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February 19, 2007

Mr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440- Functional Specification for a plastic-clay 3D surface modeler

Dear Mr. One:

Please accept the attached document, *Functional Specification for a plastic-clay 3D surface modeler*, which outlines the functional requirements of our Xcanner modeling device. Our project is to build a cost-efficient desktop device that digitally reconstructs three-dimensional plastic or clay models for gaming and movie industries, which may use the digitized 3D models in CAD programs for design modification and analysis.

In the attached document we give a brief system overview and we outline the functional requirements of the system at its various stages of development.

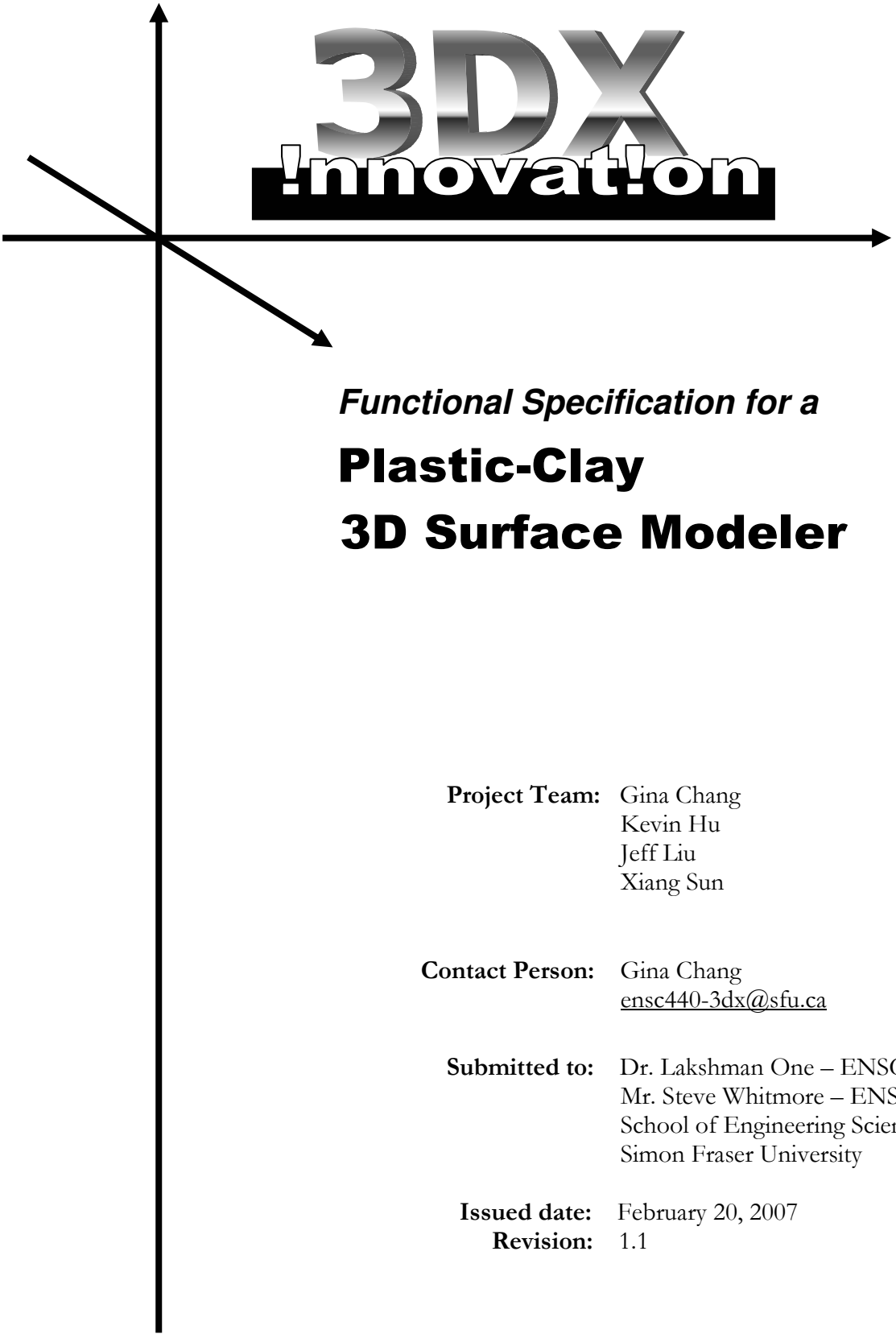
3DX Innovation is comprised of a group of four fifth-year engineering students with abundant industrial work experience. We are Gina Chang, Kevin Hu, Jeff Liu and Xiang Sun. We look forward to meeting with you and to further discuss this project. Should you require further any information, please feel free to contact me by email at ensc440-3dx@sfu.ca.

