

Artificial Life and the Web: WebAL Comes of Age

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Abstract

A brief survey is presented of the first 18 years of web-based Artificial Life (“WebAL”) research and applications, covering the period 1995–2013. The survey is followed by a short discussion of common methodologies employed and current technologies relevant to WebAL research. The paper concludes with a quick look at what the future may hold for work in this exciting area.

Introduction

Four years ago, in 2010, I clicked a link to watch the new video for the band *Arcade Fire*’s latest release, *We Used to Wait*. Five minutes later, I was sure that what I had just witnessed would change the face of Artificial Life research. This was no ordinary video, but an interactive, localised, personalised experience, coded using native HTML5 technologies. Distinct from the song, it goes by its own name of *The Wilderness Downtown*.¹

On top of the sheer impressiveness of the tightly integrated audio track and visuals based upon *Google Street View* images of any address entered by the user at the start of the experience, real time animation composited directly over the *Street View* images and guided by the detection of streets within the view, together with some deft control of action shifting between different browser windows, *The Wilderness Downtown* features some A-Life related technologies such as flocking and procedural content generation.

It graphically illustrates the potential of the Web as a platform for A-Life applications, and I felt sure when I first watched it that within the next year or two we would be seeing a great deal of this kind of work at Artificial Life conferences. However, that hasn’t happened to quite the degree I was expecting, at least not yet. *The Wilderness Downtown* gained critical acclaim and was a Grand Prix Winner at the 2011 Cannes Advertising Awards along with a host of other

¹<http://thewildernessdowntown.com/>. For further information, see <http://b-reel.com/projects/digital/case/57/the-wilderness-downtown/>.

awards.² It would appear that, for the time being, commercial development in this area is somewhat ahead of academic work.

The rapid development of the Web, and the availability of an ever increasing number of sophisticated APIs, web-focused languages and associated technologies, clearly offers rich potential for developing novel A-Life related research platforms and applications. Despite this potential, there are still relatively few people working at the interface of A-Life and the Web (WebAL). However, this is starting to change.

In this paper, I highlight some of the historical roots and early work in this area, some current work, and possible future directions. This is by no means a comprehensive review, but rather just a taster for the breadth, depth, and potential of the field.

Of particular concern in the following are the new methodologies enabled by web technologies, and the application areas made possible by those methodologies. I will also highlight some currently relevant APIs and technologies, although such things are necessarily rather transient and will doubtless be modified or replaced in the years that follow.

Previous Work

Although the latest HTML5 APIs and related technologies³ offer the possibility of programming sophisticated web applications natively, without the need of plugins or proprietary extensions, the idea of using the Web, or, more generally, the Internet, as a platform for Artificial Life research dates back much earlier.⁴ I divide the following review into

²<http://docubase.mit.edu/project/the-wilderness-downtown/>

³http://en.wikipedia.org/wiki/HTML5#New_APIs

⁴The historical roots of distributed artificial evolution may be traced back to early work on parallel genetic algorithms, with theoretical work starting in the 1960s and implementations in the 1980s—see (Cantú-Paz, 1998) for a good review. One might also consider the field of autonomic computing to be relevant, with its focus on large-scale, self-managing distributed I.T. systems in the

what I have called *WebAL 1.0* and *WebAL 2.0*, in very loose analogy to the popular uptake of the term *Web 2.0* around 2004–5 (O'Reilly, 2007).⁵

WebAL 1.0

In 1995, Tom Ray proposed building a networked version of his well known A-Life system *Tierra* (Ray, 1995). The idea was to use the Internet to create a large, complex environment in which digital organisms could roam and freely evolve. Over a period of 5 years or so, Ray and co-workers used *Network Tierra* to investigate the evolution of complexity in parallel programs (their analogy to multicellular organisms). Results were mixed: they succeeded in producing a human-designed multicellular ancestor with two differentiated cell types (parallel processes) that survived in a differentiated state under natural selection, but they failed to achieve an evolutionary increase in the number of cell types (Ray, 1998).

