

The Loughborough Wave Lab - A Mobile Virtual Electromagnetics Laboratory for iOS devices

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Abstract— Modern mobile devices have now advanced to a point where they can execute computationally-intensive mathematical problems. The Transmission Line Matrix Modelling method (TLM) is a time-domain method allowing the computation of two and three dimensional electromagnetic fields and structures. TLM is able to model complex scenarios whilst utilising a computationally simple method to model structures in discrete spatial units. This paper presents an iOS App based around a TLM solver. The simulation output is presented on the screen as the simulation progresses. The performance of the iPhone is sufficient to visualise full-field simulations and to provide an interactive interface for the user. Discussion of relative performance on successive generations of iOS devices will be presented.

I. INTRODUCTION

Mobile devices now often feature multiple cores and clock speeds of more than 1GHz. They also possess additional hardware features such as SIMD acceleration of mathematical operations. Both these features make such devices viable platforms for numerically intensive simulations. The discussion here concentrates on Apple's iOS platform as an example, although similar software has been run successfully on Android and Windows Phone devices

The Transmission Line Matrix (TLM) method provides a numerical implementation of Maxwell's equations to simulate wave propagation. Conceptually, the space to be modelled is filled with a rectangular mesh of electrical transmission lines. Junctions of the lines where they cross are termed nodes. The model is discretised in both space and time, and a simple, highly repetitive calculation models the propagation of impulses on the mesh. As long as certain mesh spacing limitations are observed, Maxwell's equations are satisfied and waves can be demonstrated to propagate on the mesh.

The method works in one, two or three dimensions, and with some additional complexity may be applied to electromagnetic as well as acoustic waves. The Loughborough Wave Lab application uses 2D TLM, visualising each node as part of a bitmap displayed on the device screen. Successive timesteps are displayed as they are calculated, resulting in an animated display of wave interactions on the device.

II. APPLICATION FEATURES

The application¹ has several pre-defined simulation modes that are intended to illustrate different principles and phenomena from electromagnetic wave theory. End-users are also able to interact with the application in a free-form manner, initiating either Gaussian or sinusoidal point sources types in response to finger taps on the screen of the device. Custom boundaries can also be placed or "drawn" in a similar fashion by dragging a finger on the screen.

Virtual Pond: This mode offers users direct interaction with the simulation, responding to touch events by producing one off pulses that interact with each other and bounce off the walls of the simulation. It is very similar to dropping pebbles in a still pond, and in the app it is accomplished by adding Gaussian/normally-distributed pulses wherever the user has tapped the screen.

Sinusoidal Sources: This mode is similar to the Virtual Pond, but in this case one-off pulses are replaced by continuous point sources that output a sine wave into the simulation. For both of the above simulation modes, users can also place multiple sources at once by double tapping the screen. This pauses the simulation and lets users queue up point sources by tapping the screen as they would normally. Users can also drag across the screen to draw chains of point sources or free-hand boundaries. Finally, the phase relationship between two queued up point sources can be set by pinching the screen. Double tap again to return to the normal simulation mode.

Virtual Ripple Tank: A simulation that mimics the often-presented demonstration during school Physics lessons, where a long, straight plane wave (which in this simulation is built up of several sinusoidal point sources) is produced at one end of a shallow tank of water by a length of wood or plastic being bobbed up and down regularly. As shown in the app simulation, if the plane wave being generated is not as wide as the tank, the edges of the wave will disperse circularly outward at both ends.

Waveguide Simulator: This demonstrates the principle of a waveguide, which are used for transmitting high frequency electromagnetic signals, where a regular cable would be incapable of doing so. This simulation depicts a top-down view of a rectangular cross-section waveguide, with a plane wave source at one end with an output frequency chosen to propagate properly down the waveguide. Try changing the frequency in the Settings screen to see how this affects the wave moving down the waveguide.

Young’s Double Slit: Another popular demonstration in school Physics lessons, a demonstration of the principles of diffraction and of interference patterns with waves invented by Thomas Young in 1803. Waves (sound, liquid or light for example) emanating from two slits or holes in relatively close proximity to one another will demonstrate their interference with each other in the form of a pattern of high and low intensity regions where the waves have constructively and destructively combined.

Custom Simulations: CEML is an XML-based configuration language designed by the authors as a platform-agnostic standard for defining Computational Electromagnetic (CEM) simulations. Users can create their own simulations to illustrate a particular effect or principle by writing a configuration file using the CEML syntax. Point sources, plane waves and boundaries can be placed anywhere in the mesh. Users can also dictate when point sources appear relative to the start of the simulation, boundary conditions and whether the simulation should have an end point or run indefinitely. For more information, please read the CEML specification².

III. BENCHMARKING RESULTS

In order to assess the true performance of the TLM solver, the graphical output of the application was disabled during performance testing. Benchmarking was conducted on several devices with both the serial and ARM NEON versions of the solver, in order to determine the precise effects that the different hardware specifications have on the application performance. Table 1 shows the differences in the hardware specifications of the devices that were tested. It must be noted that whilst the graphics performance of each device is irrelevant for this application since all computation is executed on the CPU, it is included here for completeness.