Sincerely,

Gina Chang

Gina Chang
Chief Executive Officer
3DX Innovation

Enclosure: *Functional Specification for a plastic-clay 3D surface modeler*



Functional Specification for a

Plastic-Clay 3D Surface Modeler

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Submitted to: Dr. Lakshman One – ENSC 440
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Executive Summary

Planar color scanners have a long history of development, and the standards of traditional planar scanners has long been adapted and integrated with regular computer systems. With the advance of digital image capturing and processing technology, desktop 3D surface scanners that are capable of adapting to the modern computer systems become feasible to implement using already-existing scanning standards. The Xcanner developed is positioned to provide 3D scanning that can be processed by ordinary personal computers, while the targeted users are everyone without professional training required.

The development of Xcanner was decomposed into two major stages. Stage one consists of the construction of a prototype to experimentally prove the concept of various 3D modeling techniques, and to finalize and implement the accurate 3D surface data capturing and image data conversion. At the end of stage one, the image data should be ported to files compatible to other CAD programs. At the end of stage one, the project will accomplish the following tasks:

1. The finalization of the components required to build the 3D surface modeler, such as the specific webcam and light source to be used.
2. The building and fixation of a solid enclosure to accommodate the webcam, the light source, and the target object for scanning.
3. The edge detection and reconstruction of the 3D model using Matlab.
4. The mapping of the color information on the 3D model constructed from the scanning.
5. The development of user interface that facilitated the controllability.
6. The conversion of the image data file obtained into CAD program compatible files such as VRML, OBJ, and etc.

At the end of stage two, in which the details are enclosed as the following, a product development will become mature and ready for commercial usage.

1. The extensive research to find a more suitable material for enclosure that further reduces the noise from the scanning due to the interior reflected lighting. A more suitable would also result in overall weight reduction.
2. The improvement of more user-friendly graphic user interface that enhances the controllability by general users.
3. The standardization of the production process, which would include the improvement on the reliability and stability of the product before commercialized.

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1 Introduction

The plastic-clay 3D surface modeler is a device that retrieves images from various frames of a three-dimensional object and reconstructs the surface information into an implemental virtual representation [1]. The project can be divided into three modules: input module, image-processing module, and export module. The input module consists of mainly the physical hardware mechanism, where the 3D object will be placed and the raw image data will be retrieved. The image-processing module provides surface information configuration for the preparation of object-surface reconstruction [2]. And, lastly, the export module provides a result that is importable to other 3D-image-application programs for further user implementation [3]. The purpose of this 3D surface modeler is to provide 3D artificial designers an effective solution to achieve comparable result as done by industrial 3D-image machines. The project has two development phases through the overall production cycle, in which our intermediate goal is to deliver a prototype by the end of the phase one scheduled in April 2007. After the proof-of-concept prototype is generated, we will continue to the phase two for commercial deployment.

1.1 Scope

The scope of this document provides the functional requirements for the prototype of our plastic-clay surface modeler that is to be achieved in April 2007. Basic functional requirements for further prototype and production system development are also specified in the subsequent sections.

1.2 Acronyms

BSD	Berkley Software Distribution, a flavor of UNIX operating system
CAD	Computer-aided Design
CCD	Charged-Coupled Device
CRT	Cathode-Ray Tube
FAQ	Frequently Asked Questions
GUI	Graphical User Interface
JPEG	Joint Photographic Experts Group
JVM	Java Virtual Machine
LASER	Light Amplification by the Stimulated Emission of Radiation
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
OBJ	A text file format that describes the surface of a 3D object
RGB	Red Green Blue color model
TIFF	Tagged Image File Format
UNIX	A computer operating system
USB	Universal Serial Bus
VRML	Virtual Reality Modeling Language

1.3 Intended Audience

This document is intended for design engineers, project managers and marketing personnel. Design engineers can use this document as a guideline in the product development. Project manager can use this document to for project-performance estimation and milestone scheduling. Marketing personnel can use this document for promotional usage and marketing presentation to potential customers or users.

1.4 Conventions

Conventions used throughout this document to denote functional requirements are illustrated as follows.

