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RESEARCH

SahulTime: Rethinking Archaeological Representation in the Digital Age

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ABSTRACT

SahulTime is an experimental development project to explore how archaeological knowledge might best be represented within a digitally native mode. The system incorporates an interactive, zoomable timeline with a changing geographic view, time-aware icons and detail-boxes that can themselves express temporal visualisations. The core knowledge domain currently represented is Australian archaeology in the context of changing sea-level, but the visualisation concepts developed are more generally applicable at a global level on all timescales, and may offer a first step towards the 'Digital Earth' vision of a top-down interface for exploring the world and its history.

Résumé: SahulTime est un projet de développement expérimental destiné à explorer comment la connaissance archéologique pourrait le mieux être représentée dans le cadre d'un mode digital natif. Le système incorpore une chronologie interactive et zoomable allant de pair avec une vue géographique changeante, des icônes tenant compte du temps et des boîtes de détail qui peuvent elles-mêmes rendre des visualisations temporelles. Le domaine de connaissance fondamental actuellement représenté est l'archéologie australienne dans le contexte du changement du niveau de la mer, mais les concepts de visualisation développés sont plus généralement applicables à un niveau global sur toutes les échelles de temps, et peuvent offrir un premier pas vers la vision de «la Terre Digitale» d'une interface allant du haut vers le bas pour explorer le monde et son histoire.

Resumen: SahulTime es un proyecto experimental de desarrollo con el que se pretende hallar la forma de representar mejor los conocimientos arqueológicos dentro de un modo digitalmente nativo. El sistema incorpora una línea de tiempo interactiva con zoom y una vista geográfica cambiante, iconos sensibles al tiempo y cuadros con información detallada que también pueden expresar visualizaciones temporales. El principal dominio de conocimiento representado actualmente es la arqueología australiana en el contexto de los cambios en el nivel del mar, pero los conceptos de visualización desarrollados se aplican generalmente a un nivel más mundial en todas las escalas de tiempo, y pueden ofrecer un primer paso hacia la visión «digital de la tierra» con una interfaz «verticalista» que permita estudiar el mundo y su historia.

KEYWORDS

Visualisation, Sahul, Australia, Pleistocene, Digital Earth

SahulTime is an interactive platform for representing and correlating concepts through space and time, designed specifically with the needs of archaeology in mind. The focus so far has been on representing Australian archaeology in the context of changing geography, but the temporal visualisation concepts developed are equally applicable to any part of the world on any timescale.

The basic interface of SahulTime has the look and feel of a Geographic Web browser such as GoogleMaps or GoogleEarth, with direct manipulation for panning the map, continuous zooming functions, and pop-up boxes to view details of specific elements. However, what has been lacking from existing geobrowser applications is an equivalent treatment of time, a dimension that is fundamental to the concepts explored in archaeology and the host of other academic disciplines that study the past.

In fact, the original statement of concept that gave birth to GoogleEarth, Al Gore's vision for a *Digital Earth*, had included just such a time dimension. Describing how a young student might use his proposed Digital Earth interface, Gore (1998) imagined:

> She is not limited to moving through space, but can also travel through time. After taking a virtual field-trip to Paris to visit the Louvre, she moves backward in time to learn about French history, perusing digitized maps overlaid on the surface of the Digital Earth, newsreel footage, oral history, newspapers and other primary sources. … The time-line, which stretches off in the distance, can be set for days, years, centuries, or even geological epochs, for those occasions when she wants to learn more about dinosaurs.

GoogleEarth does make some limited temporal functionality available through its authoring language, KML, but the capabilities are rudimentary at best, providing a one-dimensional timeline across which spatial objects can be made to appear and disappear at specific points in time. NASA's WorldWind can depict the Earth's seasonal cycle using satellite images taken at monthly intervals, but these observationally based approaches obviously cannot go beyond the 50-year timespan of satellite photography.

