Archaeological 3D Laser-scanning in the South Pacific

Rapa Nui: Easter Island

Dave Wellman's Magellan handheld GPS read Latitude 27 degrees 09 minutes and 00 seconds South, Longitude 109 degrees 20 minutes and 20 seconds West, which indicated that he was right in the middle of the South Pacific. He was on an island approximately 2,200 miles west of Chile in South America, 2,300 miles east of Tahiti in French Polynesia and 4,993 miles as the crow flies from his home base, the D. Wellman Surveying office in Eugene (OR, USA). The place was Easter Island, which belongs to Chile and is located on the South American mainland. It was a rather long way from home to do a laser-scanning survey but the circumstances merited the expedition to this Polynesian island of Rapa Nui, or as it is called in Spanish, Isla de Pascua. Below is the account of this laser-scanning survey.

By Dave Wellman, CEO, D. Wellman Surveying, USA

A bustling combination of Chilean and Rapa Nui residents number about 2,500. A fascinating mix of Polynesian and Spanish speaking cultures is seen daily in the small shops, modest homes and quaint hotels. Dogs and horses can be seen on the cobblestone streets and there are lively soccer games in the park overlooking the town beach on Sundays. Ever present are the silent, stone carvings. The languages spoken on the island are Rapa Nui (a dialect of the larger Polynesian language group used throughout the islands in the Pacific Ocean) and Spanish, the currency is the Chilean peso and the government is that of a Chilean colony. Since 1935 a large part of the island has been designated as a Chilean National Park. Parque Nacional Rapa Nui nearly encompasses the island and includes many of the special features along coastal and inland areas.

Toppled moai (giant statues) being scanned by Cyrax 2500

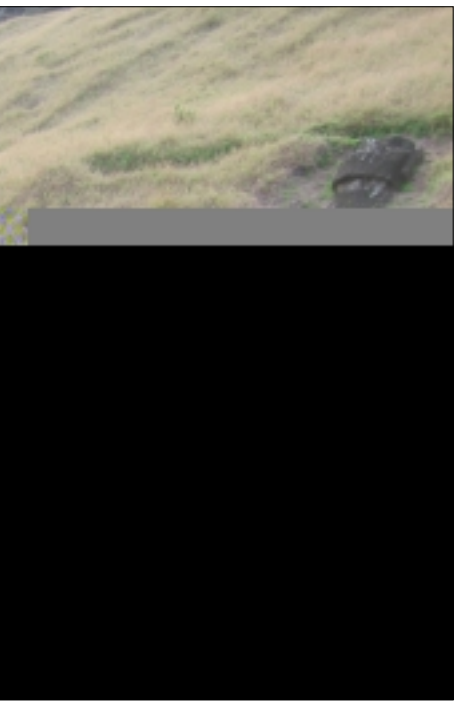
Moai on

Role in the Project

The request for our services as surveyors was based on a need on the part of the University of Hawaii Department of Anthropology to evaluate the collection and presentation of 3D digital models of the gigantic statues or moai. We were under the direc-

Front view of moai row on Easter Island

tion and guidance of university archaeologist Dr Terry Hunt. Up until this time, standard procedures such as photogrammetry, callipers and tape measures had been used to provide measurements for the study of the statues, ahu (ancient temples) and related