R[#] A functional requirement [x],

where x is either 1, 2 or 3 according to the following:

(1) A functional requirement for stage 1 prototype development
(2) A functional requirement for stage 2 commercial product development.
(3) A functional requirement for both the stage 1 and stage 2 development.

2 System Requirements

2.1 System Overview

This section outlines the basic configuration of our plastic-clay 3D surface modeler. The information that provides is intended to give users a comprehension for the overall system operation.

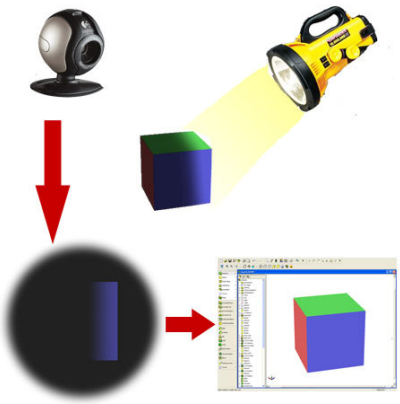

Figure 2.1: System Overview

Figure 2.1 shows the overview of each module in the surface modeler. For the input module part, the object is placed at the center in which the projection of the light source intersects the camera sight. During the operation, the background environment should be sealed from external light disturbance. When settings are ready, camera should retrieve the curvature image that the light source projects on the object surface.

By collecting curvature image from various angles of the object, the original object surface presentation will be reconstructed after stitching each curvature image in an orderly fashion through Matlab processing [2]. The final image will be produced available for further user image implementation through other existing programs [3].

2.2 System Requirements

The following three sections outline our system requirements such as the inputs and output requirements of our system. Input requirements illustrate the restriction on objects to be modeled, camera type, and lighting. Output requirements demonstrate the output of the system, from the resulting image to user application sector.

2.2.1 General

R[1] The unit dimensions will be standardized for home desktop or personal computer equipment. (2)

R[2] The unit shall be placed with specified orientation so that each module can maintain its function under consistent environment. (3)

R[3] The unit shall be of reasonable compartment so that the external light disturbance can be sealed or minimized. (3)

R[4] Camera and motor power and shall share the same connection through Universal Serial Bus. (2)

R[5] The prototype will be powered by a combination of battery and external PC USB. (1)

R[6] The production unit will be powered by a combination of external AC power and PC USB. (2)

R[7] With the exception of the interface and necessary power components, all device components shall be placed inside a rigid environment of sufficient strength. (3)

R[8] The unit shall be capable of operating at the normal consumer temperature range of between 0°C and 40°C. (3)

R[9] The unit shall be capable of operating under all domestic humidity and pressure ranges. (3)

R[10] The unit's heat dissipation shall be such that the exterior of the unit will not be more than 30°C. (3)

2.2.2 Input

R[11] The unit should take object dimension as small as 5cm x 5cm x 5cm, and as large as 20cm x 20cm x 20cm. (3)

R[12] The unit should only take objects that are non-transparent, non-reflective, and edge-clearly-defined. (3)

R[13] The unit should take objects with gross weight no larger than 500 grams. (3)

2.3.2 Performance

R[14] The unit is capable of capturing the curvature of the target object at a vertical resolution of 640x480 pixels per image frame. (1)

R[15] The default resolution in the horizontal plane of scanning is 360 frames per rotation (i.e. one image frame processed per degree of rotation). (1)

R[16] The resolution is not designed to be adjustable explicitly by the users. It can only be changed by modifying the internal code. (3)

R[17] The color information contained in the 3D model constructed should be visually similar to the original color of the target objects viewed in ambient light. (3)

R[18] The initialization time of the webcam shall be less than 10 seconds. The processing time for each standard scan with the default resolution is targeted at less than 5 minutes. (2)

2.3.3 Image Quality

R[19] The unit shall meet image specifications comparable to standard image scanner. (3)

2.3.4 Compatibility

Compatibility is not a major concern for the interconnection of the image generating and the host computer for data processing, because the webcam and rotating base for image generating communicate with the hosting computer via simple USB ports.

R[20] The host should have operating system compatible for installing motor and webcam controlling programs. (3)

Compatibility could also be a concern in the following area:

R[21] The power supply of the light source which uses 4.5V DC power should be adapted to the standard 120V 60Hz AC power to provide a steady power. (3)

R[22] The output data files as the result of scanning need to be converted to files that are compatible with data files usable for target CAD software. (3)

2.3.4 Reliability & Serviceability

The Xcanner developed should be a reliable and sustainable unit for a long period of usage under normal circumstances. This device is not designed to withstand extreme environment due to the precise positioning and calibrating required during the physical integration. However, it should provide a certain level of reliability.

