AMUSE
3-D Colour Imaging, Remote Access and Display

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Abstract:

In October, 1995, the Canadian Network for the Advancement of Research, Industry and Education (CANARIE Inc.) [a] approved the AMUSE (Geographic Independent Access to **MUSE**ums) project [b]. The objectives are to develop a commercial 3-D colour digitizing camera for high resolution imaging of museum objects and to implement an interactive multimedia presentation system to display the images in a networked-based remote virtual museum site. During the technology demonstration phase, the digitizing camera will be installed at the Canadian Museum of Civilization to digitize a collection of objects. In addition, the 3-D image data of the collection will be transmitted to a virtual museum display at a remote location. The objective of this paper is to present an overview of the project.

1. Background

During the EVA Conference in London in 1992, R. Baribeau presented a paper on the "Applications of Colour and Range Sensing for the Recording and Study of Museum Objects" [1]. The paper described a high resolution three-dimensional (3-D) digital colour imaging system developed at the National Research Council of Canada (NRC), in collaboration with the Canadian Conservation Institute (CCI) and its use for the recording of museum and cultural objects.

This work was performed using a laboratory prototype laser-based 3-D camera - often referred to as a laser scanner - patented by NRC (Figure 1). The basic elements of the system include an RGB laser source, a scanning mechanism to project a "white light" spot from the RGB source onto the object and a position and intensity sensor. The range measurement is derived from triangulation. Colour measurement is made by detection of the intensity of the RGB wavelengths of reflected light. The synchronized scanning geometry provides significantly improved performance over conventional triangulation in terms of increased resolution, reduced camera size, depth of field and immunity to ambient light interference. The

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a CANARIE Inc. is an industry led non-profit consortium established to promote government and private sector collaboration in the development of the Information Highway in Canada.

b This project should not be confused with the European Union ACTS project # AC011 which is also named AMUSE (Advanced **MU**ltimedia **SE**rvices for Residential Users). The two are not related. To avoid confusion the two can be distinguished as the Canadian AMUSE and EU ACTS AMUSE projects respectively if needed.

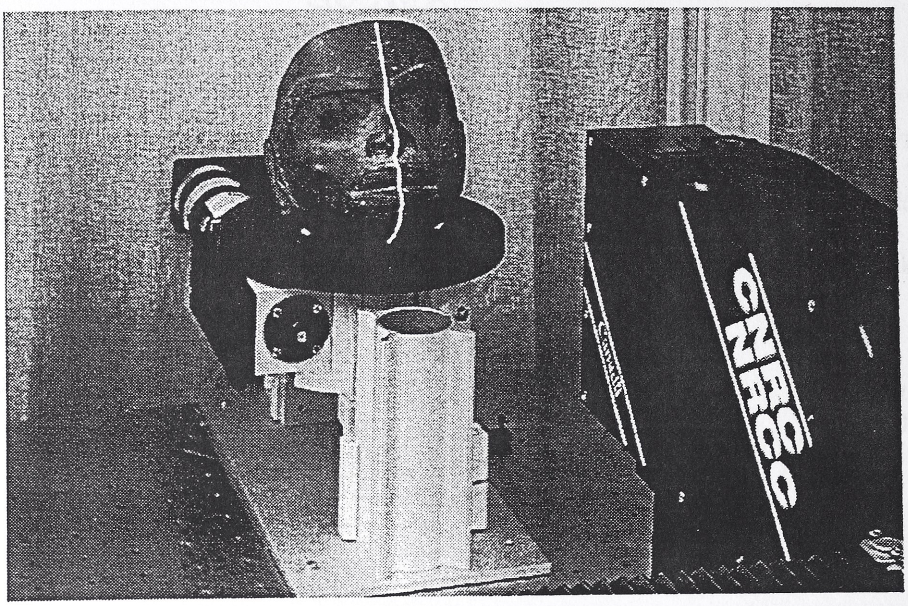

Figure 1. The NRC colour laser scanner system imaging the Tsimshian Stone Mask from the Canadian Museum of Civilization. In this configuration, a cylindrical scan is made by rotating the mask through 360° on a rotation table while the scanning mechanism in the camera projects a white laser spot (white line profile) on the surface. One profile is recorded for every degree of rotation. Due to the simultaneous digitization of the CCD pulse position and amplitude, the spatial (x,y,z) coordinates and colour (R,G,B) data are in perfect registration. For information see URL http://www.vit.iit.nrc.ca

3-D shape and colour of objects are recorded simultaneously with high resolution and in perfect registration. The technology also has a number of industrial, mining, environmental, medical and space applications. These, as well as technical details on the system, have been reported in numerous publications [2, 3, 4, 5, 6].