Easter Island

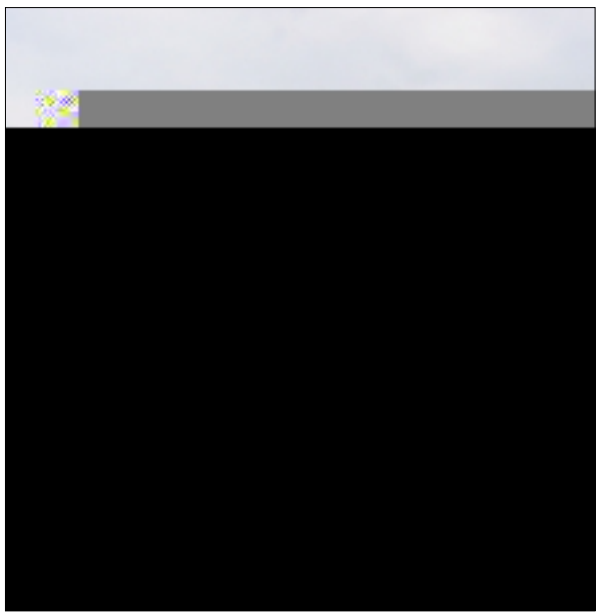
artefacts. 3D scanning technology, such as Cyra Cyrax 2500 can provide the required accuracy and completeness for data collection concerning cultural resource treasures such as the moai. A benefit of this technology is the ability to obtain data without touching the artefact. This fact alone is important in gathering dimensional data information on priceless cultural resources and artefacts.

Mosaic of Rocks

Being one of only a few companies in the Pacific Northwest using 3D survey-grade scanning technology at the time, we proposed a joint effort for this pilot project. We teamed up and pooled resources with the Honolulu office of Geo-InSight International Inc. to scan the gigantic statues on Rapa Nui (www.geoinsight.com). The project objective was to provide an assortment of 3D scanned 'point clouds' for our client to evaluate. Our mission was to provide scanning services and generate enough detailed information to demonstrate the advantages of 3D scanning technology in the field of cultural resources data collection. Upon arrival our client took us to the largest and most complex ruin in the permitted work area. Before us lay an intricate mosaic of rocks, upturned moai, toppled moai topknot hats and remnants of the ahu, temple pedestal upon which the moai stood, some parts in good shape, some in disarray. The crew quickly came up with a plan and proceeded to scan for the rest of the day.

Control Survey

While scanning, one crew established a control survey around the perimeter of the site with a key point at the top of the ruins. The non-invasive scanning technology helped maintain respect for the ahu, which hold religious meaning for the Rapa Nui people. Our control survey was to be used by the scientists at a later date to co-ordinate their aerial survey work with our scanning control and with surrounding project sites. Not having done a GPS survey control prior to arrival, we assigned temporary local project coordinates to our



Scanning sensors spread around a moai

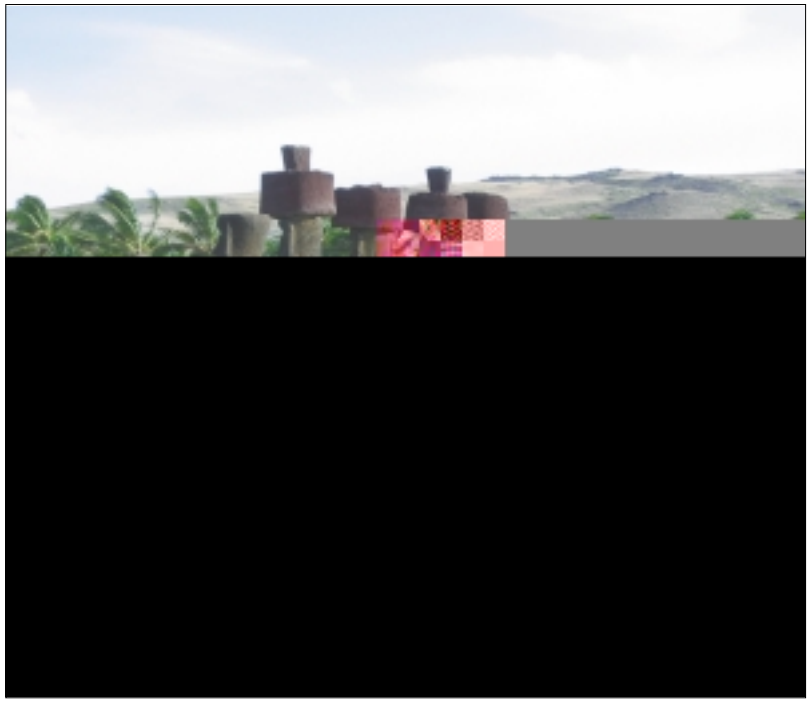
points. The complexity of the project required that we use multiple scans registered together to form one cohesive 3D model. This would allow the 3D model to have a complete scan from many angles, thus covering as many surfaces of the site as possible. As the scanning progressed, high-resolution targets were set to tie our earlier scans to the work in progress. These precise and highly reflective targets allow each of the multiple scans to be registered together, much as overlapping aerial photography uses control points.