R[23] The enclosure of the device should minimize the amount of noise to a level insignificant to the resulting scan quality, compared to the target objects. To successfully minimize the noise level, the physical enclosure must be able to insulate the interior from high levels of exterior illumination. (3)

R[24] The enclosure should be capable of dissipating excess heat generated by the light source if necessary. (2)

R[25] The unit should withstand a long operating period (~2 hours) and a long period of standby mode (1 day) without failing. (2)

R[26] The device can be reset in events of software failure, and the full functionality must be restored in this case. (3)

R[27] The unit is neither upgradeable nor serviceable directly by the end user. Users with advanced knowledge are required for any further system upgrade. (2)

R[28] The mean time of failure for the product released should exceed 35,000 hours between events of mechanical failure, under normal usage. (2)

3 User Interface Requirements

3.1 User interface overview

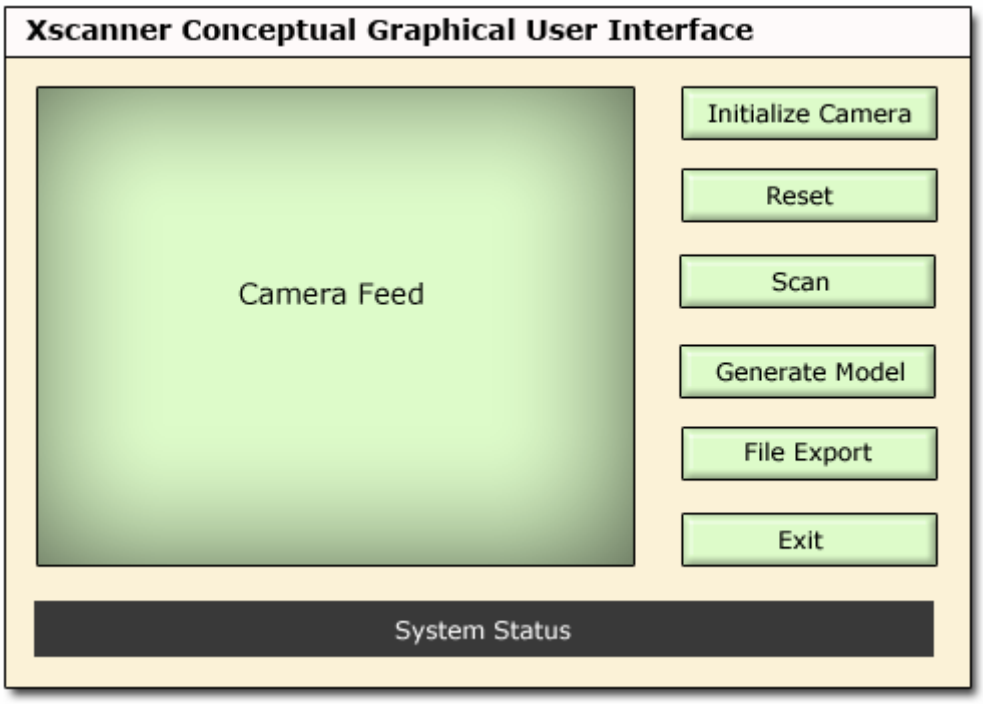

Figure 3.1 User Interface Overview

A cross-platform graphical user control program is provided to users for easy and direct control of the scanning and image-generating process. It also provides a live video feed for monitoring the process.

R[29] Graphical User Interface (GUI) runs on most Java Virtual Machine (JVM) supported platforms, including Windows 2000/XP, Linux, BSD. (3)

R[30] GUI provides a display of live camera feed at resolution of 640x480. User is able to visually monitor the scanning progress and manually intervene at occurrence of any unexpected event. (3)

R[31] A 'System Status' panel at the bottom of the GUI provides real-time status of the system, i.e. current position of the motor, progress of the surface generation, and so on. (3)

R[32] User is able to manually initialize camera by pressing a button on the right panel of the GUI. It starts the live feed of the camera. If this step is skipped, user is able to proceed with motor testing runs without the camera in order to save time. (3)

R[33] User should be give the opportunity to manually adjust where the scanning process starts by manually pressing 'Reset' button and then position the object at his/her choice. 'Reset' button also clears and initializes all data structures in the system. (3)

