Integrating Computer Aided Design and Manufacturing with Northwest Coast Designs

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ABSTRACT

This paper will explore how Computer Aided Design and Manufacturing (CAD/CAM) can be ethically merged with Northwest Coast Sculpture Manufacturing. Additional emphasis will be focused on resolving issues encountered while Integrating CAD/CAM technology with Native Design.

The basics of digitizing designs through various scanning techniques, such as the point probe and point cloud method will be discussed along with obstacles encountered during the scanning of existing sculptures.

Several approaches to computer modeling will be outlines focusing on MasterCAM's Surface, Solid, and Art modeling features, as well as Zbrush's organic tool-based digital sculpting program. The issues of integrating these technologies with Indigenous Northwest Coast design will be sewn through this discussion.

The paper will further elaborate on the market potential of sculpted cultural wood products, along with resulting intellectual property issues, focusing on current legislative protection and areas of interest for artists pursuing computer aided manufacturing of their designs.

Finally, a case study will be presented discussing ways in which Native communities, such as the Nisga'a Village of Laxgalts'asp, might benefit from CAD/CAM manufacturing. Furthermore it explores the computer aided manufacturing of a specific Northwest Coast design in wood. From this inquiry, directions forward are highlighted, focusing on how the Native Community might approach the issue of integrating this growing technology with existing design capabilities in a modern cultural context.

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1.0 INTRODUCTION

Throughout the years, the entrepreneurial spirit of the Northwest Coast (NWC) native craftsmen has helped develop the scope and quality of their work, despite the changing political and social climate of the times. This trend is evident from the early adaptation of western metal tools for the advancement of wood production, to the more recent adoption of manufacturing techniques such as power tools, modern printmaking, etching, and metal casting for a variety NWC niche products. Although there is a strong presence of mass production in the NWC products market, the adoption of computer aided design and manufacturing (CAD/CAM) technology in the production of wooden objects seems underdeveloped.

In CAD/CAM, a virtual model of a product is created and sent to a computer numerically controlled (CNC) manufacturing process to machine a physical copy of the virtual model. This procedure is very effective for rapid-prototyping and mass-customization.

Over the past few decades, CAD/CAM has developed to serve the design and production needs of industries such as metalwork, plastics, and automotive. In recent years, this technology has shifted to cater to the demands of the wood processing industry, primarily within Europe. With the advancement of globalization, these production technologies have developed and migrated globally. As suppliers have grown to meet the needs of this widening consumer base, this technology is becoming increasingly available to wood manufacturers in BC. The advancement of technology and consumer demands has driven the cost of CNC machines down to be economically feasible for the common wood producer. These machines can be linked to accessible computer modeling programs such as Pixologic's Z-Brush, an industry standard in film and videogame production[1], to design and manufacture organically sculpted wood products.

Currently, there is increased interest in developing value-added wood production in BC. This interest is driven by a number of factors, but especially the dismal lumber market and a desire to increase employment and change the cost structure of the industry to make it more profitable as a

[1] Michael Burns Burns, "Software and Services, Graphics and Publishing Review: Pixologic ZBrush 3.1," *Digital Arts Magazine*, Feb 1, 2008. http://www.pcworld.idg.com.au/review/software_and_services/pixologic/zbrush_3_1/221080 (accessed Sept. 18, 2008).

whole. CAD/CAM technology is poised to bolster the flexibility of BC's secondary wood processing sector, and NWC First Nations design could drive this sector while improving understanding about the Coastal Indigenous Culture, and fostering respectful collaboration between NWC First Nations peoples and the Private Sector[2].

Recently, it has been identified that BC wood producers lack a sense of "design culture," despite the strong historically-developed design forms of the NWC First Nations. Since the 70's there has been a developing renaissance in NWC art and culture, resulting in a number of prominent artists experimenting with various mediums and modern production techniques[3].
With the upcoming Olympics in Vancouver, there is renewed interest in developing products that could cater to the increasing tourist demand. This developing market has strong potential to bring revenue back to Native Communities and support the goal of Self-Sufficiency[4].

Ethical development of CAD/CAM technology in NWC sculpture must evolve as a relationship between the First Nations and the Private Sector, taking into consideration the traditional customs of the band.

This paper will explore how CAD/CAM can be ethically merged with Northwest Coast Sculpture Manufacturing. Additional emphasis will be focused on resolving issues encountered while Integrating CAD/CAM technology with Native Design.

[2] Forintek Canada Corp., "Meet Your Industry Advisor Barbara Bell, Wood Products Design Consultant," *Straight Woods: Solutions For Wood Newsletter*, February 2008. http://www.solutionsforwood.com/straightwoods/feb2008/advisor.html (accessed Nov 2, 2008).
[3] Brooks Yolanda, "The Renaissance of Northwest Coast Art," *Coastlines Magazine*, September 1, 2008. http://www.coastlinesmagazine.com/sepoct-2008/westcoast-story/renaissance-northwest-coast-art (accessed September 29, 2008).
[4] Brooks Yolanda, "The Renaissance of Northwest Coast Art," *Coastlines Magazine*, September 1, 2008. http://www.coastlinesmagazine.com/sepoct-2008/westcoast-story/renaissance-northwest-coast-art (accessed September 29, 2008).

2.0 TECHNICAL ASPECTS INVOLVED

This section will investigate the specific processes involved in preparing and importing a NWC design into the CNC production environment.

2.1 SCANNING AND FILE CONVERSION

To create a computer model of an object, there are several options available: laser scanning, point-probe scanning, as well as object measurement and design in a computer-modeling program.

2.1.1 Point-Probe Scanning

Point-probe scanning is achieved by manually moving a point sensor over the desired object which outputs an array of surface plot locations. Once the plots are taken, these points are connected via triangulation to create a surface model. This technology is the precursor for automated laser roaming, yet is still seen in some niche prototyping applications.[5]

2.1.2 Point-Cloud Scanning

Fully automated scanning can be performed through numerous laser configurations in which the laser roams the surface and records the position of each plotted point. Scanning aggregates are available for CNC machines allowing manufacturers to bring the scanning and machining elements into one production environment. This technology is used extensively in various applications, from fine prosthetic fittings, to vast pit mine surveying. With the use of a roaming laser, millions of surface data points are recorded with a high degree of precision, resulting in what is known as a "point cloud" surface. This point cloud provides the base for a surface mesh model of the scanned object.

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[5] S J Lee and D Y Chang, "Laser scanning probe with multiple detectors used for sculptured surface digitization in reverse engineering," *Journal of Physics 7th International Symposium on Measurement Technology and Intelligent Instruments* (2005): under "Conference Series 13, 155–158," http://www.iop.org/EJ/article/1742-6596/13/1/036/jpconf5_13_036.pdf?request-id=8a73717f-7502-4fb7-b78e-3ec4ae53fef6 (accessed Nov 17, 2009).

