Parallel processing in cancer treatment

Video game technology is helping reduce dangers in radiation treatment, writes **S Ananthanarayanan**

WHILE the treatment of cancer is effective, with aggressive radiation of tumours, the effects of radiation on healthy tissue needs to be controlled. It is, therefore, important to direct the radiation accurately at the tumour. This is usually done by imaging the tumour with X-rays and a CT Scan. But exposure to X-rays, for every spell of radiation treatment, has its own danger. Steve Jiang and others at the University of California in San Diego describe, in the journal of the *American Institute of Physics*, a way to do the imaging more economically, using technology that arose in computer graphics.

Guidance of the radiation to the correct spot has come a long way from the early practice of placing ink marks on the skin. The main device now used is the Computed Tomography Scan, which electronically records a series of X-ray images taken from different angles and uses computers to display 3D images and different views of the object of interest. This enables both the correct direction of beaming of the cancer-reducing beam as well as dosage assessment.

A refinement in CT is the *Cone Beam CT*, which allows imaging and monitoring of the tumour, even as the radiation treatment is in progress.

But the problem is that the imaging involves acquiring a large number of X-ray images to be processed for creating the 3D views. Repeating such exposure to X-rays every time the patient comes for radiation, and even continuously or a number of times during each session, creates serious tissue damage, which contributes to the discomfort of radiation therapy and even creates fresh cancer.

Methods used to reduce the exposure include reducing the number of scans as well as the intensity of X-rays used. The image is then created with this lesser data, using more involved computing. But the drawback is the time it takes, which may run into hours. Yet, it is important to reduce X-ray exposure as it is estimated that cancers resulting from CT scans could lead to thousands of deaths for each year of use.

Faster processing

It is, hence, an objective to acquire minimal but manipulate data all the faster. An area where 3D images have to be generated faithfully at great speed is in the high resolution video images used in interactive, action-oriented computer games. In these applications, the new coordinates of 2D views of moving 3D objects need to be computed and projected on the video screen every fraction of a second, in such a way that image quality and smoothness of movement are maintained.

As each of the different objects imaged have their own intelligence and capacity to move in different ways, the information set to be computed every split second can become unmanageable. As the data on the screen also needs to pass to and from applications that control the different objects as well as different players often connected through a network, the computation needs to manage with limited data.

The gaming industry has developed some of the most efficient data processing algorithms and also special hardware especially meant for high speed, high resolution graphic display.

Parallel processing

Normal computer working involves doing things in sequence, or one after another, albeit at lightning speed. One method of speeding this up is to separate the tasks that do not need to be done in sequence and to do the two groups of tasks at the same time.

For instance, to add a large list of, say, a billion numbers, we could split the list into two and compute two subtotals in half the time. Or we could split the lists into four and get four subtotals in a fourth of the time, and so on. If we split the list into 1,000 parts, we could get the job done in just over the time it takes to process a million numbers.

What we need for this kind of exercise is twofold: first, a computer programme that will split the work into parts and recombine the results; and, second, separate sets of


Steve B Jiang,PhD


Parallel processing

hardware that will work simultaneously under the control of the parallel process programme. Something like this happens, with only one processor, in the multitasking that modern computers can do. For instance, we can type a letter and listen to a CD record at the same time. Here, the operating system uses the split seconds that each programme spends in data entry or data display to allow the computer to process that data of the other programme. The operating system organises this process to adjust the time slot for each programme so the queuing time before the slots are available is short enough for smooth working.

In the case of real parallel processing, however, we do not have "empty spaces" spent in input-output and we need either a collection of connected computers or a "multiprocessor computer". A bank of computers is what happens in the *supercomputers* which implement *massive parallelism* in processing weather data or some scientific simulation programmes. In the case of the multiprocessor, we do have separate computing units but there have to be special ways of managing resources such as computer memory while the processing units work on different tasks.

Graphic Processing Unit

This is a device that combines multiprocessing ability with specially designed architecture to enable the large parallelism that we need for video games. The GPU consists of a separate device plugged into the motherboard and it has special chips, with inbuilt software, that relieve the processor or the graphics card of time-consuming processing. As the GPU does such intense computing, it needs to come with separate resources, particularly for memory. The GPU also needs special programming and this is often inbuilt for specific imaging functions.

An industry-leading GPU that the San Diego group has used integrates newer algorithms, called *stream processing*, that enable the limited parallel processing of inputs to a single processor. The latest cards also accept general purpose programming languages, like C, that allow the cards to be used for different applications.