SahulTime explores how the representational paradigms in these systems can be extended to represent concepts in both space and time. Reconstructions of ancient geography are based on what might be seen if a satellite could be taken backward in time, and the icons are time-aware, changing to reflect the temporal dimension of the feature they represent. The 'timeline' is not simply a one-dimensional line, but can display time-based representations such as graphs, time periods or event series. Additionally the timeline is zoomable, seamlessly connecting all possible timescales in the same way that GoogleEarth connects all spatial scales. Each detail-view pop-up box can incorporate a time dimension synchronised to the main timeline, which opens a wealth of possibilities for relating temporal meanings to a particular site. The result is a rich, dynamic interface for expressing concepts through space and time, deliverable directly over the Web.

Poster Presentation

This paper has been adapted from a poster of the same name that was presented in July 2008 at the World Archeological Congress in Dublin, where it won the Best Student Poster award.

Given that SahulTime is fundamentally about representing archaeology within a digitally native mode, it at first seemed paradoxical to try to present the experience of this dynamic interface in the form of a static paper poster. On the other hand, the poster provided the opportunity to communicate the concept to the viewer at a glance.

With this in mind, the poster (Figure 1) was designed to depict the path of experience a user might encounter in using the system. The arrows create a flow between the screen of a laptop and two screenshots that represent a progression through geographic zoom and timescale zoom. In practice, the detail-box pops up within the SahulTime interface, overlaying half of the geographic view, but the poster provided the opportunity to display multiple detail-boxes floating outside the browser window, each with its own explanation of significance.

The reader can access the current prototype version directly online at the SahulTime website: http://sahultime.monash.edu.au but it should be noted that the system is in continuous development, and many of the more advanced functions will remain behind-the-scenes until they can be given a proper contextualisation alongside the interface.