The CCI has participated with the NRC in the development of the scanner for museum and cultural applications. In the course of this work, objects from the Canadian Museum of Civilization, the National Gallery of Canada, the Canadian Museum of Nature and the National Museum of Science and Technology, have been brought to NRC for testing. The objects have included paintings, artifacts, sculptures, natural history specimens and scientific instruments.

The results, as reported in several publications [7, 8, 9,10,11,12,13], have shown that the technology can be applied to a variety of traditional museum activities. In addition, it offers several new applications and "electronic highway" opportunities. For example:

- Accurate, high resolution "gold standard" or archival quality digital records of the shape, colour and dimensions of objects are obtained. The data can then be used for a variety of activities within the museum without the need to re-record or re-photograph the object. These include display, research. scholarship, conservation, publication, reproduction, insurance and repatriation activities.

- Using a 3-D graphics workstation, viewers can interactively rotate and view the images from any angle as well as magnify or reduce them in scale. Features can be accurately measured, examined under different lighting conditions and displayed in 3-D with or without colour. Details such as the impasto effect of brush stroke, tool marks on a small figurine or the shape of an archaeological find can be recorded, examined, displayed and if necessary, replicated. Participants wearing stereo viewing glasses can perceive the objects in full depth and colour (Figure 2).

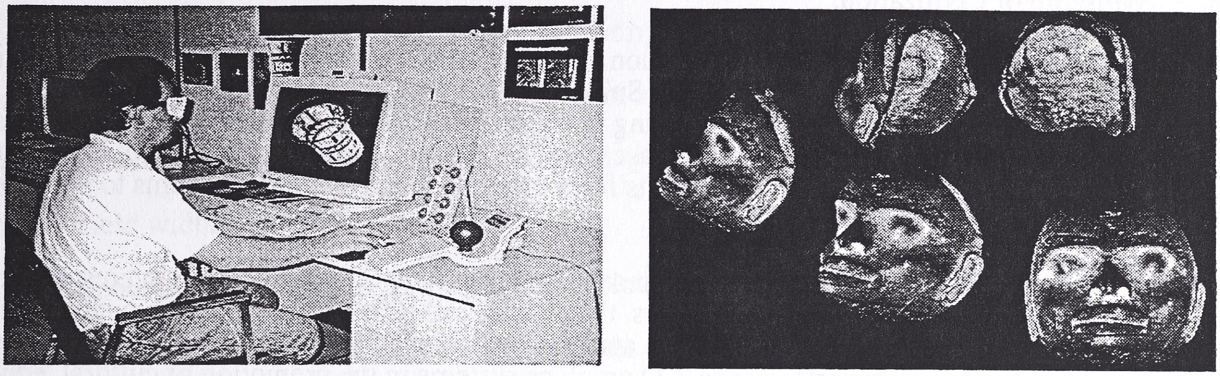

Figure 2. Using a graphics workstation, the object images can be rotated, zoomed, measured, illuminated with synthetic light sources and viewed with or without colour and in stereo. The photomontage on the right illustrates rotational views of the Tsimshian Stone Mask from the graphics workstation.

- The image data can be incorporated into electronic museum or gallery database systems for virtual museum, information kiosk, CD-ROM or related interactive multimedia applications. The compact file size also facilitates data transmission to remote electronic museum sites using standard communication links.

- Comparisons between similar objects or the same object at different points in time can be made. Replicas can also be fabricated using modern rapid prototyping technologies.

- The data record enables the interactive rendering of more rich images of objects than conventional television or related systems and is ideally suited for display on the high definition monitors of the future.

2. The AMUSE Project

In October, 1995, CANARIE Inc. approved the AMUSE project under its Technology and Applications Development (TAD) program to transfer the technology to the commercial sector. The lead contractor for the project is Hymarc Ltd. Hymarc manufactures commercial Hyscan 3-D laser digitization systems for the automotive and aerospace industries. Partners in the AMUSE project include InnovMetric Software Inc., Silicon Graphics Inc., Electrohome Ltd., the National Research Council of Canada, the Canadian Museum of Civilization, the Canadian Conservation Institute and the Canadian Heritage Information Network.