The year 1995 also saw the launch of the web-based artificial life virtual world *TechnoSphere* (Prophet, 1996). The front-end of the system was a website where users could design their own creatures by selecting from a limited range of pre-designed body parts. Once created, the user submitted their creature to the web server, and it was tagged with the user's email address and a unique ID. Submitted creatures were released into a 3D virtual world (which was not rendered live on the website), featuring a fractally generated landscape with trees existing in a certain band of elevations, other creatures designed by the authors and other online users, and ecosystem rules governing the interaction between all of these components. At key moments during a creature's life, and when interactions occurred with other creatures, the user would receive an update by email. For interactions with other creatures, the email addresses of both authors were shared, so that they could discuss the interaction. Users could also request "postcards" of their creatures, which were generated by rendering a scene showing the creature in its current location. In 1996 the *TechnoSphere* world reached a peak population of 90,000 creatures. In 1998, work started on a version with real-time 3D rendering (Prophet, 2001). This was exhibited at a number of art galleries and museums over the period 1999–2001, although this version ran on a local network of PCs rather than on the Web.

Another early networked A-Life art project was *Life Spacies*, introduced in 1997 and followed by *Life Spacies II* in 1999 (Mignonneau and Sommerer, 2001). This was an interaction environment installed in a museum in Tokyo and

Internet age (Kephart and Chess, 2003). However, as the focus is on engineering reliable I.T. systems rather than A-Life *per se*, I will not discuss this further here.

⁵However, this was a gradual transition of ideas and technologies rather than a sharp divide, so I do not wish to place too much weight on this distinction.

connected to a website through which users from all over the world could design virtual creatures that would then be introduced into the environment displayed at the museum. The creatures were specified on the website by a novel text-to-creature encoding system. A related web-based system, *Verbarium*, was also introduced in 1999, and allowed users to create shapes and forms in real-time using the same idea of a text-to-form encoding and an online interactive text editor (Sommerer and Mignonneau, 1999).

Moving from art to computer games, the mid-1990s saw the release, in 1996, of the A-Life focused game *Creatures*.⁶ The main characters in the game were digital life forms, called *Norns*, that were capable of evolution and lifetime learning, and possessed a physiology, drives, communication abilities, and other life-like skills. Although the first version of the game ran on standalone PCs, a growing online community of players soon started exchanging their *Norns* via enthusiast websites (Jepsen, 1999). In the following years, two further versions of the game were released, and 2001 saw the release of *Creatures Docking Station*, an Internet-based add-on to *Creatures 3* that allowed *Norns* to travel between different online worlds.⁷

A somewhat different kind of A-Life related game was developed by the British design group *Soda Creative* in 1998. Their system, *Soda Constructor*, was written in Java and employed a 2D physics engine.⁸ It presented users with an online editor with which they could construct creatures based upon mass-spring systems with oscillating muscles. By mid-2000, the popularity of the game had soared through "word of email", and an online forum enabled users to share their creations.⁹ *Soda Creative* won an Interactive Arts BAFTA Award in 2001 for their work.¹⁰ In 2002, they teamed up with Queen Mary University London to develop *Sodarace*, a shared online environment where users from around the world could pit their creations against each other in competitions.¹¹ The development of *Sodarace* was supported by the UK's Engineering and Physical Sciences Research Council, and had a strong public outreach and educational flavour.¹²

In 2003, Stanley and colleagues initiated development of the computer game *NERO*, which allowed users to train a

⁶[http://en.wikipedia.org/wiki/Creatures_\(artificial_life_series\)](http://en.wikipedia.org/wiki/Creatures_(artificial_life_series))

⁷Source: Wikipedia article in previous footnote.

