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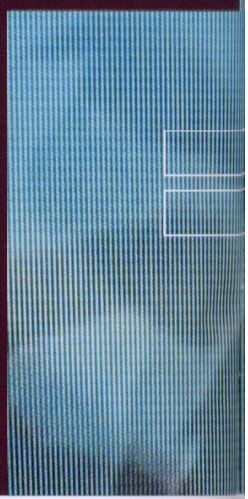
The mind is all that matters ...

Breathing New Into Accessibility

The MindGames group is an interdisciplinary team at MIT Media Lab Europe that integrates intelligent biofeedback, computer gaming and sensory immersion to develop techniques for positively affecting the state of mind. These are based on an extensive signal processing framework.

05

Still Life is one of the MindGames projects being developed in conjunction with physiotherapists at the Central Remedial Clinic in Dublin, Ireland. The project uses a movement interface to creatively reward a participant for controlling their physical movements in a calm and relaxed way. It can be customized so that a patient is rewarded for practicing a movement over and over again and doing it correctly, thereby turning previously monotonous exercises into a more engaging interaction. The program is also able to track progress, so that a physiotherapist needn't always be present to monitor improvement during daily exercises.

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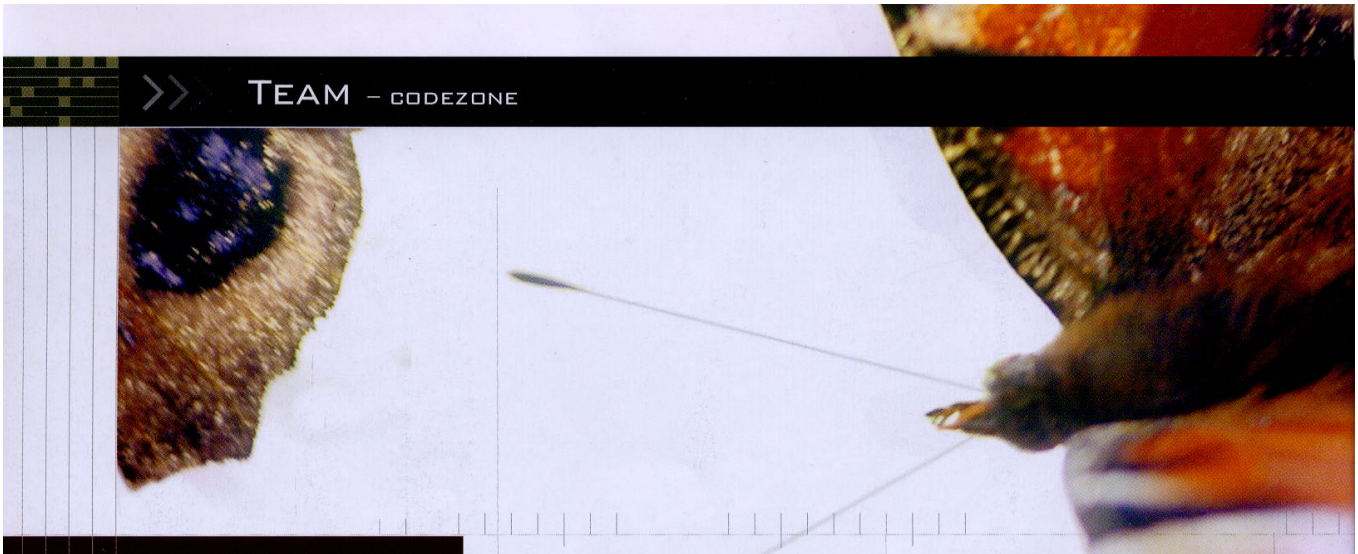


a

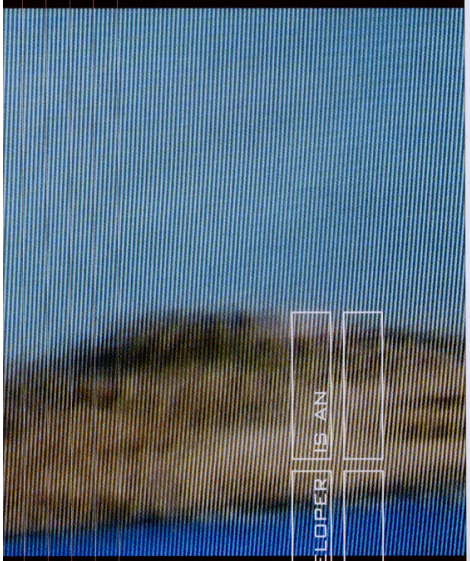
The stars of the Féileacán project in rehearsal, as seen through the eye of Still Life

b

One of the Counterbalance dancers glows even brighter as Still Life highlights her movement across the stage

c

In Mind Balance, only brainwaves provide the interface that helps take the "Mawg" out for a walk across the cosmic tightrope



The Butterfly Soars

Still Life leapt from the world of physiotherapy into the performing arts in early September as part of the Féileacán project, a performance that had its debut at the closing ceremonies of the 2003 conference for the Association for the Advancement of Assistive Technology in Europe (AAATE). Féileacán is the equivalent for the word 'butterfly' in gaelic, the Celtic language.