The Steriolithographic (.stl) file is a common type of surface mesh file format used in CAD/CAM production. This format is supported by nearly all 3D design software packages, and commonplace in rapid prototyping and CAM. These .stl files express the surface geometry of a 3D object, without representing color, texture, or other CAD model attributes. The .stl file describes the raw, unstructured, triangulated surface by the unit normal and vertices (ordered by the right-hand-rule) of the triangles using a three-dimensional Cartesian coordinate system. The .stl format has two separate representations - ASCII and Binary. Binary files tend to be more common due to their compact size. [6]

2.1.3 Obstacles with Converting Scanned Files

When scanning a real object with automated laser algorithms, there is bound to be incorrect data in the resulting point cloud. The "point cloud" surface data must be reviewed and filtered to remove extraneous points and ensure that the surface has no unintended features. If scanning is contracted out, the process should be performed by the Scanning Agency; however, this process often leaves many manual "touch-ups" to be made before machining starts, adding further cost, as seen below in Figure 1.

Figure 1. Raw and Repaired Scans of Beaver Frontlet. These images show the alterations made to a raw scanned .stl file. On the left shows the raw scan shows mis-scanned ears, due to the thinness of material. Also seen on the left is the mis-scanned eyebrows, due to paint color variation of the original carving. Finally the shape of the abalone eye inlays were captured improperly, due to the reflection variation as the laser roamed the original surface. On the right is the result of several hours of "touch-up" work in the ZBrush modeling environment.

[6] Wai Hon Wah, "Introduction to STL Format," The Ennex™ Companies Advanced Technology Concepts, http://rpdrc.ic.polyu.edu.hk/old_files/stl_introduction.htm (accessed March 19, 2009).

Both the manufacturer and scanning agency should be in accord with the final purpose of the scan and related quality tolerances needed for this application. This seamless communication is seldom achieved and usually results in costly file-prep issues and troubleshooting - this adds to the difficulty in dealing with scanned files.

Furthermore, scanning services are predominately contracted out to non-Aboriginal labour, diverting this potential income from the Native community. With the particular training and additional file preparation costs related to scanning, it is much more accessible to educate artists in the "design-oriented" field of computer modelling.

2.2 COMPUTER MODELING

The scanning methods described above represent a form of reverse engineering which can be more complicated and costly then modeling a similar design from scratch in the digital environment. With advancements in computer modeling software such as SolidWORKS, Maya, Matbrush and Z-brush the technology exists to design original organic shaped objects. Although there are many computer-modeling options available, we will focus on Z-Brush design capabilities and its connection with MasterCAM, a CNC industry standard[7]. These programs offer a tangible option for development, given MasterCAM's presence in manufacturing, and Z-brush's accessibility to artists and designers.

With advances in computer modelling driven by the Film and Video Gaming industries, computer modeling has become increasingly robust and user-friendly. [8] This progress has resulted in programs that are built for designers and artists, catering specifically to the needs of aesthetic digital sculpting.

[7] CT Tolland, "Mastercam #1 Amoung CAM Software," ThomasNet Industrial NewsRoom, http://news.thomasnet.com/companystory/488971 (accessed Sept 23, 2008).
[8] Harold L. Vogel, *Entertainment Industry Economics*, Chapter 10 Playing the Game: The Economics of the Computer Game Industry., 5th ed. (Cambridge University Press. (c) Cambridge University Press, 2001),

First I will discuss the MasterCAM applications along with their strengths and weaknesses in modeling, then I will focus on Pixologic's Z-brush modeling platform and how it answers many of the obstacles seen by digital artists looking to create organic sculptural forms.

2.2.1 MasterCAM

There are a variety of CAD/CAM programs available in industry. For this report, we will be focusing on the MasterCAM program, which is common to CNC producers. MasterCAM offers several options to render a part in a computer design environment. These options are designed primarily for engineering purposes and include Surfaces, Solids and Art Surfaces.

2.2.1.1 MasterCAM Surfaces

The MasterCAM Surface Function acts similarly to other vector design such as VectorWORKS, Maya, and StudioMax. The Surfaces Function stretches a "skin" over a desired perimeter, resulting in a surface that can act as a tooling boundary of a part when sent for machining. MasterCAM surfaces work best for smooth flowing curves. [9] They pose significant design obstacles in welding multiple organic surfaces together for machining. Additionally, surface-based modeling approaches the design process from an engineering perspective, limiting an artist's iterative design execution.

2.2.1.2 MasterCAM Solids

MasterCAM Solids are parts defined in MasterCAM as having an exterior shell filled with substance. The program recognises the object as solid by defining the interior and exterior surface. Through "knowing" that the part is a solid, we can perform many complex constructions such as Boolean addition and subtraction of objects. Solid functionality is particularly tailored toward plastics and metal manufacturing because knowledge of interior volumes and configurations are critical to the mould making and machining casts. [10] Again, like surface modeling, the process of solid modeling is quite rigid and formulaic, potentially limiting the

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[9] CNC Software, Inc., "Powerful Surface Modeling," Mastercam Design Tools, http://www.mastercamdesigntools.com/SurfaceModeling.html (accessed May 24, 2008).
[10] CNC Software, Inc., "What Mastercam Solids Delivers," Mastercam Design Tools, http://www.mastercamdesigntools.com/SurfaceModeling.html (accessed May 24, 2008).

ability of artists to design organic forms. For this reason many CAD packages such as MasterCAM contain a limited art feature – MasterCAM Art.

2.2.1.3 MasterCAM Art

The auxiliary Art feature within MasterCAM allows the user to create complex forms through manipulating variable-based design parameters on a specified Art surface. Originally created for the Sign-Making Industry, this type of surface allows slightly more flexibility in creating complex design-based reliefs.[11] Unfortunately, this auxiliary feature has a separate tool path generator with limited machining capabilities. Art surfaces can be exported as active MasterCAM surfaces in order to garner a wider range of machining possibilities, although this option creates further issues for toolpath generation.

Although MasterCAM Art is a feature "catering" to the aesthetic aspect of CAD, it once again is centered around limited variable-based design tools, that often result in rigid, forced forms. Furthermore, the significantly high price point of a MasterCAM design package, currently exceeding a thousand dollars, leaves the majority of artists and designers on the sidelines.