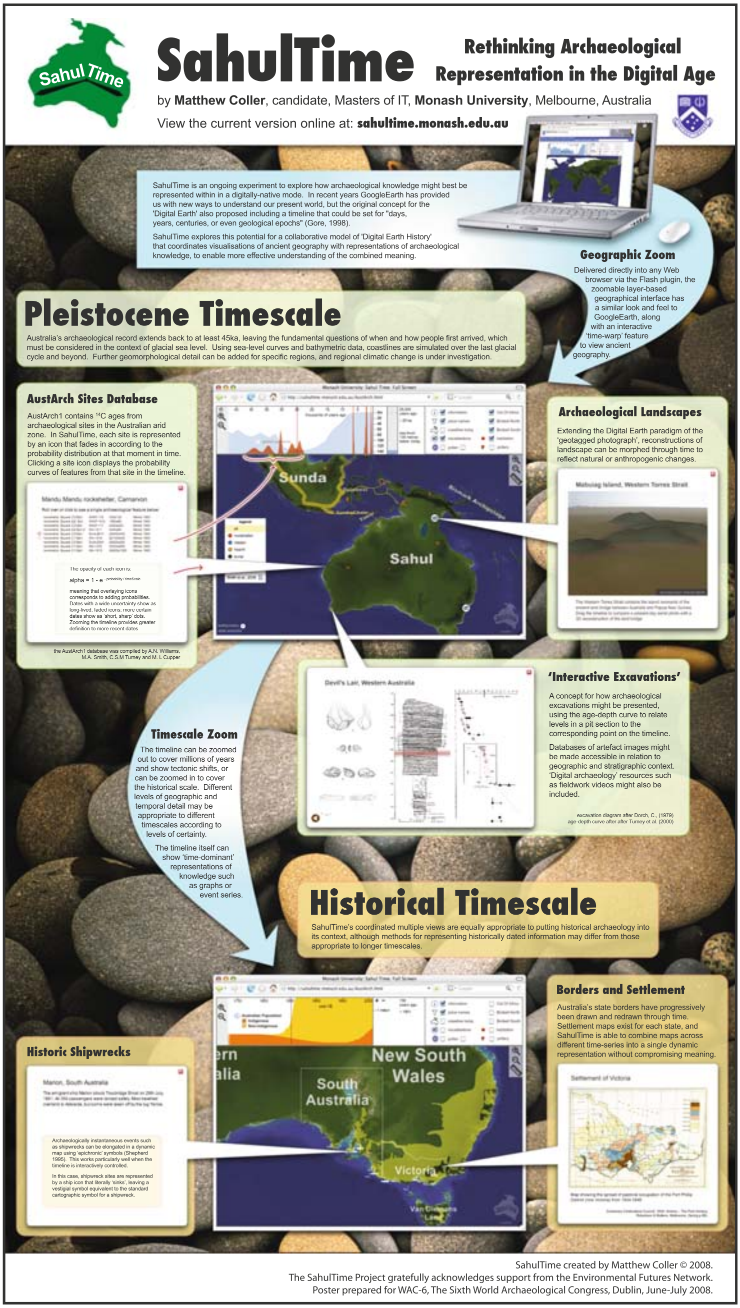

Figure 1. SahulTime poster as presented at WAC-6 in Dublin, July 2008

Pleistocene Timescale

The initial impetus behind SahulTime was to relate Australian archaeology to the changing geography of the continent on the glacial timescale. 'Sahul' is the name given to the ancient land-mass that existed when Australia and New Guinea were connected by a land bridge, and the fundamental questions of when and how people first arrived on the continent must be considered in a geographical context at lower sea level.

Discussions of the Australian archaeological record typically begin with a map of Australia supplemented with contours of the sea-floor to represent the coastline of Sahul at points in the past (eg. O'Connell and Allen 2004, O'Connor 2007). These maps are often accompanied by sea-level curve to indicate temporal progression (eg. Mulvaney and Kamminga 1999, Hiscock 2008).

The Western tradition of map-making tends to assume a coast to be a simple line delineating land from a homogeneous sea. Yet shallow marine environments can provide some of the most abundant resources for sustaining a population. The equal importance of land and sea is reflected in Torres Strait Islander traditions, where one place-name often refers to a particular part of the island along with its surrounding waters (Duncan Wright, pers. comm.).

SahulTime's views of the continent are generated from a topographic/bathymetric digital elevation model, using depth-shading that colours shallower water such as reefs in a lighter shade of blue than deeper ocean. For present sea-level this approximates the colouration seen in a satellite image, and for lower sea-levels it simulates a satellite view of ancient seas. For Pleistocene sea level, the north-west coast of Australia exhibits an extensive reef system punctuated by islands, a feature that has a particular importance given that it is one possible site for the first arrival of humans. While this depth-shading procedure generates good representations of the sea, the representation of land is fairly arbitrary. A treatment of palaeoclimate and vegetation models is under investigation, which might yield a simulation of seasonal cycle for times past.

SahulTime uses a sea-level curve (after Lambeck and Chappell 2001) to interpolate between incremental sea-level views and relate any point in time to the corresponding outline of Sahul. The user can drag the mouse-cursor across the timeline to explore the effect of sea-level over time (Figure 2). Additional spatio-temporal features are overlaid on the map, such as the ancient Lake Carpentaria (after Reeves 2004), and the mid-Holocene inundation of the New Guinea lowlands (after Chappell 2005). Many further features are still to be included in the visualisation, such as Lake Eyre, the ancient Bass Lake and the Willandra Lakes System.