⁸<http://soda.co.uk/work/sodaconstructor>

⁹<http://www.acmi.net.au/soda.htm>

¹⁰<http://awards.bafta.org/award/2001/interactive/interactive-arts>

¹¹<http://sodarace.net/>, <http://soda.co.uk/work/sodarace-online-olympics>

¹²In 2013, Szerlip and Stanley developed an open-source browser-based version of *Sodarace*, called *IESoR* (Szerlip and Stanley, 2013). It features a developmental encoding of creatures suitable for evolutionary experiments, and is designed to be an accessible platform that other researchers can easily use.

team of in-game agents using a real-time version of the NEAT architecture (Stanley et al., 2005). Once trained, the team could be put to battle against an opposing team designed by another (possibly remote) user. Battle mode ran on a server such that both users could watch the battle while running the program on separate internet-connected machines.¹³

To end this *WebAL 1.0* section I take a brief look at some WebAL systems from the online virtual world *Second Life*, an environment that itself straddled the transition period from *Web 1.0* to *Web 2.0*. The two most notable projects are *Svarga* and *Terminus*, both of which first came to prominence in 2006. The first of these, *Svarga*, was an island with a fully functioning ecosystem comprising a weather system and various types of plants and animals.¹⁴ Shortly after the release of *Svarga*, a separate effort was launched by the *Ecosystem Working Group* and associated with the in-game location *Terminus*.¹⁵ The group's aim was a develop an open source programming language that would not only allow developers to freely create their own creatures, but would also allow the creatures in *Terminus* to interact and evolve using a shared language. Sadly, it seems that the project ran into funding and resource problems, and is no longer available.¹⁶

WebAL 2.0

An interesting early WebAL project that explored the potential of distributed computation and native client-side storage was *Pfeiffer*, released in late 2001¹⁷ (and still running today¹⁸) (Langdon, 2005). This was a browser-based system that allowed users to evolve 2D patterns described by L-Systems. A user was presented with a variety of patterns on screen, and could select those they thought were good and bad, which directly influenced their evolutionary fitness. The user could also select patterns to be parents for a new offspring. Surviving patterns were made persistent on the client-side using cookies. Users could name their favourite patterns, and save them, in which case they were not only stored locally but also uploaded to the system's global server where they would become available to be sent to other users.

¹³*NERO* was originally distributed as a binary file running on Mac or Windows. In 2009 work commenced an open-source version called *OpenNERO* (<http://nn.cs.utexas.edu/?opennero>).

¹⁴http://nwn.blogs.com/nwn/2006/05/god_game.html, <http://nwn.blogs.com/nwn/2010/03/svarga-returns.html>

¹⁵<http://news.nationalgeographic.com/news/2007/03/070308-second-life.html>

¹⁶<http://forums-archive.secondlife.com/191/83/133314/1.html>

¹⁷I include *Pfeiffer* in the *WebAL 2.0* section because of its emphasis on native web technology.

¹⁸<http://www0.cs.ucl.ac.uk/staff/W.Langdon/pfeiffer.html>

Pfeiffer therefore implemented distributed web-based evolution with aesthetic selection

One of the first projects to really embrace the potential of multi-user collaboration provided by *Web 2.0* technologies was the web-based evolutionary art system *Picbreeder* (Secretan et al., 2008). This is a collaborative interactive evolution that allows users not only to evolve their own images online via the project's website,¹⁹ but also to continue evolving images produced by other users. *Picbreeder* thereby allows the evolution of very deep lineages of evolved pictures, and the collective exploration of a vast search space of images.

An example of an online game using evolution based upon the behaviour of multiple distributed users is *Galactic Arms Race (GAR)* (Hastings et al., 2009).²⁰ This includes a genetic algorithm that evolves new weapons (based upon particle systems) according to the users' current playing styles. In single-player mode, the weapons evolve according to the single user, but in full multiplayer Internet mode the weapons evolve based upon the aggregate usage of all players. The end result is the continual introduction of new in-game content based upon the players' tastes.

The *Picbreeder* system, described above, allows the evolution of 2D images. In 2011, Clune and colleagues introduced the *EndlessForms* website for the collaborative interactive evolution of 3D forms.²¹ *EndlessForms*, like *Picbreeder*, is based upon an underlying CPNN representation of form (Clune and Lipson, 2011).