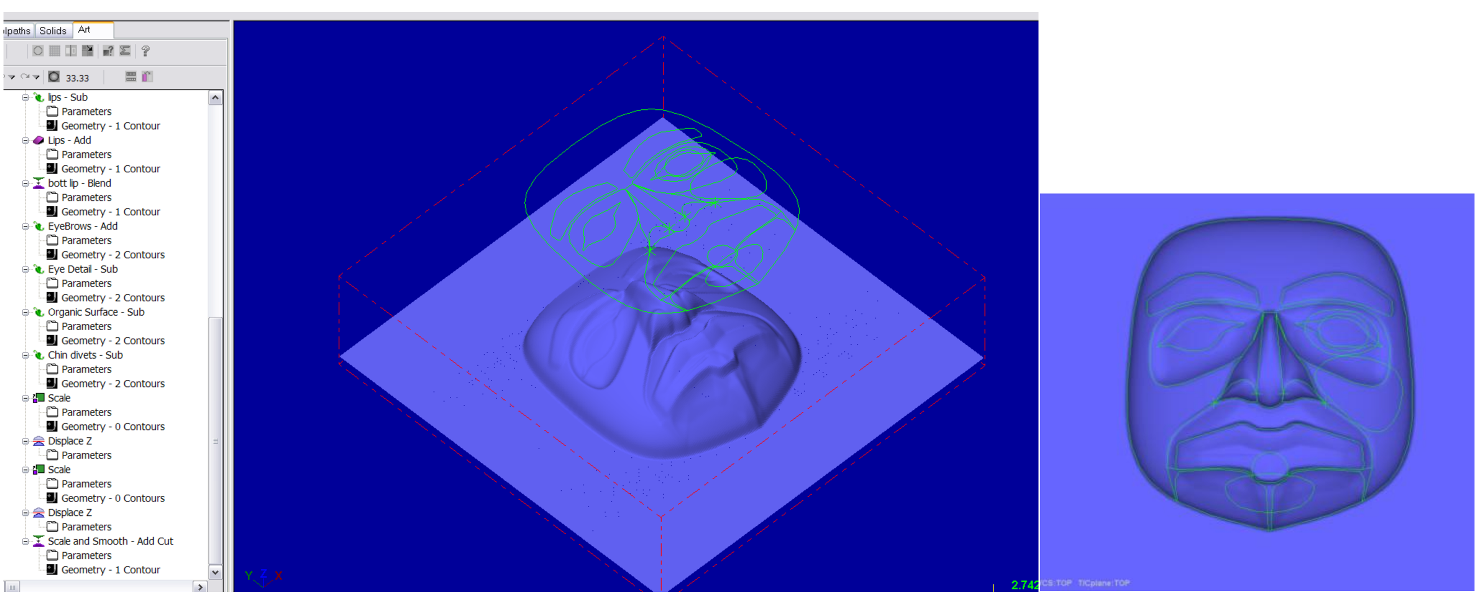


Figure 2. Mask Modeled by Andrew Pershin in MasterCAM Art. This image shows a mask that was modeled in the MasterCAM Art feature. On the left one sees a partial list of the cumbersome variable-based modeling actions involved in its creation. These modeling actions are layered on top of each other and are based off of the thin lined 2D formline face, seen lightly in green. The bulging, bulky appearance should be noted, along with the sculpturally simple connections between features.

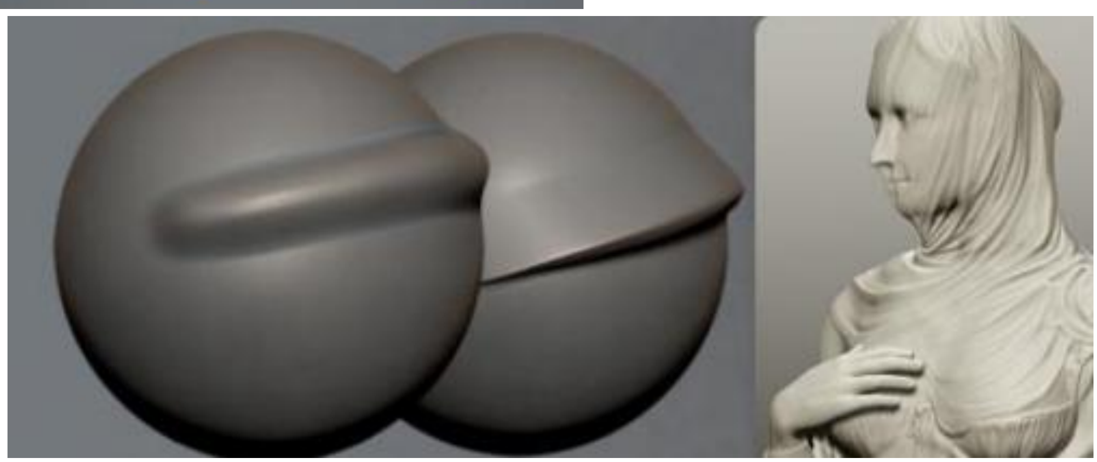
[11] CNC Software, Inc., "Combining an Artist's Eye With a Computer's Ease," Mastercam Art, http://www.mastercamdesigntools.com/SurfaceModeling.html (accessed May 24, 2008).

2.2.2 Zbrush

Commonplace in the Film and Video Gaming Industries, Z-brush provides a robust modeling environment that can be linked with digital drawing tablets, giving aesthetic control back to the artist.

Similar to the Adobe suite of digital image software, Z-brush provides the user with various adjustable tools that mimic the actions performed manually by the artist, such as brushing, smoothing, and pinching. Z-brush allows the user to manipulate digital clay surfaces to create a desired form. The digital clay is comprised of an adaptable polygon mesh that can be manipulated in various ways by the digital sculpting brushes. Each node on the polygon mesh has a Z-plane value, perpendicular to the mesh, allowing the artist to add or subtract from these surfaces in different ways using the various sculpting tools.[12]

A.



B.

Figure 3. Sculpting Brushes of Pixologic's Zbrush. Above shows the sculpting pattern of several brushes (A.), the resulting strokes and possible outcomes (B.)

[12] Pixologic Inc., "ZBrush Overview," Pixologic: Makers of ZBrush, http://www.pixologic.com/zbrush/features/01_UI/ (accessed Aug 14, 2008).

This tool-based iterative approach to CAD differs from traditional solid or vector based modeling, giving the artist a wider range of accurate analogs to manually sculpture in the real world. In addition to the use of a mouse, Z-brush can be linked to digital drawing tablets that allow the user to interact with the model via a pressure sensitive pen - this significantly furthers manual interactivity.