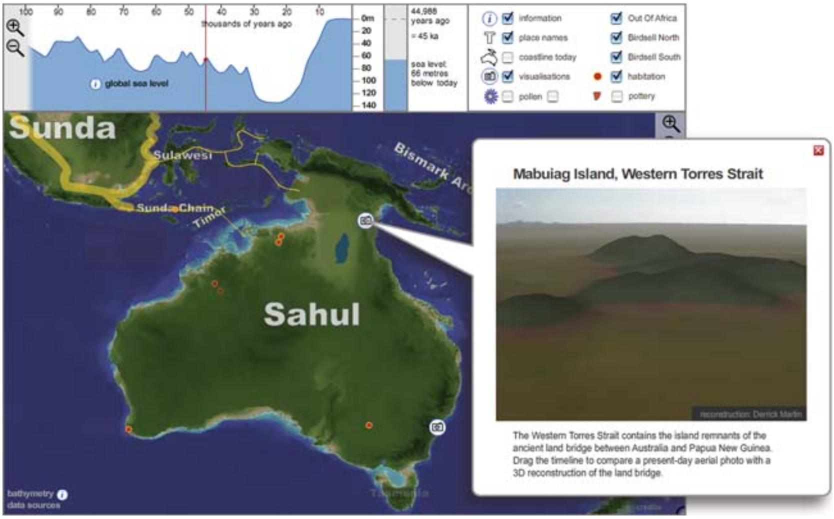

Figure 2. SahulTime interface with the timeline set to 45 ka. Clicking a 'camera' icon opens a 'landscape' view which shows an aerial photgraph in the present-day, fading to a recostructed view of the ancient land bridge at times of lower sea level

Archaeological Sites and Landscapes

By turning on extra layers in SahulTime, early habitation sites around Australia are indicated by red dots that fade in at the appropriate time (Figure 2). Clicking the dots displays a detail-box which can show further explanation or link back to primary sources such as the site report from the original excavation. Other layers present possible migration routes, such as the island-hopping routes between Sunda and Sahul proposed by Birdsell (1977).

The icons in the camera layer are analogous to the photograph icons in GoogleEarth, except that SahulTime can display a temporally dependent visualisation for a particular site. In the case of Mabuiag Island in the Torres Strait (Figure 2), the detail-box shows an aerial photograph in the present day, and fades to show a reconstructed view of the ancient land-bridge in the past.

This feature offers myriad opportunities for representing the temporality of landscapes as envisioned by Ingold (2000), and the same principle might be applied to represent archaeological interpretations of actual remains. Reconstructions of activities would be shown that are known to have taken place in the past from a site's archaeological record, and the corresponding image for the present day might show a photograph from the excavation that recovered the evidence.

AustArch Sites Database

A data-driven application of SahulTime is the visualisation of the AustArch1 database (Smith et al. 2008), a compilation of radiocarbon dates from archaeological sites in the Australian arid zone. Using calibrated radiocarbon probability distribution files from OxCal 4.0, icons fade in and fade out in each of the site locations.

Clicking a site icon displays the probability curves from that site in the timeline, and the detail-box (Figure 3, top) lists the site's raw radiocarbon dates. The exponential formula used to determine the transparency of each dot means that overlaying dots is equivalent to plotting the sum of probabilities, which in turn can be considered a proxy for habitation intensity at that location.

The overall result is a time-based regional view of excavation results from a distributed set of sites, but one which takes a fuzzy approach in representing the time dimension. Dates with a wide uncertainty show as long-lived, faint icons, whereas more certain dates show as 'short, sharp' dots. This is understandable at an intuitive level, in the same way that a blurry-edged shape implies an uncertain boundary.

This visualisation is not currently part of the public interface, but can be loaded up using a private URL. It is still under development and full technical details of the final methodology will be published elsewhere.

Interactive Excavations

The data-driven, icon-based approach described above bears some similarities to GIS mapping, but demonstrates the potential of truly time-based icons. However, it still takes a fairly reductionist approach to the information yielded by an excavation, whereas developing chronologies from a given site is a more complex process.

Stratigraphic excavation relies on the law of superposition, the principle that the spatial arrangement of strata in an excavated deposit may be used to infer the spatio-temporal process of deposition, and thereby determine temporal narratives of site use from the context of artefacts. Radiometric dating now enables the assignment of absolute ages within a stratigraphic sequence, and has become a routine component of excavations in Australia.