Based on these resources, the team has developed an innovative CT reconstruction algorithm which allows images to be derived from fewer and less intense scans within about two minutes. The number of exposures has reduced to 20 to 40 from the norm of 360, "resulting in 36 to 72 times less radiation exposure for patients", says Steve Jiang. "In my mind, the most interesting and compelling possibilities of this technique are beyond cancer radiotherapy," he adds.

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How a red dot swung it for Open champion

The strategy employed by golfer Louis Oosthuizen demonstrates the growing importance of mental techniques in the field of competitive sport. **Steve Connor** reports

A SMALL red spot on the glove of golfer Louis Oosthuizen is credited with playing a critical role in his winning of the Open Championship at St Andrews last Sunday. The coloured spot was a visible manifestation of the growing influence of psychology in sport — it was designed to help the 27-year-old South African concentrate on his swing in the crucial moments leading up to a shot.

Sporting professionals are increasingly turning to similar mind-training tricks to improve their performance on the field. It may involve mental imagery that allows them to rehearse a game in their heads, or psychological blocking techniques that stop them from dwelling on past mistakes. In the case of Oosthuizen, an outsider who was widely expected to collapse under the pressure on the final day, it was a simple dot on his glove that helped him focus on his swing. The idea came from Karl Morris, a Manchester sports psychologist who was asked to help Oosthuizen improve his concentration before starting his swing after a string of disappointing results in previous golfing events.

"His pre-shot routine was all over the place. I suggested he changed his whole game plan after he told me that when he played in the US Open last month he was making split decisions instead of thinking about what he should have been doing. One of the tips I gave him was to put a red spot on his glove and to focus on it during his swing," Dr Morris said.

The ability to focus on the task in hand is one of the key techniques that sports psychologists try to refine when dealing with professional sports people. "There is a lot of evidence that the best sportsmen and women have a lot of psychological skills that allow them to concentrate and to control anxiety," said Dr Tim Rees, a qualified psychologist who specialises in sport at Exeter University.

"Psychological skills may be more important in some sports than others. Endurance sports such as rowing, for instance, require a very

The idea for the red dot on Oosthuizen's glove (above) came from sports psychologist Dr Karl Morris (right) who was asked to help the golfer improve his concentration when preparing his swing.

different psychological approach from less physical sports like golf where the actual playing of shots constitutes a tiny fraction of the time it takes to complete the course. Rowing and other endurance sports involve intense activity for prolonged periods, whereas there is so much more time for psychology in sports like golf. There is a lot of evidence to show that once someone gets to a certain level of skill, it is the differences in their psychological approach that differentiates people at the very top," he said.

The red spot on Oosthuizen's glove was one way of focussing his mind on the process of playing a shot rather than thinking of the consequences. It is a classic example of what it known as "process goals" in sports psychology, when the athlete is asked to focus on something, however minor, to stop him/her thinking of what happens if the shot goes wrong — it brings him/her back to the here and now before the shot is actually played, Dr Rees explained.

Other mental tricks may focus on "thought stopping". Instead of dwelling on a missed shot, whether it is a failed penalty or disastrous return on the tennis court, the athlete is trained to put such negative thoughts into a mental "black box" that can be dealt with after the match. A simple trick is to get the athlete to think of a stop sign immediately after he/she makes a mistake. "It allows them to park the problem so they can deal with it later. It takes a lot of practice to get it to work but it allows them to focus on what they have to do next rather than what they have just done," Dr Rees said.

Almost all sports involve what psychologists call imagery. Athletes often describe how the day or night before a crucial game they mentally rehearse what they intend to do — even to the point of walking up to the winner's podium. (According to Rees, this is why so many first-time winners often look relatively relaxed and at home on a podium because they have rehearsed the moment so many times in their heads.)

David Beckham, for instance, is said to have stored and replayed mental "video clips" of how the ball will bend when he takes a free kick at goal. Skiers at the top of a run often close their eyes briefly and sway from side to side just before they take off down a slope, as if they are rehearsing the difficult movements they are about to make. "Imagery is most effective when it is used in conjunction with actual practice," Dr Rees said.

Physical perfection, skill and technique are obviously critical to athletic performance, but the whole point about sports psychology is that the mind can so often be employed to overrule matter. This is never more true when it comes to the sort of psychological support that can decide whether a player wins or loses. Several studies have shown that the emotional support given to an athlete from family, friends and even professional managers can make a significant difference to sporting performance. In one study of 197 male amateur golfers, for example, Dr Rees found that the social support they received before a game affected how well they did. "While training, tactics and luck all play a part, the encouraging words or kind gestures of a partner or friend can make the difference between a footballer scoring that winning goal, or a sprinter achieving a record time," he said.