In Z-brush. users can easily adjust the resolution and scale of a model's polygon mesh - advancing the detail the model when needed and easing its file transfer between programs and CNC production. Z-brush's exportable object file type (.obj) can be easily converted into an array of CAM compatible file formats, such as stereolithography files(.stl) mentioned previously.[13]

Finally the economic cost of the Z-brush program, currently less than five hundred dollars, increases its accessibility to emerging artists and designers, allowing for a much wider adoption of the program. This pricing strategy is similar to Google Sketchup's positioning in the aesthetic design sector - bringing user-friendly vector-based modeling to the masses.[14]

As Z-brush continues to hold its industry standard position in the Film and Video Gaming Industries, the Wood Products Sector should take note of this robust organic modeling program, for its connection possibility to CNC production applications.

2.3 OBSTACLES IN CAM

Depending on the features used in model creation, a variety of process specific issues may arise when preparing one's model for machining. While working with MasterCAM surfaces, part files with complex shapes, involving many surface intersections and high polygon surface resolution,

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[13] Michael Burns Burns, "Software and Services, Graphics and Publishing Review: Pixologic ZBrush 3.1," *Digital Arts Magazine,* Feb 1, 2008. http://www.pcworld.idg.com.au/review/software_and_services/pixologic/zbrush_3_1/221080 (accessed Sept. 18, 2008).

[14] Hobbs Ron, "Google SketchUp's Software Review," Construction Software Review, http://www.constructionsoftwarereview.com/learning_center/user_reviews/sketchup/google-sketchup-software-review (accessed May 27, 2008).

can cause costly time delays and bugs through rendering delay issues. These issues can be tackled by adjusting the surface resolution, or further smoothing the raw .stl file. Additionally, mismatched edges can result when modifying the surface or applying fine toolpaths over the edges. Scanned parts can be modified by filtering the point cloud data, or adjusting the tolerances when converting from the .stl to surface.

The solid modelling feature in MasterCAM demands high precision geometry to create a seamless skin in order to identify what area of the model is the solid part. If the skin is not perfect, the program will not read the part as a closed loop; one must investigate the part and cleanup the geometry or input data for the command to be actualized. This process can consume an exorbitant amount of time, rendering the process economically infeasible.

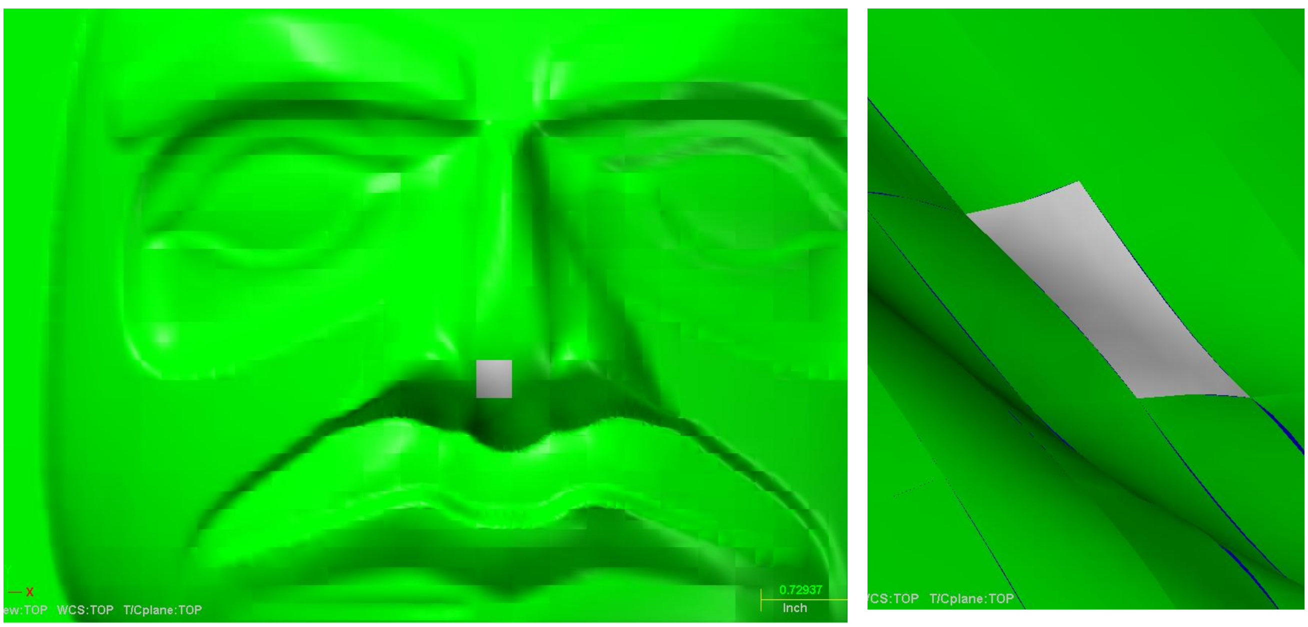

Figure 4. MasterCAM Surface Mismatch. The image on the right is a close-up of the surface connection errors when converting .stl files into MasterCAM surfaces.

MasterCAM Art has several issues stemming from its auxiliary nature within the program. Art-based toolpaths do not allow for 5-axis machining, significantly limiting the tooling options. In order to generate the full range of toolpath options, one must export the Art-surface as an active MasterCAM surface to generate the full range of toolpath options. MasterCAM Art has several Xform functions to aid the transition from Art surface to MasterCAM surface; however, these features are far from comprehensive. Filtering and smoothing the Art-based model will allow

MasterCAM to more smoothly draw the surfaces, minimizing voids caused by mismatched edges.

MasterCAM Art has limited 3-axis machining capabilities, but it has advantages in visualizing the .stl file that is being machined. One can then setup auxillary geometry to bound the toolpath, while using the.stl file as a drive surface. By creating an Art surface from the STL file, one can visualize the model when creating toopaths in the MasterCAM environment - this highlights the visualization and rendering downfalls of MasterCAM in dealing with complex polygon files. There are significant limitations when importing large high-resolution files.

It is important to be aware of the trade-off between surface tolerance, and rendering time of the resulting file size. If tolerances are too tight, the resulting file will be large and cumbersome, creating additional challenges in rendering and toolpath creation. As mentioned previously, importing tolerances can be adjusted to achieve desired surface quality while mitigating design and rendering time. Furthermore, the raw model file should be as small as possible before importing to avoid additional file-prep challenges.

2.4 CNC MACHINING

Computer numeric controlled (CNC) routers conventionally drive the tool along the three axis of the Cartesian coordinate system (XYZ). This allows the router to machine surfaces from the top face of the routing material. A roughing pass is generally used to quickly remove excess material and take it to a point where the bit used on the final pass can safely process. A variety of large diameter tools are used in the roughing pass such as endmill hogging bits, or sawblade aggregates.