The primary objectives of the AMUSE project are:

- To design and build a commercial Hymarc ColorScan laser scanner digitizing system for high resolution, 3-D colour recording of museum objects. The ColorScan system will integrate NRC synchronized scanning technology, Hymarc controller electronics and software from NRC, CCI and InnovMetric.

- To implement an interactive multimedia presentation system to enable 3-D colour images of objects to be transmitted and displayed at remote "virtual museum" sites.

- To demonstrate the technology by operating the digitizing station and display system at the Canadian Museum of Civilization.

It is anticipated that the ColorScan digitization station will be completed and installed at the Canadian Museum of Civilization in January, 1997. Subsequently, it will be operated as a technology demonstration for the following year. During this time it will be used to digitize a suite of objects from the CMC collection which will form the database for a "virtual museum" display. It will also be used to undertake demonstration scanning of objects from the collections of other museums to demonstrate the technology.

With the emergence of VRML, similar representation standards and the growing interest in presenting 3-D models in information highway applications, the system will provide accurate high quality virtual models of the shape and colour of objects for these applications. The project will also demonstrate the power of data networking and high performance 3-D graphics systems in the promotion of cultural, educational and scientific objectives.

2.1 System Architecture

As illustrated in Figure 3, the AMUSE system consists of three major subsystems:

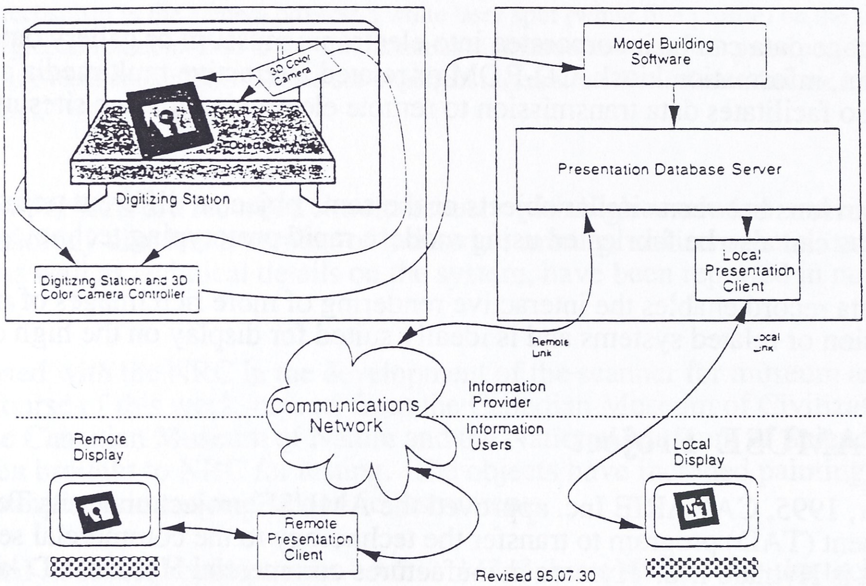

Figure 3. Conceptual view of the AMUSE system architecture.

- A digitizing station which consists of the Hymarc ColorScan 3-D colour camera, its controller and a coordinate measuring machine (CMM) to position and translate the camera.

- Digitization station software which includes data acquisition, calibration and data modelling software.

- A presentation system which includes graphics hardware and software, a large or small screen stereo display and networked database client server hardware and software.

2.1.1.Digitization Station Features

As discussed above, the 3-D colour camera used in the digitization station is based on the synchronized scanning geometry developed by NRC and described in the publications cited above. The important features of the digitization station include the following [c].

- Range measurement resolution of < 5 µm (.005 mm) and an accuracy of 50 µm (.05 mm) .
- Sample point interval of 100 µm x 100 µm (.1 mm x .1mm) or 10 pixels/mm sampling density.
- Data collection rate of up to 10,000 points/second.
- Path or field width/scan of 80 mm.
- Simultaneous capture and register of range and colour information at each point.
- A laser source consisting of three laser wavelengths in the red, green and blue parts of the spectrum.
- A CMM camera positioning device (Figure 4) which will permit a scanning volume of 1016 mm x1016 mm x 525 mm. This system provides five degrees of freedom to precisely move the camera over the object. It also includes a rotation stage which enables the object to be rotated during scanning. This significantly increases the effective working volume of the system.