Even the emotional support of a relative stranger can boost performance, according to another study by Exeter colleague Paul Freeman. Just listening to an athlete's problems and offering simple advice and encouragement can make a significant difference to an athlete's success, Dr Freeman said. "It is significant that the support I offered, as a relative stranger, had such a marked influence on their results. The findings suggest that amateur and professional athletes would benefit from seeking social support, whether this is from a friend or family member or even from a professional," he said.

This is why even a manager can make a psychological impact that makes the difference between winning and losing.

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Making of the universe

Is the search for the Higgs particle the end of or the beginning of how it all began? **Premnath Singh** elaborates

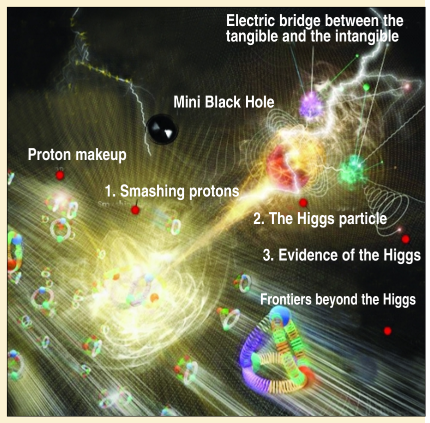
CIVILISATION'S advance is best gauged by the search for the ultimate, which, naturally, began with the dawn of intelligence that sought newer dimensions. In time, matter was found to comprise molecules that, in turn, spawned knowledge of atoms. These, we were pretty convinced, were the smallest and ultimate existing objects until the discovery of protons, neutrons and electron clouds revealed their configuration.

Could we have imagined that each proton (or neutron) has about 2,000 times the mass of an electron, that an electron cloud is about a hundred-millionth of a centimetre and a nucleus is a 100,000 times the size of an electron cloud? Amazing is only the half of it!

So what determines the size of objects we see around us or, indeed, even our own size? We could say the answer lies in the size of the molecules and, in turn, the atoms that compose these molecules. But then, what determines the size of the atoms themselves?

Nature has given us more than one elementary particle and each comes with a wide variety of masses. The behaviour of all known subatomic particles can be described as falling within a single theoretical framework called the Standard Model. This incorporates quarks and leptons as well as their interactions through strong, weak and electromagnetic forces. Only gravity remains outside the Standard Model. The force-carrying particles are called gauge bosons and these differ fundamentally from quarks and leptons. The fundamental forces appear to behave very differently in ordinary matter, but the Standard Model indicates that these are basically very similar when matter is in a high-energy environment.

The theory of particles and their interactions requires their masses to be zero. But with a whole variety of masses, how do they derive out of nothing? How does a particle acquire mass, how did so much mass in the universe emerge from a singular point?



In 1964, Scottish physicist Peter W Higgs of Edinburgh University proposed a mechanism that provided an explanation of how fundamental particles could have come together. He theorised that all of space was permeated by a field, now called the Higgs field, similar in some ways to an electromagnetic field. As particles traversed space through this field they acquired what appeared to be mass if they interacted.

Quantum theory speaks of wave-particle duality. While all fields have particles associated with them, the electromagnetic field has particle-associated photons and the particle associated with the Higgs field is the boson named after him, a particle with no intrinsic spin or electrical charge. Although called a boson, it does not mediate force as do others of its ilk.

The Higgs boson has not yet been observed but its discovery would be the key to whether the Higgs field exists or whether the physicist's hypothesis of the origin of mass is, indeed, correct. Importantly, it would also justify the survival of the Standard Model.

To find an answer to all these questions, the Large Hadron Collider was built by the European Organisation for Nuclear Research (Cern) with the intention of testing various predictions of high-energy physics, including the existence of the hypothesised Higgs boson. On 10 September 2008, proton beams were successfully circulated in the main ring of the LHC for the first time, but nine days later operations were halted because of a serious fault between two superconducting magnets. Repairing the damage and installing additional safety features took over a year.

Then on 20 November 2009, the proton beams were successfully recirculated, the first proton-proton collisions being recorded three days later at an injection energy of 450 Generalised extreme Valcue (GeV) per beam. On 30 March 2010, the first planned collisions took place between two 3.5 Teraelectron (TeV) beams, which set a new world record for the highest-energy manmade particle collisions.

Cern scientists estimate that if the Standard Model is correct, a single Higgs boson may be produced every few hours. At this rate, it may take about two or three years to collect enough data to discover the this boson and to draw meaningful conclusions.

The LHC experiments did spark fears among the public that the particle collisions might produce doomsday phenomena involving the production of stable microscopic black holes or the creation of hypothetical particles called strangelets. But the Cern authorities have since rejected any possibility of such danger.

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