To achieve smooth, curved surfaces on a 3-axis machine, ball-nose endmill tools are generally used; these will result in a ribbed finish because of the geometric limitations of rounded bits in approaching a vertical orientation. With the additional axes of a 5-axis machine, the router head is able to twist and tilt, providing the user with more control of the tool’s approach to the piece, resulting in reduced machining time, improved surface finish, and increased machining possibilities.

With the increased tool approach capacity of 5-axis machines, one is able to use flat-bottom endmills, keeping the tool perpendicular to the surface with low step-over in place of the traditional 3-axis high step-over ball-nose approach.

The 5-axis functionality can save considerable production time while increasing the surface finish quality by reducing the number and size of ribs associated with passes required to machine a smooth surface. While 3-axis machining is sufficient for executing simple relief-based pieces, the features of 5-axis machining becomes increasingly valuable when attempting to process more complicated sculptures, such as those found in Northwest Coast Indigenous design.

Although 3-axis routers can process multiple faces, they often require complex jigs and additional re-positioning time. 5-axis routers are able to process from virtually 360°s allowing multiple-face processing without the required fixtures, and adjustment-time of 3-axis machines. The undercutting possibilities of 5-axis machines allow for a more complete processing of 3-dimensional sculptures commonly found in the Northwest Coast market.[15]

The robust machining possibilities inherent in 5-axis CNC routers, combined with recent economic availability of these machines, contributes to an ideal climate for introduction of CNC technology into the Northwest Coast sculpture manufacturing niche.

While mentioning cost and accessibility of CNC machines, one must look at the product range, size, quantity, and price point of products to be machined before blindly selecting a new top-of-the-line CAM solution. One may achieve greater payback and more easily justify a "lower-tech" 3-axis CNC solution tailored to their specific product mix. This method of minimizing asset costs in selecting a CAM solution may see additional hand-finishing production steps, but in many cases it could lower the net unit cost. Providing hand-finishing work is another way to build bridges with the current method of Northwest Coast wood sculpture production.

[15] Tri-Tech Precision Products Inc., "5-Axis Benefits," Tri-Tech, http://www.5-axis.com/Benefits.html (accessed Feb 23, 2008).

2.5 HAND FINISHING IN CNC APPLICATIONS

An additional consideration to CNC processing is the trade-off between quality and machining time. This aspect is highly dependant on the product mix and varies greatly from small, high volume craft products to large, high quality installations or gallery level production. Although it is technically possible to achieve flawless finishes on CNC routers this adds significant toolpath design and machining time, eating into profit margins and financially justifying hand-finishing in many cases. Furthermore, the presence of hand-finishing following CNC production should not be seen as a failure of technology, but rather a vital step towards successful integration with "purely" traditional carving methods. Hand-finishing, particularly in cultural wood products, adds significant value at the marketplace and maintains a consistent human element, as seen in Figure 5 below. Historically, technology has been successfully merged with downstream processing steps, such as chainsaw rough-stage carving, while maintaining consistency in the traditional finish and craftsmanship of hand detailing. For this reason post CNC hand-finishing should be embraced as an initial bridge toward the production of CNC cultural products.

Figure 5. CNC vs. Hand-Finishing Detail by Andrew Pershin. These images show the small amount of hand finishing needed to bring a sculpture from a CNC ballnose toolpath finish with 80% stepover (left) to a finished product (right). It should be noted that fine-point CNC detailing is time consuming from both file prep and machining execution aspects. It is likely that sanding or hand-tooling cleanup will be required to remove machining marks before finishing even if V-bit detailing is performed by a CNC router.

3.0 MARKET POTENTIAL OF SCULPTED CULTURAL WOOD PRODUCTS

Tourism in BC has seen steady increases, particularly in the coastal region, focusing commerce around the major metropolitan centres of Victoria and Vancouver, and several rural native communities situated along the Alaska cruise ship route. With the upcoming Olympics slotted for Vancouver 2010, there is additional momentum in the growth of tourism related markets. The Olympics, in addition to sport, will focus the global spotlight on native culture and tradition, swelling demand for Indigenous design.[16]

In the past, tourism demand has driven the conception of argillite, jewellery, printmaking and moulded reproduction products. Currently there are several stratifications of Northwest Coast sculpted wood products in the market including original artwork, handcrafted production, and moulded resin reproductions. [17]

Each of the aforementioned product stratifications fills a particular market niche, though there is a significant price differential between high priced handcrafted wood products, and low cost moulded resin reproductions. Market expansion and unsaturated demand, particularly on the cruise route, leads to considerable potential for a variety of Northwest Coast niche products to satisfy this intermediate price window.

As discussed above, accessible CNC technology and CAD modeling packages are poised to help local designers, artists, and producers harness this growing market potential. While CNC technology is well suited to aid in the advancement of sculpture production, it is imperative that we consider the issue of intellectual property rights to design, and how this technology might affect the communities from which these designs originate.

[16] The Vancouver Organizing Committee for the 2010 Olympic and Paralympic Winter Games, "Aboriginal Participation," Vancouver 2010, http://www.vancouver2010.com/en/sustainability-and-aboriginal-parti/aboriginal-participation/-/31654/hi=1/18gdwb9/index.html (accessed Sept 12, 2008).
[17] Brooks Yolanda, "The Renaissance of Northwest Coast Art," *Coastlines Magazine*, September 1, 2008. http://www.coastlinesmagazine.com/sepoct-2008/westcoast-story/renaissance-northwest-coast-art (accessed September 29, 2008).

4.0 APPROACHES TO NORTHWEST COAST NATIVE DESIGN INTELLECTUAL PROPERTY

Technology has pried open Pandora's box, leaving policymakers, artists, and manufacturers scrambling to deal with the wake of human rights issues that lay before them. The global community is tasked with the responsibility of discerning how information can be ethically utilized in a modern context.

To morally use intellectual property, we should be aware of the copyright, industrial design and trademark legislation. In addition, where gaps exist in legislations it is essential that customary laws and protocol be respected in order to ethically use the traditional knowledge that is available.