Figure 4. Hymarc Hyscan model 45C laser scanner installed on a Zeiss CMM. A similar CMM system will be used for the Hymarc ColorScan camera system.

This combination of accuracy and working volume will enable the high resolution digitization of the majority of "two handable" museum objects. Larger and more complex translation systems are available to accommodate larger objects. From research undertaken by CCI it was been found that a scanning density of 100 µm/pixel (.1 mm/ pixel) in x and y directions is desirable for high resolution documentation. This level of recording is required for conservation and curatorial research applications which include, for

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c For detailed specifications on the system, contact Hymarc Ltd., 38 Auriga Dr., Unit 5, Ottawa, ON, Canada, K2E 8A5.

example, the examination of features such as brush stroke, impasto, crack formations (Figure 5) and signature details on paintings (Figure 6) and tool mark features on artifacts.

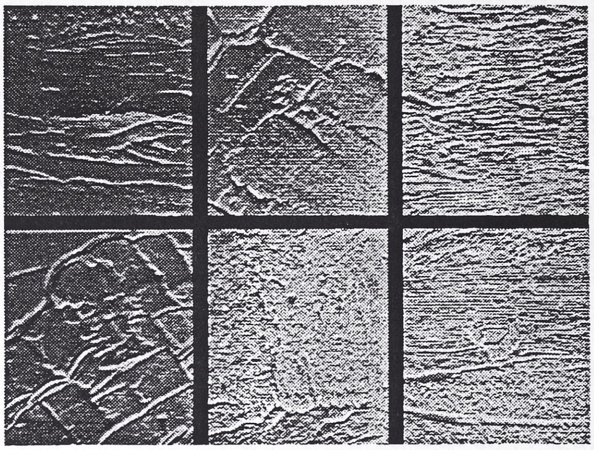

Figure 5. Detail images of six sections (50 mm x 50 mm each) from a test painting used for conservation research on vibration scanned at a .1 mm x 1.mm sampling density. Note that the brush stroke details, cracks, losses and canvas tear (upper left) are clearly visible. See Reference no.10 for details.

Figure 6. Detail of signature area on the Corot painting Auvers, Street Descending, from the National Gallery of Canada. The brush stroke details on the laser scanner image (left) can be examined using the artificial shading feature of the software. In the case of paintings, a unique feature is that the laser penetrates through the varnish layer. As a result, the 3-D image originates from the surface of the paint layer rather than from the varnish surface. Consequently, the brush stroke details and impasto details are recorded and can be displayed with or without the colour data.

This was an important consideration in the design specification of the ColorScan system. This scanning density enables a one time high resolution archival quality or "gold standard" record of an object to be made which can be used for a wide range of applications within the museum. These applications include conservation and research studies, general cataloguing and display, publication, reproduction, insurance and repatriation applications.

For recording three dimensional objects such as sculptures, masks and figurines, scans are taken from multiple points of view. This is typically accomplished by rotating the object through 360° in front of the ColorScan camera and recording scans of a number of views taken sequentially around the object. To ensure that all surfaces - such as the upper and lower surfaces of protruding or undercut features - are recorded, sequential views are usually taken by tilting the camera head as required to capture views of the entire surface. The multiple views are then integrated into a single triangulated 3-D surface using the POLYWORKS™ software described below.

Objects such as paintings, watercolours or, the "box shaped" sides of rectangular objects with relatively flat surfaces, are normally scanned in an x-y "raster scan" mode in 80 mm wide sections. The sections are integrated or merged into a single image using the software.

2.1.2. Software and Image Processing Features

Software is being developed to control the digitization station hardware during scanning as well as to model the image data. For the operation of the camera, Hymarc is adapting its existing data acquisition interface to handle colour in addition to geometry data. This interface will provide immediate visual feedback to help guide the data acquisition process as well as the handling of the camera configuration, its control and the output data management. It will also enable calibration of the camera optics and electronics in order to recover accurate surface reflectance and geometry measurements.