In Figure 3 (bottom), the section diagram for the West Australian site of Devil's Lair (after Dortch 1979), is combined with an age-depth curve determined from radiocarbon dates (after Turney et al. 2001) to develop a spatio-temporal visualisation of stratigraphy for the site. As a user runs through the timeline, a red bar moves down the excavation, guided by

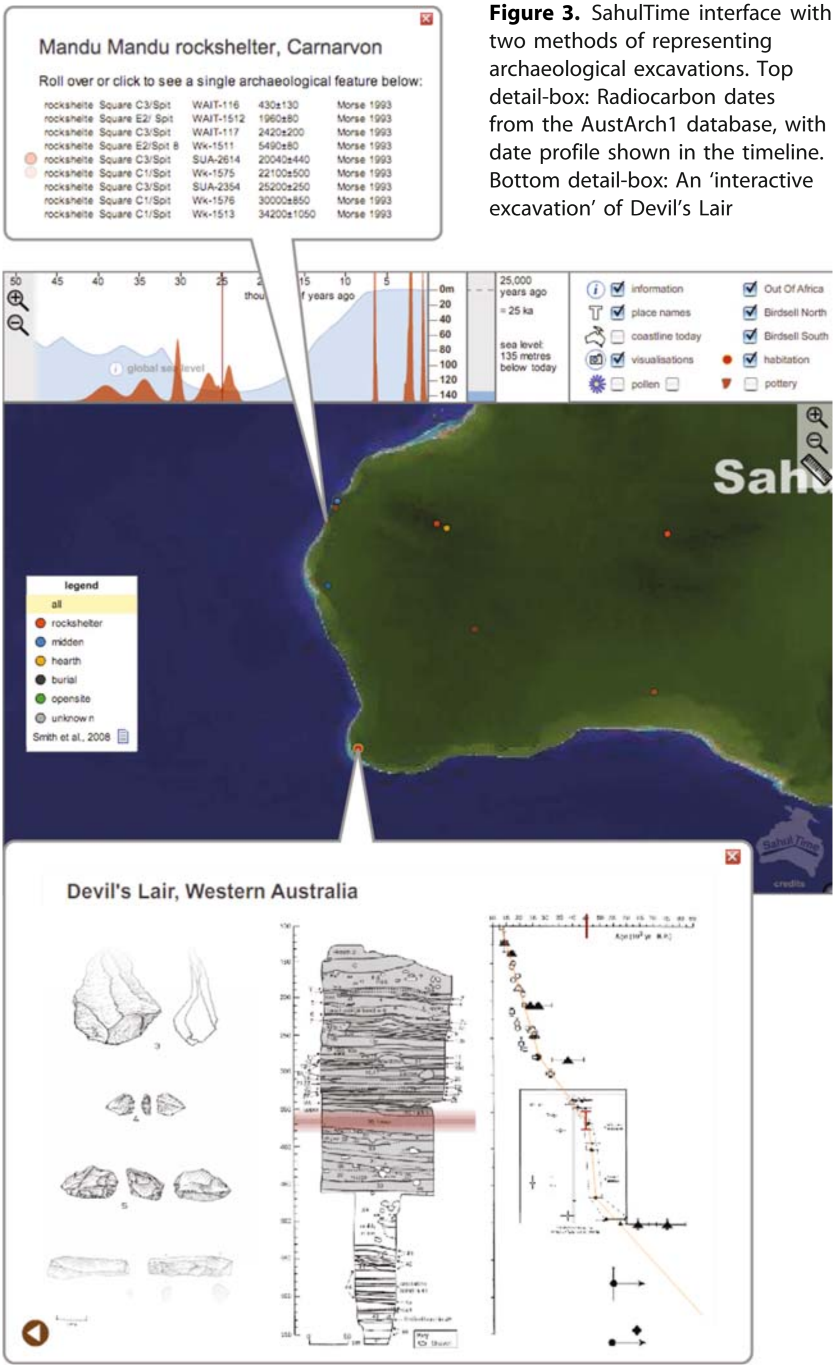

Figure 3. SahulTime interface with two methods of representing archaeological excavations. Top detail-box: Radiocarbon dates from the AustArch1 database, with date profile shown in the timeline. Bottom detail-box: An 'interactive excavation' of Devil's Lair

the age-depth curve, thereby indicating which level of the excavation corresponds to each particular point in time. The uncertainty in the age-depth curve is expressed by the ‘fuzziness’ of the bar, which appears well-defined at the top and bottom of the excavation, but blurred in the middle where the sedimentation rate was more rapid. There is an option to show the artefacts that correspond to particular depths, although this is a proof-of-concept at present–the artefacts shown are not truly correlated to time.