4.1 COPYRIGHT LEGISLATION

The goal of Copyright legislation is to foster statutory public access to information, while giving the artist the right to determine these terms.[18]

The breadth of copyright protection covers a spectrum of Aboriginal works such as art pieces, sculptures, carvings, books and even films. In Canada, all artistic creations both digital and physical are covered under Copyright protection once they are completed, if created by a Canadian Citizen. Artists retain copyright of their original works for the duration of their life and the copyright remains active until 50-years post mortem, unless reproduction rights are transferred by limited or unlimited copyright contract. Artists selling copies of their creations retain all net profit. Artists can sell their design with either limited or unlimited Copyright. Limited Copyright lets the artist determine the terms under which the buyer can reproduce the design. However artists should be aware that Unlimited Copyright allows the buyer to reproduce the artwork, be it digital or physical, in any scale, medium, or number. Artists should also realize that it is expensive to prosecute a buyer if the Copyright terms unclear, so it is best to formally establish their terms before selling. [19]

[18] Indian and Northern Affairs Canada, "IP Rules in an Aboriginal Context," Indian and Northern Affairs Canada, http://www.ainc-inac.gc.ca/pr/ra/intpro/iprac_e.html (accessed Mar 28, 2008).
[19] Indian and Northern Affairs Canada, "IP Rules in an Aboriginal Context," Indian and Northern Affairs Canada, http://www.ainc-inac.gc.ca/pr/ra/intpro/iprac_e.html (accessed Mar 28, 2008).

When a work is reproduced without permission and infringement of copyright law is suspected, significant evidence must be gathered to substantiate the claim. With the advancement of globalisation and technology it is becoming increasingly difficult to monitor and enforce copyright law, especially in developing countries where copyright laws may not be well established or enforced.[20]

Given the complexity and global scale of copyright issues, many artists have banded together to form copyright collectives, which specialize in monitoring and enforcement from a central point. By pooling resources infringement claims can more easily be substantiated, and the collection of royalties can be channelled through a few key organisations.[21]

Despite Copyright protection of indigenous works, there are some areas in which it falls short. Copyright is designed to protect the right of new art. Although Copyright is well-suited to support the creation of new art forms, it fails to address the areas of cultural preservation and appropriate use of traditional knowledge. Furthermore, the limited duration of Copyright protection brings into question whether or not traditional designs would be protected for the long-run, or considered public domain.

Although reproduction of Copyrighted works is prohibited, there is little preventing the use of ideas contained within a given work. Copyright law does not prevent non-Aboriginal entities from producing "original" cultural works based on traditional knowledge, leaving large tracts of indigenous history in the public domain. The issue of protecting traditional knowledge inherent in many cultural works reaches far beyond the scope of copyright law as it stands today. [22]

Indigenous groups are working within the current copyright guidelines, while highlighting areas in which legislation may be strengthened in order to more fully encompass the needs of creators and users of traditional design.

[20] Greg Young-Ing, "Intellectual Property Rights, Legislated Protection, Sui Generis Models and Ethical Access in the Transformation of Indigenous Traditional Knowledge." (Diss., University of British Columbia, 2006)
[21] Indian and Northern Affairs Canada, "IP Rules in an Aboriginal Context," Indian and Northern Affairs Canada, http://www.ainc-inac.gc.ca/pr/ra/intpro/iprac_e.html (accessed Mar 28, 2008).
[22] Greg Young-Ing, "Intellectual Property Rights, Legislated Protection, Sui Generis Models and Ethical Access in the Transformation of Indigenous Traditional Knowledge." (Diss., University of British Columbia, 2006)

4.2 INDUSTRIAL DESIGN LEGISLATION

The Industrial Design Act was established in order to protect the aspect of a product's visual appeal. The Industrial Design Act pertains to both hand-made and machine-aided production. As with copyright, industrial designs are protected only if the shape or ornamentation is decidedly "original".[23]

Although registered industrial designs are commonplace, a survey of the Canadian Intellectual Property Office (CIPO) archives shows a scarcity of registered Aboriginal designs. [24]

The lacking initiative to register industrial design may reflect the desire of Native groups to find a more permanent form of protection. The limited 10-year timeframe and enforcement of industrial design legislation for this form of IP defence may not serve the needs of Indigenous communities looking to establish longstanding ownership of their designs. Furthermore, industrial design legislation does not prevent non-Native producers from registering designs imitating those of traditional Native culture.

Finally, there is ambiguity whether or not traditional designs would meet the "originality" criterion outlined by this legislation, given that many Indigenous designs may be considered public domain due to their use in the communities from which they originated. For these reasons, the Industrial Design Act has seen limited success in the sphere of providing legal pathways to ethically access Indigenous design.

4.3 TRADEMARK LEGISLATION

Trademark is another type of industrial property, used primarily to differentiate a product at the marketplace, for branding or authenticity purposes. This mark generally protects a word or phrase, symbol or design, that can be used together to tell the consumer a message about the producer of set product.[25]

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[23] Government of Canada, "Industrial Design Act," Department of Justice Canada, http://laws.justice.gc.ca/en/showdoc/cs/I-9///en?page=1 (accessed Apr. 20, 2008).
[24] Indian and Northern Affairs Canada, "Industrial Designs," Indian and Northern Affairs Canada, http://www.ainc-inac.gc.ca/pr/ra/intpro/iprac_e.html (accessed Mar 28, 2008).
[25] Government of Canada, "Trade-Marks Act," Department of Justice Canada, http://laws.justice.gc.ca/en/TMarch 19-13/index.html (accessed Apr. 20, 2009).

Similar to industrial design protection, trademarks must be applied for through the CIPO office to be validated. If a mark is registered, but not used, the mark then becomes open to adoption by other commercial entities. Trademark legislation was created to protect the holder of the mark, thereby providing direct proof of ownership, strengthening the owner's protection in the case of a challenge. This protective structure places the task of proving ownership on the challenger in the case of a dispute.[26]

Trademark legislation has been used by First Nations groups in the protection of a variety of applications such as crests, traditional words, and authentic craftsmanship. Most trademark cases of traditional knowledge involve non-Aboriginal firms registering Indigenous symbols, designs, or names (i.e., the 2010 Vancouver Olympic Logo).

With existing trademarks imitating Indigenous design, such as the Vancouver Canucks logo, Native groups are finding it increasingly difficult to create marks to distinguish Indigenous goods in the marketplace. Several countries such as the Philippines and US have curtailed the use of Indigenous designs by non-Indigenous users, though globally this continues to be a rampant concern.

Cases such as that of the Syumeymux people protecting their traditional petroglyphs, where trademark law was twisted into the realm of defensive protection, highlight the need for new legislation to be developed in order to allow Indigenous groups to claim their cultural rights. With the current dysfunction in legal protection of traditional knowledge, one must respect the rights of Indigenous groups and acknowledge customary law in order to build relationships and ensure continued access to cultural design. [27]

4.4 EMERGING PROTECTION

By combining varied conceptual and policy tools, *sui generis* legislation serves to customize legal protection for Traditional Knowledge (TK) in the environment from which it originates.