Combination of Methods

A combination of methods was used for the registration on this project. Within the Cyra Cyclone software is a target scanning and registration routine. Precise real world or project coordinates of the targets do not need to be known for the scans to be registered to each other. The arbitrary coordinate system created by the scanner becomes the coordinate system for the model. The software automatically registers multiple scans together by matching the naming convention applied to each target by the scanner operator. However, we elected to tie as many of the targets as possible with our reflectorless total station, a Leica TCR703, calculating and noting the project coordinates of each target. This methodology essentially tells the scanner the coordinates of specified targets, restrains the registration reduction to those coordinates, then allows for a redundant analysis in Cyra's least squares registration routine.

Infectious Enthusiasm

This portion of the project covered two days of scanning. Each day's target coordinates were entered into a separate registration routine and designated as the 'home scan'. An analysis of the residuals of the registration process allows the operator to cast out redundant outlier target registration combinations that degrade the validity of the solution. Once the registration is completed, each point generated by the scanner has an assigned project coordinate. The entire 3D model is then ready for inspection, surface modelling, detailed measurements or export to third party software and use for any number of different applications. Scanning enthusiasm became infectious both within our group and



Rear view of moai row on Easter island

Cyrax 2500 3D Laser Scanner as it scans Orongo. Island of Motu

History of Rapa Nui

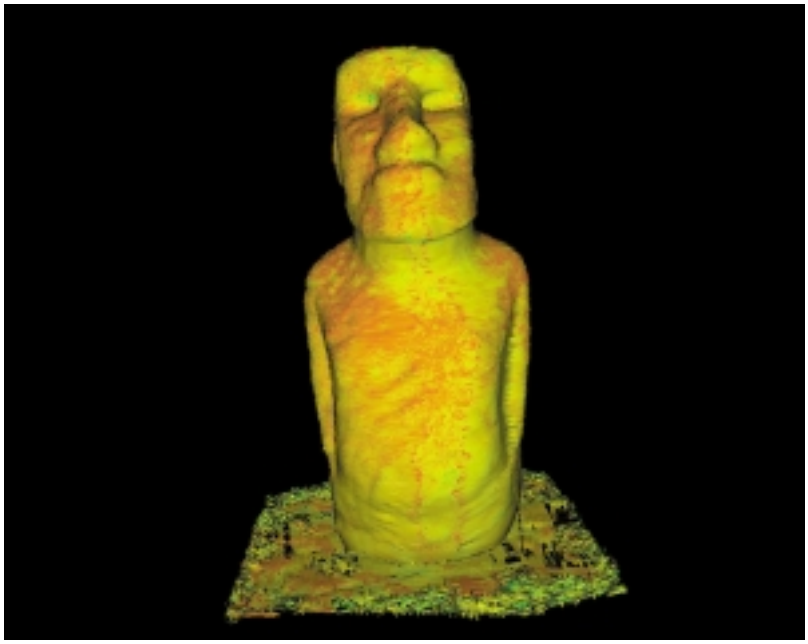
Present theory and legend suggests that indigenous Polynesian settlers arrived as early as 400 to 800 AD. Legend suggests that Polynesian King Hotu Matu'a brought three hundred settlers from the West, somewhere in eastern Polynesia. Research, and the isolation of the island, indicates that the new inhabitants developed a culture free from interference from the outside world until Europeans showed up on the scene. The most intriguing aspect of the Rapa Nui culture, and certainly the interest of the present-day tourists, is the ever-presence of the famous, huge stone statues called moai, found throughout the island. Most moai are 20 feet tall or larger and weigh up to 80 tons. The largest is 69 feet long and would have been taller, but was never finished. It was the Dutch explorer Jacob Roggeveen , in search with his three ships of the mysterious Great South Land (which in fact did not exist) who 'discovered' Rapa Nui on Easter Sunday in 1722 and called it in Dutch 'Paas Eiland' (Easter Island). He mentioned the moai and the inhabitants in his journals. The British Captain Cook arrived on the island in 1774, looking for a place to 'rest his men' after searching in vain for Antarctica. Cook found that some of the moai had been "toppled from their platforms". Visits by other explorers, as early as 1825, recount that all the moai had been toppled. Starting in 1805 and continuing through the mid-1860s, slave traders raided the island to supply workers for the Peruvian guano mines. The native population was decimated both by slavery and the introduction of smallpox and tuberculosis. Less than one hundred direct descendants of the original population remained on Rapa Nui. A validated oral history of the islands has thus also been lost. Rapa Nui was among the first Polynesian cultures to have a written language, as was evidenced by the discovery of the rongorongo. These inscribed tablets display special characters, yet those who could read them were lost with the rest. With no understandable written language and the break in the chain of oral history, much of Rapa Nui and its incredible past has remained a mystery. Why these colossal stone heads and temples? How were these moved and erected? Why were they toppled?