The excavation chosen here is a relatively simple example with layered stratigraphy, but the same principles might be adapted to reconstructing the deposition/disturbance process from a Harris matrix. Alternative interpretations of the deposition process might be offered as options for the user to explore.

Timescale Zoom

A feature of the SahulTime interface that sets it apart from typical animation approaches is the ability to zoom the timeline and thereby combine phenomena that become apparent at different timescales upon a single, unified timeline. Although archaeology was SahulTime’s initial primary purpose, its coverage has been expanded to a greater range of timescales, and its disciplinary focus has likewise broadened to encompass geology, biogeography, history, climatology and a host of other spatio-temporal knowledge domains. Different levels of geographic and temporal detail may be appropriate to different timescales, as some phenomena will be known to a high resolution of understanding, while others have been intentionally left indistinct to cue the viewer to the associated uncertainty.

Historical Timescale

Zooming to a timescale of 300 years, the timeline changes to display dates in years CE, and graphs appear showing population based on census data and estimates of pre-European indigenous population (Figure 4). This data is very much open to critique but at least gives some visual impression of the impact of European settlement on the indigenous population. A dashed line acts as a cue indicating that values before 1901 are merely estimates, although the post-1901 census data might equally be criticised for assuming a clear and constant distinction exists between Indigenous and non-Indigenous Australians.

The progression of pastoral settlement across the continent is shown by animated shading in yellow, based on combining historical maps for each of the states (Figure 4). This is part of a wider project to correlate palaeo-environmental records with the time of initial European disturbance.

Meanwhile, the 'placenames' layer shows the names given to the Australian continent through the period of European 'discovery', settlement, the subsequent carving-up into states and the shifting of state borders.

Shipwrecks

Historical dates must be elongated in a dynamic map using 'epichronic symbols' that appear for longer than an instant (Shepherd 1995). Shipwreck dates and locations from the Australian Shipwreck Database are symbolised in SahulTime by an animated ship icon that literally 'sinks' to indicate the meaning of the space-time event. Because the timeline is interactively controlled, the automated flow of 'display time' can encode separate meanings from the 'synchronic' dimension of the timeline itself.

The symbol used in SahulTime reflects the dual meaning of a shipwreck: as a historical event, and as an archaeological site thereafter. Once the sinking animation has completed, a vestigial symbol remains in place, which is equivalent to the standard cartographic symbol for a shipwreck site.