Also in 2011, a project was launched of a rather different nature to those discussed above. *OpenWorm* is an "open science" project to develop a detailed 3D dynamic simulation of the nematode *C. elegans* (Palyanov et al., 2012). Although the simulation itself is not web-based, the core team are distributed across the world and have regular team meetings using web-based collaboration tools. The project website actively seeks to recruit new members to the team, including scientists, programmers, artists and writers.²² All code, data and models produced by the project are open-source under the MIT licence. The project also pursues a crowdfunding approach, seeking donations via the website, and, in 2014, via a successful *Kickstarter* campaign that raised over US\$120,000.²³

A novel variety of WebAL was reported by Auerbach (2012). This work evolved 2D images with a similar representation to that used in *Picbreeder*. However, the key difference was that the fitness of each image was determined automatically rather than by user selection, and the fitness

¹⁹<http://picbreeder.org/>

²⁰<http://gar.eecs.ucf.edu>

²¹<http://endlessforms.com/>

²²<http://www.openworm.org/>

²³<https://www.kickstarter.com/projects/openworm/openworm-a-digital-organism-in-your-browser>

function included a call to *Google Image Search*.²⁴ The rationale was that images of interest to humans would return many similar hits from the Web, hence, number of returned hits was a component of the fitness function.

Hickinbotham et al. (2013) describe work using the *YouShare* software-as-a-service infrastructure²⁵ to create an online “ALife Zoo”. They demonstrate the potential of the system by setting up various well known ALife systems as services, including *Tierra-as-a-service* and *Avida-as-a-service*. The system allows software written on diverse architectures to be run in a consistent framework, and for web visitors to run and interact with the services for research, education, and archival purposes.

Finally, another WebAL system with an educational flavour is *Ludobots*,²⁶ developed by Bongard and colleagues and launched in 2012. This is an infrastructure for teaching undergraduate-level evolutionary robotics using 3D simulations and other tools. The simulations are not web-based, but the website makes available a series of assignments that anyone can register to complete. Progress involves not just successfully completing the assignments, but also web-based peer review of other students’ work. Having completed all assignments, a student is eligible to collaborate on research projects with other graduates of the system.

Methodologies and Technologies

The work summarised in the previous section demonstrates a variety of ways in which the Web can be used for A-Life research and applications. Some broad categories of methodology are outlined below (this is by no means an exhaustive list):

Distributed computation It is becoming increasingly possible to use the Web as a distributed computation platform. Much of the work surveyed above involves some aspect of distributed computation. The HTML5 and related APIs such as *Web Socket*, *Web Workers* and *Web Storage* make it easier to implement these kinds of distributed computation systems using native technology. Furthermore, a number of technologies are currently being developed to allow fast client-side processing at speeds approaching those of local binaries: Mozilla’s *asm.js*,²⁷ and Google’s *Native Client*,²⁸ are the most prominent of these.

Human and hybrid computation Closely related to the idea of distributed computation on the Web, and also a feature of much of the work surveyed above, is the idea of *human or hybrid computation*, where some part of the

computation is performed by human users of the system. A *human based genetic algorithm* was first proposed by Kosorukoff (2001), and there is a large literature on the more general areas of *human computation* and *crowd creativity* (for good reviews, see (Malone et al., 2009), (Maher, 2010), (Quinn and Bederson, 2011) and (Yu et al., 2012)).²⁹

Cloud APIs The work by Auerbach (2012), described above, illustrates one way in which Cloud interfaces and APIs (in his case, *Google Image Search*) may be used as components of computational intelligence systems. It is not hard to think of many other ways in which Cloud APIs could be employed to provide enhanced capabilities to WebAL systems.

Persistent systems Most A-Life experiments typically run for a few hours, days, or maybe weeks on a local machine or compute cluster, data is collected, results are written up, and no further experimentation is done. A feature of web-based A-Life systems is that they are persistent and offer the possibility of on-going runs that last for years (or, in theory, indefinitely). Furthermore, using client-side processing and data storage APIs (e.g. *Web Workers* and *Web Storage*), these systems can potentially be massively distributed and extended across space as well as time. Systems such as *Pfeiffer* and *Picbreeder*, discussed above, give some indication of the potential benefits of web-based experiments, and many other types of long-term experiment can be imagined.