A key innovation to the AMUSE system is the incorporation of colour modelling software to allow the recovery of colour reflectance. This method has been put forward in the Ph. D thesis of one of the authors [14], and has been tested by CCI on a collection of museum objects using the NRC prototype. It recovers unique values for colour components that depend only on the physical properties intrinsic to the surface elements. Because this information is independent of the scene conditions such as ambient lighting and view point, colour data from objects that is obtained from multiple scans can be integrated seamlessly.

The image data will be processed using POLYWORKS™ software developed by InnovMetric Software Inc. [d]. POLYWORKS™ includes a complete line of software tools for generating 3-D colour models from 3-D colour imaging systems (Figure 7). A unique feature of the software is the ability to generate a closed model from multiple scans taken at different view points. Orientation parameters supplied by the CMM, as well as surface registration algorithm, are used to recover the mathematical transform that brings data from camera-centred coordinate systems to a single common system. A non-redundant triangular mesh that represents the original data at full resolution, with an intrinsic colour value at each vertex, is then produced. This model can be compressed within a preestablished error threshold, with the colour information of the removed vertices transformed into a texture map to be applied over the remaining triangles. This second form of models is particularly suited for dynamic viewing, such as interactive manipulation or virtual reality, on low end graphics workstations.

Special viewing software is needed to examine the 3-D colour models produced with the above scheme. InnovMetric Software Inc. distributes its own viewer under the name of IMView. It allows the rendering of the models as points, wireframes or shaded polygons, with or without colour texture, and a variety of

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d InnovMetric Software Inc., 2065 Charest Ouest, Suite 218, Ste-Foy, Québec, Canada, G1N 2G1. Tel: 418 688 2061, fax: 418 688 3001, email:msoucy@imetric.qc.ca, URL http://www.innovmetric.com options. It permits rotation and translation of the displayed model, as well as zoom. It relies on Motif™ and Open GL™ to provide transportability to various computer platforms.

A translator to VRML format will also open access to a realm of VRML viewers from other parties.

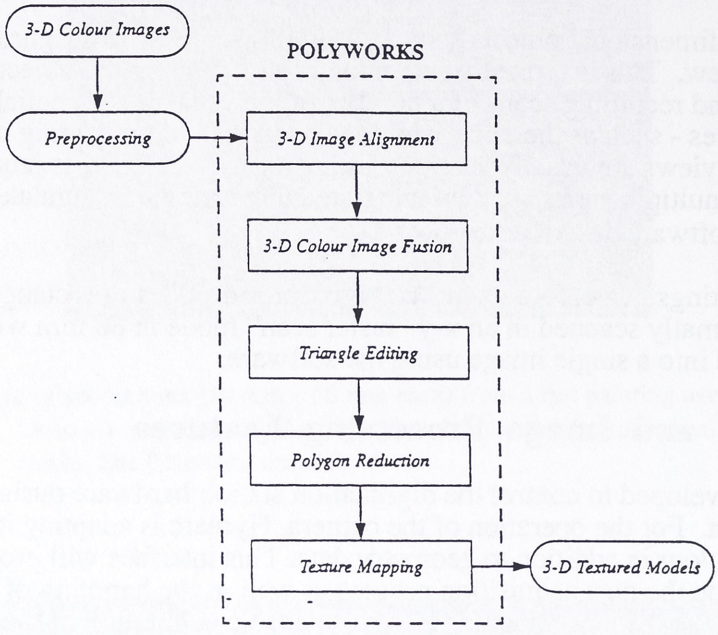

Figure 7. POLYWORKS™ 3-D colour modelling system.

2.1.3. Public Display System

The Public Display System will have the following features:

- A large screen stereo display which will render and display 1280 x 1024 pixel colour images of 3-D models.
- Multimedia presentation system display software which will support simultaneous display of text and 2-D graphics (with optional audio) to provide contextual support for 3-D models.
- The system will permit interactive inspection of the objects by viewer-driven rotate, pan and zoom features.
- Network support for remote access to the presentation database.

The system, which is currently in the planning stages, will be somewhat similar to the system shown in Figure 8 which was used at CMC to display images of palaeolithic figurines during the Mothers of Time Exhibition in 1995. In this display, visitors were able to interactively manipulate images of the figurines on a large screen stereo display using a trackball.