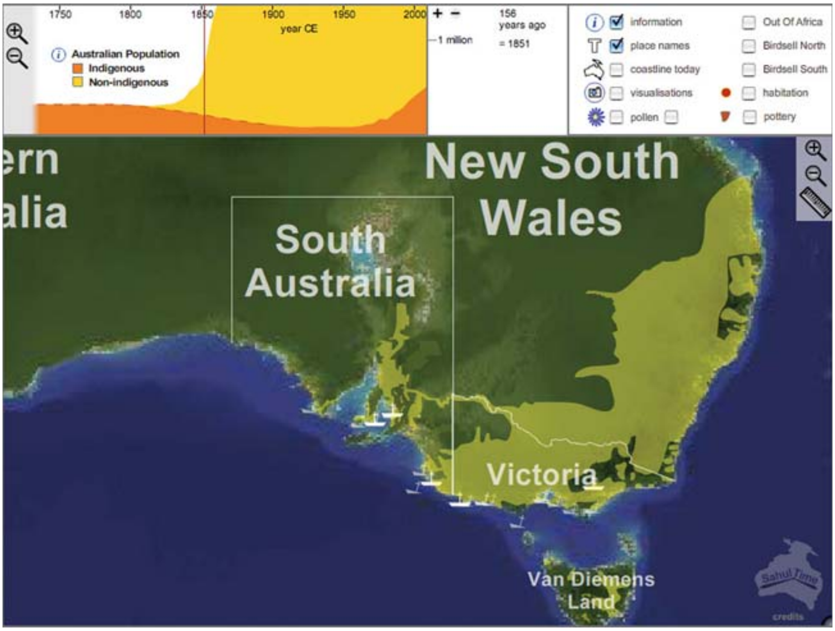

Figure 4. Historical timescale in SahulTime, showing population, state borders, shipwrecks and the spread of European setttlement across the continent

Rethinking Archaeological Representation

From the start, the development of SahulTime has been motivated by archaeologists' needs for a means of expressing temporal meanings. The original idea emerged from an expedition to the Torres Strait Islands, where the archaeological record must be interpreted in the context of changing sea level and a host of spatio-temporal phenomena such as island formation and reef growth (David and McNiven 2004).

Paper is a poor medium for representing space and time together; the result is often a representation with a 'dimensional dominance' (Langran 1992). For example, the tendency to overlay the outline of Sahul with a modern-day coastline is a case of telescoping time into a single space-dominant representation, and has the effect of prejudicing our conception of the past. Today's coastline has a very practical importance to today's archaeologists, but for understanding a Pleistocene site from the point of view of its contemporary inhabitants, it matters not. The principle behind SahulTime is to place meanings into their proper temporal context; to make a connection between conceptions of the same site at different points in time.

SahulTime demonstrates how a range of phenomena may be synthesised in a visual interface yet linked back to the underlying support material. This opens the possibility of using the spatio-temporal visualisation as the primary interface to archaeological results, while maintaining the ability to 'drill down' to the primary sources.

In 1999, Hodder suggested a danger that the Internet would simply translate old forms of elite knowledge into new forms, thereby excluding the un-networked. In the decade since, platforms such as Wikipedia have indeed begun to erode hierarchical systems of knowledge and demonstrate that new models are possible based on networks and flows, just as Hodder (1999) had hoped.

The Digital Earth initiative has demonstrated how a tremendous informational resource, satellite imagery, can be made accessible to specialist and non-specialist alike. GoogleEarth finds as much use today by archaeologists searching for potential sites as by ordinary people planning a holiday. GoogleEarth and GoogleMaps are said to have launched the 'Geographic Web', which allows information to be browsed according to its location of relevance, as opposed to the traditional structure of pages and documents.

Archaeology and related disciplines hold a wealth of knowledge about the past, yet much of this knowledge resides in journals, expressed primarily in textual forms that are inaccessible to the non-specialist. As a result, popular representations of the past can be poorly integrated into the minds of the public. For example, many people seem to confuse the timescale of the glacial cycle with the timescale of tectonic movement of continents. One of the most significant features of the Australian archaeological record is the 50,000-year antiquity of human arrival, but for this timescale to be meaningful it must be expressed in more than just numerical terms.

A visual interface such as SahulTime can therefore serve a twofold purpose: firstly as a tool in the process of archaeological knowledge-making, and secondly as a means of interpreting the results for the wider public. Already the process of developing the content has highlighted unanswered questions, and even revealed a few misconceptions among the experts. Likewise, it can help archaeologists to explain their research to the communities with which they work. Bahn, (1997) asserts that 'Archaeology's ultimate goal—if it is to have any meaning or justification—must be to convey its meanings not only to students and colleagues, but above all to the public…', yet this purpose has taken a secondary role in archaeological practice in favour of more theoretical discussions.

The ambitious target set by Al Gore's Digital Earth vision is to 'put the full range of data about our planet and our history at our fingertips' (Gore 1998). For archaeological knowledge, such a challenge is considerably more difficult—both epistemologically and technically—than for satellite imagery, since conceptions of the past are never definitive, and are always open to review and re-evaluation. SahulTime is perhaps only a small step toward this vision, but it is the journey that matters as much as the destination.

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