[26] Indian and Northern Affairs Canada, "Trade-Marks," Indian and Northern Affairs Canada, http://www.ainc-inac.gc.ca/pr/ra/intpro/iprac_e.html. (accessed Apr, 20, 2008).
[27] Greg Young-Ing, "Intellectual Property Rights, Legislated Protection, Sui Generis Models and Ethical Access in the Transformation of Indigenous Traditional Knowledge." (Diss., University of British Columbia, 2006)

TK has emerged on the international stage developing into a key issue at a significant number of UN and WTO forums. The process of formally dealing with the TK's vast implications has begun, engaging Indigenous communities and policymakers worldwide. Through emerging legal protection, such as *sui generis*, standards are being set that are poised to permeate throughout the UN and its member nations, through to the Indigenous communities from which the dialogue emerged. [28]

Upon review of the current legislative tools available to protect the intellectual property of aboriginal communities in Canada, it is evident that policymakers and the international community are adapting the system to fill the gaps that currently exist. The UN is beginning to set standards to integrate traditional knowledge into legal protection. Though gaps exist in legislation, the private sector should respect traditional knowledge to build enduring relationships that ensure continued access to the cultural design of Indigenous groups. As the international community is working with Indigenous groups to integrate customary laws into legislation, so should indigenous groups be aware of the current legislation and how it can be used to protect the value in their hereditary designs.

[28]Greg Young-Ing, "Intellectual Property Rights, Legislated Protection, Sui Generis Models and Ethical Access in the Transformation of Indigenous Traditional Knowledge." (Diss., University of British Columbia, 2006)

5.0 CASE STUDY: DEVELOPING CULTURAL TECHNOLOGY: NISGA'A PROJECT

The proposition of CNC Carved Northwest Coast Wood Products was raised with the direction of Martin Brokenleg at the Consortium of Indian Scholars meeting at the Vancouver School of Theology 2008, in response to my Wood Products Processing directed studies project "Product Development: The Creative Design of a Wooden CAD/CAM Niche Product". Upon introduction to Jacob and Moses McKay, Nisga'a Elders from the village of Laxgalts'ap, I was invited to present the idea as part of the 2008 Laxgalts'ap Career Expo. This exposition was followed by a potlatch, where I was invited to witness the cultural tradition and meet members of the community. The following sections will describe the development work that ensued.

5.1 PROJECT BACKGROUND

The village of Laxgalts'ap is located at the mouth of the Nass River in North-Western BC on the traditional lands of the Nisga'a Territory. The Nisga'a Nation was the first modern native treaty in the year 2000, Canada entitling self-governance, and land ownership[29]. Since then, the community of Laxgalts'ap has grown to understand the critical link between local economic development, and self-sufficiency. To foster tourism and cultural awareness, the Nisga'a community of Laxgalts'ap is constructing four clan longhouses as part of the Cultural Spaces Development Project under the direction of the Gitxatin Development Corporation and Laxgalts'ap Elders.

5.2 PROJECT NEED

Currently, the local hand carving capacity is too small to economically undertake all the aspects of this project, particularly that of marketable gifts (e.g. bowls, spoons, plaques, bentwood boxes etc). The community is seeking channels to supplement the local hand-carving capacity to aid local economic development.

Delayed completion of the Cultural Spaces project would result in loss of potential tourism revenue. There would also be increased completion costs through undertaking the project with

[29] Indian and Northern Affairs Canada, "Fact Sheet: The Nisga'a Treaty," Indian and Northern Affairs Canada, http://www.ainc-inac.gc.ca/ai/mr/is/nit-eng.asp (accessed Fec, 20, 2008).

the limited capacity of local hand-carving. Not pursuing this endeavour may also leave the community at a disadvantage in capitalising on the existing and future market potentials of Northwest Coast computer aided carving. Under the direction of the Laxgalts'ap community, the ethical development of this technology provides a model for future technology advancements, avoiding the appropriation of traditional knowledge.

5.3 PROJECT PROPOSAL

The 5-axis CNC carving capability at the University of British Columbia (UBC) would be used to investigate its feasibility in the prototyping of wooden sculptures with the community's direction. In cooperation with the Nisga'a Community of Laxgalts'ap, we proposed the development of a prototype product, which would coordinate the skills of local artists with the research and development capabilities of UBC's Centre for Advanced Wood Processing (CAWP).

5.4 COMMUNITY FEEDBACK AND RESPONSE

The community of Laxgalts'ap was interested in the idea of mechanizing the carving process to supplement their cultural spaces project, and invited UBC to present the proposal to community. As part of the 2008 Laxgalts'ap Career Expo in UBC shared the idea of joint technology development with the community through an open information booth and formal presentation and dialogue.

Overall the community response was positive, eliciting much interest and follow-up from elders and carvers. This Nisga'a community showed a readiness to look further into these ideas for development, however concerns about the technology and intellectual property exist at this stage.

Concerns revolving the CNC routing technology's replacement of traditional hand carving exist. It is important to consider the ways that new technology may impact the current craft. However, it should be noted that throughout the years the entrepreneurial spirit of the NWC native craftsmen has helped develop the scope and quality of their work, despite the changing political and social climate of the times. This trend has been evident from the early adaptation of western metal tools for the advancement of wood production, to the more recent adoption of manufacturing techniques such as power tools, modern printmaking, etching, and metal casting for a variety NWC niche products. Although there is a strong presence of mass production in the NWC products market, the adoption of CAD/CAM technology in the production of wooden objects seems to be underdeveloped.

Development of the technology, concerning how artists would be in control of the process and receive compensation were of interest. The fear of cultural designs appropriation subsided when parallels were drawn to the community owned textile company which works with artists to produce their designs at a large scale. Further illustration of technology that has been successfully integrated is that of prints, in which the artist defines the edition number and terms under which they are copied. Discussion concluded that similar copyright contracts and conditions could be established by the artist before releasing their designs to production.

Positive community feedback centered around the aspects of CNC carving that could supplement existing hand carving. Currently carvers concentrate mainly with a few workable wood species, such as red cedar, yellow cedar, and alder. Interest emerged from the idea of using alternate wood species that are not economical with traditional hand-carving techniques, such as Douglas Fir and Hemlock. Additionally the elders were interested in the prospect of engaging a wider range of employment beyond the specialized craft of wood carvers. CNC carving production provides the opportunity to employ a range of skill sets from basic manual labour, to native designers and entrepreneurs. With a larger range of employment, the process furthers the community's vision for social, cultural and economic development. Furthermore by actively connecting the voids between culture and technology the community is reconciling how to view their history in light of the modern context.

Cultural benefits of CNC carving were discussed, including preservation and restoration of deteriorating historic monuments. In addition interest was seen in using this economically feasible technology to revive cultural traditions such as personalized potlatch gifts, which have been replaced with generic western commodities.