TABLE I. PROCESSOR SPECIFICATIONS FOR SELECTED IOS DEVICES

Device	CPU Clock (GHz)	Graphics		RAM	
		Cores	Clock (MHz)	Channels	Clock (MHz)
iPhone 4S	0.8	2	200	2	400
iPad 2	1.0	2	250	2	400
iPad 3	1.0	4	250	4	400
iPad 4	1.4	4	300	4	533

Benchmarking testing of each device consisted of measuring the average observed frame rate, and using that to calculate a performance figure in nodes.s⁻¹. These figures were then normalised to the observed serial performance of the iPhone 4S. The results are shown in Fig. 3.

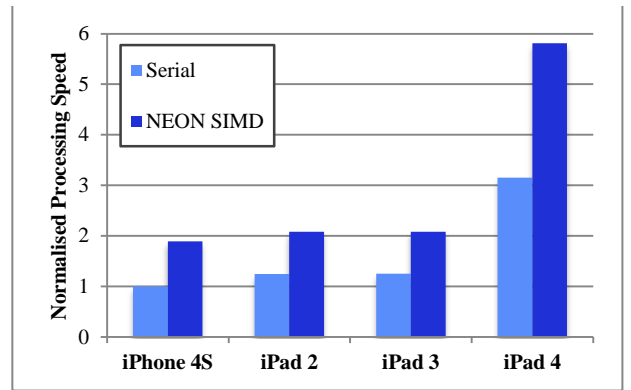


Figure 1. Normalised performance benchmarking metrics for the iOS version of the application across multiple devices.

As expected, in general faster CPU clock speeds on the newer devices result in better overall performance in both serial and ARM NEON execution modes. The serial performance of the solver when running on the iPad 2 and 3 is 25% faster than the iPhone 4S, which can be explained by the CPU clock speed increase from 800MHz to 1GHz. The relative performance different between the ARM NEON and serial modes is 89% on the iPhone 4S, compared to only 67% on the iPad 2 and 3. This is most likely due to the fact that the RAM clock speed did not increase, whereas the CPU clock speed did increase. The iPad 4 displays a large increase in performance, even when compared to the iPad 2 and 3. Serial performance in this case is 215% faster than the iPhone 4S, and ARM NEON performance is 480% faster. Firstly, the CPU clock speed for the iPad 4 is 75% faster than the iPhone 4S, which accounts for a portion of the performance increase. Also, the RAM clock speed has increased 33% when compared to the iPhone 4S, whilst also increasing from dual to quad channel memory.

IV. END-USER UPTAKE STATISTICS

The application was first released for the iOS platform in November 2010. An Android version was released in February 2012, followed by a Windows Phone version in August 2012. As shown in Fig. 4, despite very little promotion, interest in the application has been sustained across all platforms since release. This illustrates the relevancy of the application with students and academics that are interested in applications of this nature. It is interesting to note the large amount of downloads for the Windows Phone application upon its release, which was caused by a prolonged presence on the “New” section of the Windows Phone Marketplace.

The updates to the performance and functionality of the application on the iOS and Android platforms coincide with an increase in the weekly download figures of the application on these platforms. For the iOS application, average downloads per week have increased by 112% after the 2.0 release. For the Android application, average downloads per week increased 70% after the 2.0 release. This illustrates the value that end-users place on application performance and features.

At the time of writing there have been a total of 11,500 downloads for iOS, 7,100 for Android and 3,900 for Windows Phone.

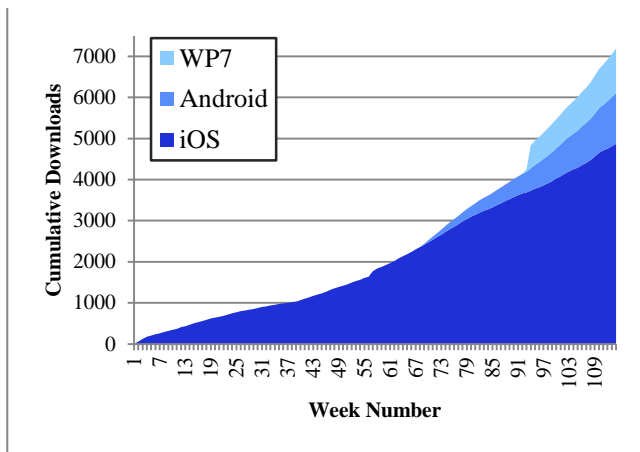


Figure 2. Cumulative application downloads across different platforms.

V. CONCLUSIONS

This paper has presented an educational application targeted at undergraduate students, which has been highly-optimised to take advantage of ARM NEON SIMD hardware

features present in modern mobile computing devices. The performance increases due to these optimisations have been quantified, and specific percentage increases explained. The application is multi-platform and is mature software, having now been available since November 2010. Updates to the application have added support for the CEML standard proposed by the authors. This allows educators and other end-users to configure custom simulations in addition to the default ones included in the application. End-user uptake of the application has been sustained since its release on each platform, and increasing weekly download figures suggest that there is evidence that end-user opinion has become more favourable following updates to improve performance and functionality.

REFERENCES

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