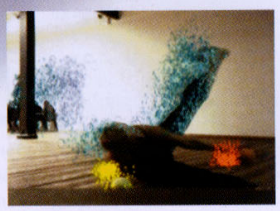
a Féileacán united the teenagers from four Special Schools in Ireland, who both inspired and expressed the project's narrative. The Féileacán itself serves as a symbol for rebirth that provides the focus of the storytelling: the children of the world, fed up with prejudice and poverty, build a spaceship to take them to a better world. The ship evolves into the Féileacán that guides them to a new space. There the children can breathe new life, encounter new friends and overcome their fears.

b The Féileacán story is told through a dance performance that stars the children themselves alongside Dublin's Counterbalance dance troupe. The performers are supported by a variety of innovative technologies, including Still Life, that facilitate new forms of expression. Still Life is presented on a wall-sized screen behind the performers, effectively turning that wall into a "magic mirror" that serves to reflect the youthful performers. The program tracks their movements and responds in a variety of ways – for example by causing dancers to glow, orbs to radiate energy, and elements of the new world to be revealed as though they were being painted by the movement of the performers.

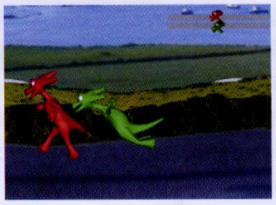
c Still Life is just one of the projects the MindGames group has been working on as part of their contribution to the 2003 European Year of People with Disabilities. Other projects include Mind Balance — a game that uses EEG brain wave activity as a control interface — and Biomelodics, which uses musical biofeedback to help teach a participant how to better control their heart rate.

MindGames has been using C# and the .NET Framework for over a year to develop the engine that provides the foundation for all of these projects. The software architecture developed in-house by the group includes Sponge, a real-time signal processing engine that can dynamically adapt to absorb the

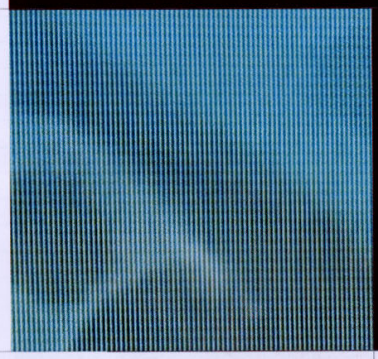
Relax to Win breaks all the rules of competition



Counterbalance dancer Jenifer Fleenor experiments with Still Life, while Still Life experiments with the CLR's garbage collector



No stress was involved when Relax to Win was ported to the PocketPC.



available resources on a LAN; and Puck, a 3D scenegraph and graphics library that utilize many advanced features of Managed DirectX 9.

The Need for Speed

MindGames discovered firsthand that when working with the .NET framework technologies, rapid development doesn't necessarily come at the expense of rapid execution. The Mind Balance project relies on the extremely precise presentation of visual signals which are processed by the brain, and then reliably detected as electrical signals acquired non-invasively from the surface of the head. Mind Balance uses the Puck and Sponge libraries, is written entirely in C#, and runs robustly at over 100 frames per second. (Also see the Mind Balance sidebar on page 37 for more information).

As another example of how fast the engine runs, some of Still Life's particle effects produce and destroy literally thousands of new objects a second — an egregious abuse of memory which is handled with great panache (and without hiccups) by the Common Language Runtime's garbage collector.

Developers are not an Island

During development, the involved team was keenly aware that the C# language itself doesn't exist in a vacuum. Visual Studio's fully-featured development environment, and the ease with which native code can be debugged, facilitated the rapid integration of the legacy C++ code used for biological data acquisition.

With the nascent Compact .NET Framework, users are not even tied their desktops anymore. In a matter of days, a miniaturized version of the architecture was used to port another major project, Relax to Win, to the PocketPC. Relax to Win is a two-player competitive racing game that is controlled by each player's level of relaxation. Measuring this level by the players' galvanic skin response, the technology is similar to the one used in lie detectors. As the players relax, their dragons move faster. Therefore, unlike in most competitive games, in Relax to Win it is the player who can better overcome the tendency towards increased tension and stress that wins.