R[34] Scanning process is accessible by 'Scan' button on the right panel of the GUI. User should able to stop the scanning process at any given time by pressing the same button during the scanning process. (3)

R[35] Post-scanning process is initiated by pressing 'Generate Model' button on the right panel of the GUI. It then executes image processing procedures and generates a 3D surface model of the object. User should be to cancel image-generating process at any given time by pressing the same button again during the image-generating process. (3)

R[36] User should be able to export the surface model image into OBJ file format, which is readable by most CAD and CAD-like 3D modeling software [3]. (3)

R[37] User should be able to exit the program at any given time in case of emergency. (3)

4 Host Computer Requirements

R[38] Minimum requirement on host computer is 1.0 GHz CPU, 512 Megabytes memory and 500 Megabytes free space. (3)

R[39] Two USB 2.0 ports are required on the host computer, one for camera and the other for servo motor controller. (3)

R[40] A display (CRT or LCD monitor) is required at minimum resolution of 800x600 pixels. (3)

R[41] Operating system must have the windowing display capabilities, i.e. running X Window system on UNIX, UNIX-like operation systems. (3)

R[42] Operating system on the host computer must fully support JVM 1.5.0 or later. (3)

R[43] Phidgets Java Library is installed for servo motor controller [4]. (3)

R[44] Matlab is installed and properly set-up for image processing [2]. (1)

5 Device Requirements

R[45] Enclosure should be resistant to external light penetration and internal reflection. (3)

R[46] Enclosure should have flexible room for camera and shadow position adjustment. The minimum dimension should be 40cm x 40cm x 60cm. (3)

R[47] Lighting should be uniformed white light source and/or line laser with consistent brightness through out the scanning process. (3)

R[48] Webcam should have wide-angle that is capable of capturing stream video at resolution of 640x480 pixels. (3)

R[49] A Servo motor set capable of rotating at minimum of 360 degrees at precision of 0.1 degree [5] should be positioned in which the object is placed. (3)

6 Regulatory Requirements

Xcanner will meet various industrial standards to best ensure workplace and user safety.

R[50] Xcanner will be CSA, CE and FCC approved. (2)

R[51] Xcanner uses laser of Class IIIa standard, approximately 5mW powered. (3)

R[52] The overall enclosure is sharp-edge-free and illumination sealed. (2)

R[53] All electrical components are kept away from user's operational reach to ensure safety and durability. (2)

Note that the device works in a sealed environment and should be kept away from water at all times. Users should always keep their hands clean at all times when operating the device since any contamination to the camera and the modeling object will lead to inaccurate results.

7 Documentation and Training

The primary application of Xcanner is to provide a cost-efficient desktop device that digitally reconstructs three-dimensional plastic or clay models for gaming and movie industries. The documentation provided will assist the user intuitively from step one to the last.

R[54] An installation and operation user manual will be provided in English and French. (2)

R[55] The user manual will be able user-friendly, so even the users with minimal practical knowledge or experience in electronics will be able to follow. (2)

R[56] Online manual will be available. (2)

R[57] Online step-by-step installation and operation video clip will be available. (2)

R[58] All documentation contains the company's contact information and will provide immediate help upon request. (3)

R[59] Troubleshooting and general concerns will be included in both the user manual and on the online website. (2)

R[60] Basic functions, features, operating modes and calibration tools of the system will be provided in the documentation. (2)

R[61] Warranty and replacement information will be included in the user manual. (2)

8 Conclusion

The functional requirements outlined in this document are not to be implemented strictly according to the stage assigned. The assigned stage of development to each requirement is rather a guideline to facilitate the flow of the project. Stage 1 focuses on proof of concept and the implementation of the design, while the main focus of stage 2 is the usability to produce a device that is user friendly with all the required functionality. The targeted completion date is schedule as April 2007.

9 Reference

[1] Proposal for a Plastic-Clay 3D Surface Modeler, Group 1

[2] Matlab Image Processing, 3D Laser Scanner, http://n.ethz.ch/student/pleiness/index.php

[3] Exporting OBJ Files from Matlab, http://www.nada.kth.se/~asa/Ray/matlabobj.html

[4] Motor Library, Phidgets Inc, http://www.phidgets.com/modules.php?op=modload&name=Downloads&file=index

[5] Motor Precision, http://www.phidgets.com/documentation/1000.pdf