

distinction

portable mass produced devices.

The third element is the application. All system components and procedures are packed in the digital watermarking application. The end user is interested in functionality; integrating the hardware and software components in a user friendly application is a key factor of a successful product.

The project was a very ambitious plan. An inexperienced student might think that taking a digital watermarking algorithm and making it run on a dsp in real time is rather straightforward. But, as we soon discovered, it requires effort.

Understand the theory

Firstly, we had to understand the theory behind the digital watermarking algorithm so we could optimise the design of its components. Secondly, we needed to understand the dsp hardware, instruction sets, addressing modes and development tools. Additionally, we needed to understand the peripheral hardware – such as a/d and d/a converters, communication busses and the host pc interface.

It is important to note the feasibility of such an implementation was not certain, since no real time watermarking application existed. This uncertainty was a risk for us, because committing to a project in the Technion's Signal and Image Processing Lab means you have to deliver – failing would delay our graduation.

With much work to do, there was no time for apprehension. Since the most valuable resource is time, we organised our work in order to get maximum throughput.

After high level design of the application



The moment of victory! From the left: Gene Frantz, head judge; Nimrod Peleg, advising professor; Shay Mizrahi, project supervisor; Jack Kilby; Yuval Cassuto and Michael Lustig.

blocks, we split the block assignments between us. Whenever we achieved a testable feature, we merged the blocks and conducted tests. Simulations were also performed to validate overall system performance and accuracy.

Once a week, we reviewed the project with Shay Mizrahi, the project supervisor. In these meetings, we mainly discussed different ways of implementing the design and organised the work schedule.

A major factor in the project's success was our diverse characteristics. Differences in our working methods and preferred solutions worried us initially, but these differences turned to be a great advantage. Whenever we faced a problem, we managed to come up with different approaches and one usually worked. Whenever one person's method was found to be slow or inefficient, the other's approach brought progress.

One lesson we learned is that, unless you properly document and present your work, what you have done and learned does not exist. It's not enough to do something; you must also explain the complexity of the problem, outline your solutions and prove they work. Though writing articles and making presentations is not our 'hobby', we found these tasks essential for the project's overall success.

We had to write so many documents because we took part in three important congresses worldwide. This kind of international experience is not common for undergraduates and, thanks to TI, we had the chance to explain the project to many engineers and researchers.

In ICASSP 2000, in Istanbul – the most important annual acoustics and signal processing conference – we presented the project at the TI booth as a part of an academic and commercial application exhibition. Attending this conference gave us ideas of how to improve the application.

We also attended the Third European DSP Education and Research Conference. Our presentation, and demonstrating the project's real time capability, received much attention. This motivated us to take the project a step nearer commercial reality.

Last year, we were invited to take part in the TI DSP and Analog Challenge. The competition offers students the opportunity to develop cutting edge signal and image processing algorithms on real time platforms, experiencing a 'real world' development process. Our paper was one of 240 other pro-

jects aiming to win the \$100,000 first prize. We realised that, by joining the competition, we needed to work to a high standard and to submit a quality project. We expected the project to be judged professionally and seriously. Our acquaintance with TI engineers left us in no doubt.

After we delivered the paper, we forgot about the competition, due to the work load at the Technion. We were surprised when we were invited to present the project in the competition finals in Dallas. The three day competition was superb event and describing it would really require a separate article.

Satisfying achievement

Reaching the last three in the competition was even more satisfying, particularly bearing in mind the quality of the projects submitted by the other two finalists: Rice University from Texas and the National University from Taiwan.

Being nominated for the grand prize required us to make a 20 minutes presentation: a tough time limit in which to outline 18 months of work. We then faced 10 minutes of questions from the judges: distinguished researchers in the field. The questions were not only on the project, but also tested our general understanding of dsp theory and practice.

There was a long wait before we found ourselves on stage, being handed a 2m cheque for \$100,000 by Nobel laureate Jack Kilby – inventor of the transistor! **NEoC**

Author profiles:

Yuval Cassuto and Michael Lustig are students at Technion, the Israel Institute of Technology.

Prime example, says TI

"Technion's winning project is a prime example of the many applications that are made possible using TI's programmable dsps," said Torrence Robinson, worldwide DSP University Program Manager and Challenge coordinator.

"TI is committed to nurturing innovative thinking and creativity from students and will continue to support DSP education and research via programs such as the DSP and Analog University Challenge."