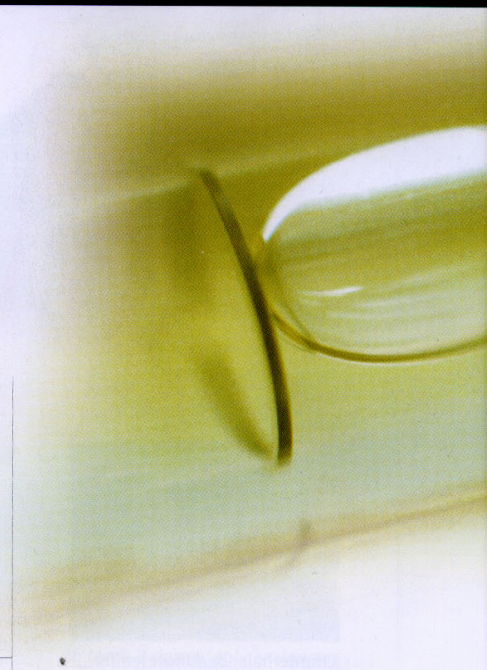
MindGames was thoroughly impressed with how the .NET technologies have not only allowed them to develop a strong foundation, but also to rapidly build and deploy such a wide variety of applications. Through their work with the Central Remedial Clinic in Dublin and other partners, these technologies helped create tools for empowering people with special needs — with applications as far-reaching as physiotherapy and even the performing arts!

ROBERT BURKE

MindGames Group, MIT MediaLabEurope, rob@mle.ie

...would like to acknowledge his advisor, Gary McDarby, and all the members of the MindGames group for their immense contributions to all of these projects, as well as our collaborators on the Féileacán and Mind Balance projects: the CRC, University College Dublin, SMARTlab UK, Counterbalance, and New York University's Center for Advanced Technologies.

The Control System You Have in Mind



Imagine a world where your brainwaves offer you another degree of freedom in a control system — and consider how useful that freedom would be for someone who can't use a conventional controller like a mouse.

We can't use Jedi Mind Tricks to move starfighters just yet, but the MindGames group is taking strides in that direction by putting their .NET codebase to use for the non-invasive analysis of human brainwaves. Mind Balance is the first application developed by the group as part of an ambitious collaboration with researchers at University College Dublin to implement new brain-computer control interfaces.

Taking the Mawg for a Walk

In Mind Balance, a participant must assist the Mawg, a tightrope-walking behemoth (Scottish, apparently), by helping him maintain his balance as he makes his way across a cosmic tightrope. All in a day's work for a typical computer gamer — but the participants at the helm of Mind Balance have no joystick, no mouse, and not even a camera. All they work with is a brain cap that non-invasively measures signals from the back of their heads.

Specifically, the cap monitors electrical signals from the surface of the scalp over the occipital lobes (just above the neck and the home of the brain's visual processing), which offer an effectively direct connection to the eyes via the brain's optical nerve. When participants look at areas on the screen that are blinking at known frequencies, their brain process that blinking in enigmatically complex ways. But one side-effect of that processing — an increase in electrical activity at the same frequency as the blinking orb — is sufficiently pronounced so that it can be detected in the electromagnetic soup at the surface of the head. These detectable signals are called Visually Evoked Potentials, or VEPs.

Use your brainwaves to keep the Mawg on track as he crosses the cosmic tightrope.

If the Mawg slips to the right, the participant can help shift the creature's balance back to the left by staring at the orb flickering on the left-hand side of the screen. The subsequent change in the participant's brainwaves is detected by the system as a VEP, and transformed into a one-dimensional analog control axis that can be used to get the Mawg figure back on track.

