2P) applications: Instead of being propagated in a breadth-first manner, like the morphogen gradients, the agents spread the data structure as they randomly move across the network. As a result paths are created between peers that share similar files, thus enabling a fast content-based navigation in the network of peers.

5. FUTURE DIRECTIONS

Future systems will have vast number of computing mechanisms with decrease in price and size. When the number becomes large enough, the appropriate programming technology will be amorphous computing. Research into self-healing structures, circuit formation, programmable self-assembly and self-organizing communication networks are a sample of the works undertaken.

Its transition effect will also appear in various fields like

1)Sensor Networks(Ad-hoc): Paths are created between peers that share similar files, thus enabling a fast content-based navigation in the network of peers.

2)Robotics(Modular robotics): In modular robots, modules decide how to bend their actuators depending on the locally perceived hormone pattern.

3)Persuasive computing(using fields and gradients):This scenario strongly resembles the Amorphous Computing model and possess similar challenges, with the significant addition of mobility.

Thus, amorphous computing has become an essential technological tool in synthetic biology now-a-days, to solve the biological problems.

6. CONCLUSION

Amorphous computing systems are used in various fields and the technological advancements are highly enhanced after incorporating the principles of this type of computing .In this paper we have tried to present the principles and trends of amorphous computing along with few current applications in real time of this type of computing system. The model of amorphous computing when exploited fully by the researchers may prove to be a cutting edge technology in future as evident from our study in this field.

7. REFERENCES

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