amongst the other professionals on the island. Application ideas grew in number.

Accuracy

Product specifications of the Cyrax system are published as 1 sigma single point position accuracy of approximately 6mm within the 1.5metre to 50metre range. Previous experience with the scanner suggests accuracy better than this at nearly twice the distance. We have found high angles of incidence and shiny surfaces affect accuracy the most dramatically. Our subject survey error budget for this project was well within this range. There would be no visible way of checking our accuracy resolution due to the nature of the rock, erosion and degradation of the stone, and to varied shapes of the objects. We felt that the truest representation would best be generated by dense overlapping scans. Multiple points could then be statistically modelled into a more true-to-form shape of the subject piece, using third party surfacing software. Scans for this trial were at a nominal 6 x 6mm spacing. The amount of data collected and the representation of the point cloud exceeded the client's expectations. The ability to collect such a comprehensive dataset far exceeded the archaeologist's efforts to date.

petro glyphs at the ceremonial village of Nui in distance



Finished scan showing a 'meshed' 3D point cloud. Colours representing intensity values of the laser reflecting off surface

Another Scan

Another scan for evaluation was that of the impressive petroglyphs at Orongo. The petroglyphs are carved on a rock outcrop located at the terminus of a precarious, knife-edged ridge - 1,000 feet high - that separates the caldera (blown-out volcano mouth) of an ancient volcano from the Pacific Ocean. The objective of this portion of the project was to evaluate the use of scanning to 'digitally preserve' the petroglyphs. The Consejo de Monumentos Rapa Nui (monuments council), charged with preserving Rapa Nui's treasures, is concerned about the degradation of the petroglyphs in such an exposed location and about imminent destruction should the ridge tumble into the Pacific Ocean.

Reflections

I can think of few other careers that offer the chance to be allowed to undertake such a unique project in such an environment. I can think of few that provide as much enjoyment in allowing us, as professional surveyors, to use our skills and equipment to assist other professionals with their efforts. Add a little flavourful travel, intriguing clients and a few technical hurdles and you end up with a rewarding surveying career.

Acknowledgement

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Biography of the Author

Dave Wellman

Dave Wellman is licensed as a surveyor and engineer in Oregon, Washington State and Maine, and has been practising since 1985. Located in Eugene (OR, USA), his firm (www.wellmansurveying.com) offers traditional, cadastral and telecommunications lease site surveys, long and short-range 3D scanning, and aerial photography.

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