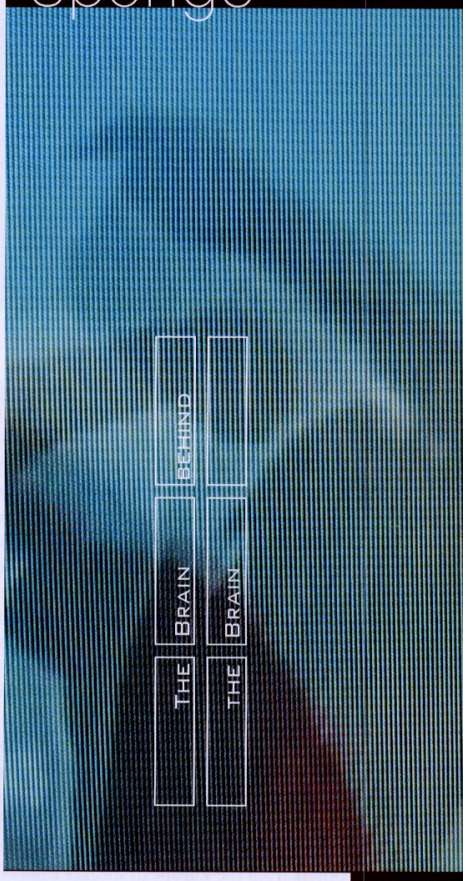
The Brain behind the Brain

All of this requires some fairly fancy graphical and signal-processing footwork. In order that the blinking of the orbs produces a signal that can be reliably detected, the orbs must be rendered at a consistent 60 frames-per-second (fps) or more. Our in-house C# graphics engine and scenegraph, Puck, is capable of rendering the orbs, together with the animated Mawg and his environment, at over 100 fps on conventional hardware running Windows XP.

With performance figures like these, it would certainly be possible to perform signal acquisition and processing on the same PC that is rendering the graphics. But in order to facilitate rapid development, and decouple the signal acquisition and processing steps from the actual gameplay, we used the Sponge signal processing framework to offload signal processing to another PC. On that signal acquisition PC, the electrical signals are acquired from the brain, VEPs are detected, and the left-right feature is extracted. That simple feature is then sent across the network to the computer that controls the Mawg and renders the Mind Balance world.

It's a comparably simple step to take the Mind Balance technology and add another axis, thereby turning it into a two-dimensional controller. And another technique currently under development involves the observation of imagined muscle movements: instead of staring at the blinking orb, you just imagine moving your left hand, and the character moves left. So although today we're just taking the Mawg out for a walk, tomorrow we may indeed be making Jedi Mind Tricks a reality!

All the .NET's a Sponge



A real-time signal processing framework named Sponge is an important component of the MindGames code-based architecture. It is used in our applications to process everything from video signals to brainwaves.

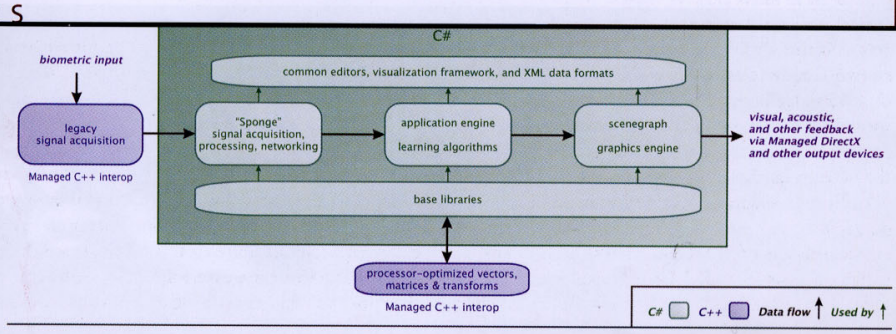
Sponge provides a visual interface which allows designers to drag and drop atomic Signal Processors. These can perform operations ranging from Fourier transforms and windowing functions to color tracking and image differencing. They can be assembled into real-time Signal Processing Networks that are used by an application.

One particularly useful feature of Sponge is its ability to dynamically harvest available resources on a Local Area Network. Sponge uses WMI technology to query other computers on the LAN that are running a sentinel program and determine what processor and memory resources they have available. Then, using .NET Remoting, Sponge can connect to chosen machines and deploy signal processing tasks.

The original intention for creating Sponge was to facilitate system designs where signal acquisition and processing could be performed on unspecified computers in a potentially dynamic LAN environment. Sponge has allowed for this and also offered MindGames some delicious low-hanging fruit. For example, Still Life can use Sponge to record a live video of a performance by streaming screenshots to another computer over the LAN in real-time. These can be processed off-line to turn them into a moving video file. Trying to stream the screenshots to the hard disk of the computer rendering Still Life was prohibitively expensive, but Sponge can do the job with only a moderate frame rate hit.

A number of features of the C# language made the development of Sponge straightforward. The language's unified type system allows our Signal Processors to acquire Objects as Inputs and Outputs, and thereby accept boxed primitive types (and arrays of primitive types) in addition to more complex Objects. Reflection is heavily used by the visualization framework to allow it to automatically detect available Signal Processor subclasses. These are made available for interactive construction by using Windows Forms features like the powerful PropertyGrid control. And Serialization — both binary and using a custom XML format — is used to store Signal Processing Networks, and even transmit them over the net. All of this has meant rapid development, the integration of powerful editors and visualizers, and the ability to leverage powerful existing tools in our architecture.

MIND GAMES



High-level view of the MindGames system architecture. Sponge includes a networking layer and feeds processed inputs — biological and otherwise — into the application engine.