The Web as a Complex Environment Some of the early papers on WebAL, such as (Ray, 1995) and (Langdon, 2005), discuss the possibility of A-Life agents roaming the Internet and evolving in the complex environment that it provides. Some of the experimental work discussed above shows aspects of this kind of free-roaming agency, but it seems likely that this kind of ability could be explored and exploited much more thoroughly. The *Web Socket* API provides a useful way in which this agent migration can be implemented natively (albeit always via the server from one client to another).

Crowdfunding While not related to WebAL technology as such, another important way in which the Web can enhance A-Life is through *crowdfunding* of research and applications. The *OpenWorm* project, discussed above, is one example of a research effort that has succeeded in raising significant funds through a *Kickstarter* campaign and other crowdfunding efforts.

Steve Grand, author of the *Creatures* game discussed above, also successfully secured *Kickstarter* funding of

²⁹An interesting recent study that conceptualises human decision making and creativity as evolutionary computation is described by Sayama and Dionne (2014).

²⁴<http://www.google.com/imghp?sbi=1>

²⁵<https://portal.youshare.ac.uk/>

²⁶<http://www.uvm.edu/~ludobots/>

²⁷<http://en.wikipedia.org/wiki/Asm.js>

²⁸[http://en.wikipedia.org/wiki/](http://en.wikipedia.org/wiki/Google_Native_Client)

[Google_Native_Client](http://en.wikipedia.org/wiki/Google_Native_Client)

nearly US\$57,000 in 2011 to develop a new A-Life powered game, currently still under development.³⁰

Another A-Life veteran, Jeffrey Ventrella, has also recently secured *Kickstarter* funding of over US\$15,000 for his company *Wiggle Planet*³¹ to develop an augmented reality A-Life game.³²

Between them, these three projects have raised nearly US\$200,000 of funding through *Kickstarter*. These examples demonstrate that it is possible (although still far from easy) to obtain substantial funding for A-Life projects via crowdfunding.

Looking Forward

The preceding sections have looked at ways in which web technologies and A-Life techniques have been combined in domains as diverse as collaborative design, human computation, education, outreach, persistent and long-running experiments, the archiving, sharing, reproduction, and reuse of scientific experiments and platforms, for collaborative open science, for art, computer games, crowdfunding, and more.

As web technology continues to develop, and particularly with the move towards native APIs in place of proprietary plugins, the potential for developing complex web-based A-Life research and applications grows greater each year.

Whether or not a WebAL project is primarily focused on education or public outreach, the very nature of the Web means that WebAL research is inherently open and can reach a wide audience (unless steps are taken to actively prevent this). As funding councils around the world place increasing emphasis on the public understanding of science, WebAL is well placed to play a significant role in the communication of A-Life research to a wide and diverse audience. Furthermore, WebAL not only enables wide dissemination of results, but it also promotes public *engagement* and *participation* with A-Life research.

Looking back over the research reviewed here, it is clear that great strides have been made over the last 18 years. However, as web technology and APIs develop, I have the feeling that current work is only the tip of the iceberg of what could be possible. *The Wilderness Downtown*, itself four years old now, still remains a great showcase of some of the possibilities of the HTML5 era, and yet there are undoubtedly many other possibilities, some as yet unimagined. Advances will doubtless be made in all of the areas outlined in the previous section, and likely in completely different areas as well.

³⁰<https://www.kickstarter.com/projects/1508284443/grandroids-real-artificial-life-on-your-pc>

³¹<https://www.wiggleplanet.com/>

³²<https://www.kickstarter.com/projects/1582488758/peck-pecks-journey-a-picture-book-that-spawns-virt>

It is a truly exciting time to be involved in WebAL research. I cannot predict what advances and achievements will be made over the next few years, but I look forward to witnessing what emerges, and eagerly await a WebAL system that gives me a similar sense of awe as when I first watched *The Wilderness Downtown*.

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