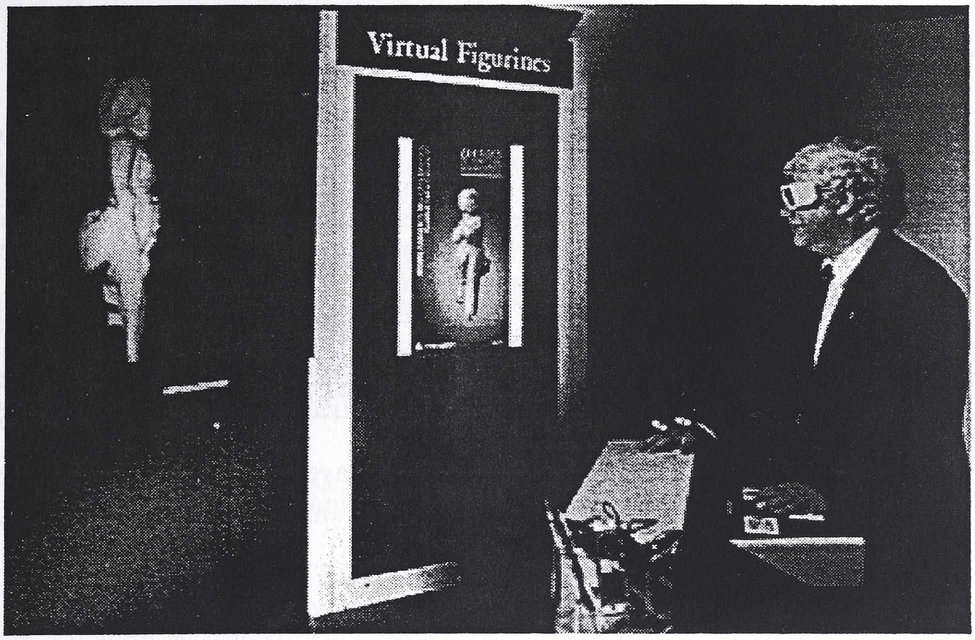

Figure 8. A virtual museum display of a 3-D image of a Palaeolithic Figurine from the Mothers of Time exhibition at the Canadian Museum of Civilization. The viewer can interactively examine the images in stereo using a track ball and stereo viewing glasses. The Public Display system will be similar to this display.

A Silicon Graphics Indigo 2 Maximum Impact computer will be used at the CMC site to provide graphics rendering for the public display, computer services for the modelling software and will also function as a presentation server to the remote site.

2.2. Technology Demonstration Phase

The Technology Demonstration Phase is an important element of the AMUSE project. The Demonstration will feature:

- The Digitization Station will be installed at the Canadian Museum of Civilization and will be used to digitize high resolution colour 3-D archival quality images of objects from the CMC collection. It will also be used to demonstrate the technology to other museums and clients.
- A multimedia Public Display System will operate nearby the Digitization Station in CMC and will be used to display 3-D colour images of the digitized objects as well as text information on the objects.
- A second multimedia Public Display System or "virtual museum" will be established in a geographically remote museum and linked via a communications network to CMC to display the digitized objects.

It is anticipated that the system will be installed at CMC in May, 1997 and that the Technology Demonstration Phase will operate for the following 12 months. CMC plans to install the Digitization Station and multimedia Public Display in a public area in the museum. This will facilitate public awareness and promotion of both the recording and display aspects of the technology and presents an excellent opportunity to showcase the technology in a cultural setting.

Discussions are currently in progress with CMC on the collection or suite of objects to be selected for scanning. Once this decision is made, the location of the remote museum site for the virtual museum display can be established.

2.3 Conclusion

As discussed above, the primary objective of this project is to develop the ColorScan system on a commercial basis for the digitization of museum objects and to demonstrate the technology for networked based remote virtual museum applications. Following completion of this project, the ColorScan system will be commercially available to the national and international museum community. For example, AMUSE is currently working with ARTIST (Arts Recording and Three-dimensional Information System Technology Ltd), a representative group of leading U.K. artistic interests. ARTIST Ltd. is committed to the development of common procedures for the implementation of the digitizing system through the provision and management of standards, services and distribution of 3-D colour images.

In addition to the museum market, other markets which have been identified for the technology include, entertainment, medical, food inspection, forensics, shelf space/product design space applications.

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