5.5 CASE STUDY RESULTS AND CONCLUSION

The project was set to move forward and technology transfer funding was approved, pending seed funding from the Gitxatin Development Corporation. However, Gitxatin cited cash flow issues, and was incapable of contributing the fifty-percent seed funding required before the window for funding the project was closed.

Realizing that the initial plan for the project was not going to go through at this time, an alternative course of actions was pursued to test, concretely, the feasibility of applying CAD/CAM to Northwest Coast design.

Figure 6. Scanned Pieces of Nisga'a Artist Roy McKay (above). and Hand Carved Originals (right):
Beaver Frontlet (top), Feasting Dish (middle), Eagle Grease Spoon (bottom)

Through the generous donation of a Laxgalts'ap artist Roy McKay, we received beaver frontlet, scoop, and feasting dish woodcarvings to apply the CAD/CAM process to. The pieces are shown in Figure 6.

The plan for CAD/CAM processing of these pieces was to first scan them to obtain a computer model representation of each, and then convert these models to a format readable by the 5-axis router for machining. The scanning procedure was carried out by 3D Technics who used the point-cloud method of scanning (See The Scanning and File Conversion Section for full description). The scanning process was expensive, and generously paid for by the Centre for Advanced Wood Processing at UBC. The scanning took approximately two months, from delivery of the originals to a raw .stl scan file that had been stitched together. The scanned pieces are shown previously in Figures 1 and 6. The scanned files were not without their problems – there were many inconsistencies between the surfaces of the original pieces, and the surfaces described by their virtual counterparts. As well, there were problems with colour/gloss differentials in the original files, again see Figure 1. These inconsistencies required extensive manual retouching, which was done by converting the .stl file into an Object (.obj) file compatible with the Zbrush program. The file was retouched in Zbrush then converted back to .stl format and scaled to its original size.

With the retouched scanned files obtained, the next step was to prepare them for interpretation by MasterCAM for routing tool paths to be made for the 5-axis router. This step was the most time consuming. Upon importing the scanned, .stl files into the MasterCAM program, we were alerted that the file sizes were much too large for determining a tool path – the MasterCAM support staff maintained that any sized .stl file should work, and that they were not sure what the problem was. Unfortunately, after repeated inquiries, the MasterCAM support staff was unable to determine the problem, and the issue was put on hold.

Near the end of this process it became clear that scanning was not the right fit for CAD/CAM production of NWC native art at this time, especially since intricate designs lead to large .stl scanned file sizes, which will not be interpretable on the current MasterCAM X2 and 5-axis router set-up.

An alternate approach was conceived – As apposed to merely replicating a designed work, design could take place within the digital modelling program so that a resulting model file would be compatible with the routing process.

This procedure would not exclude traditional artists, either – In fact, it would give them a higher stake in the CAD/CAM process. The first procedure included obtaining an artist's work, scanning it, scanned file conversion/touch-up, tool-path definition, and machining. In this process the artist would only be involved in the initial design and fabrication of the piece. The second, proposed procedure includes the artist designing a piece in a 3-D modelling program, minimal file conversion, tool-path definition, and machining. Not only is the second process faster, the steps of scanning and awkward file conversion “touch-ups” are cut out, giving the artist a larger proportion of the tasks. However, what the second alternative does require, is that the artist knows how to use a 3-D modelling program for design. This could be seen as a capacity building opportunity, as education and training in 3-D modelling programs builds on the design skills that Indigenous artists currently have, while providing an array of sought-after computer skills.

With the underlying goal as using a 3-D modelling program to design an artistic piece from scratch, MasterCAM Art was selected first for modelling.

Within MasterCAM Art, a human mask was designed. This process was awkward and clunky, as mentioned above in the MasterCAM section. although MasterCAM Art is a feature “catering” to the aesthetic aspect of CAD, it is centered around limited variable-based design tools, that often result in rigid, forced forms. The resulting design is shown below in Figure 7.

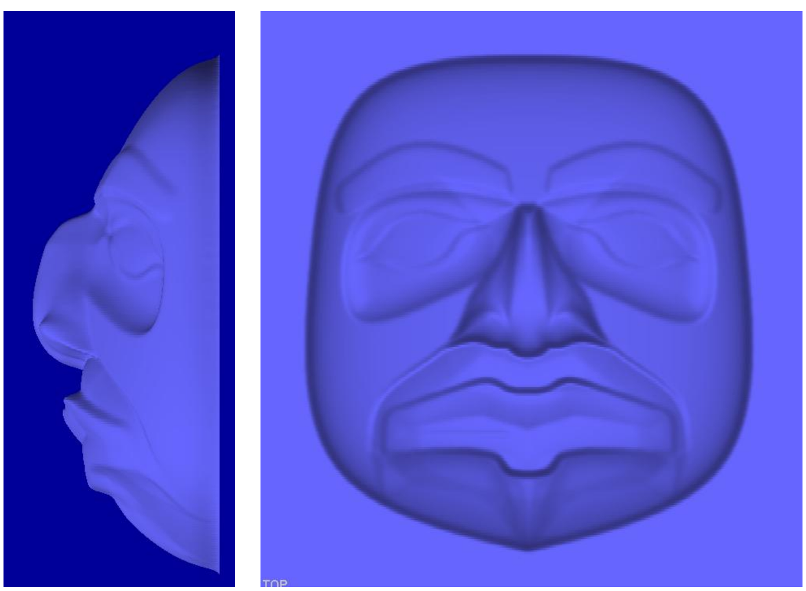

Figure 7. Human Mask Modeled in MasterCAM Art by Andrew Pershin

Since the MasterCAM Art program yielded a dismal result, further research was put into the selection of another 3-D modelling program. The Z-Brush 3-D modelling application was recommended for its user-friendly interface and accessible price, by a colleague working in the Film Industry, and was subsequently chosen to proof of concept. As a proof of concept, a NWC First Nations style Moon Mask, and a Human-Frog Transformation Mask were modelled in Z-Brush from start to finish. Here are the results in Figure 8:

Figure 8. Moon Mask (left) and Frog Mask (right) Modeled in Zbrush by Andrew Pershin

Figure 9. CNC Carved Progression of Moon Mask with hand finishing (left) CNC Carved and hand finished Frog Mask (right)

The next step in the procedure was file conversion. To do this, the Z-Brush exportable object file type (.obj) needed to be converted to the MasterCAM compatible .stl file type. The Rhinoceros® software application was used for this conversion.

The final steps are tool path definition and machining. The .stl files for the Moon Mask and Human-Frog Morph mask were imported into MasterCAM, and tool paths were defined for each, using the .stl file as the drive surface. Since Zbrush allows the user to easily switch between mesh detail levels, one can deal with file-size issues much more efficiently by adjusting the original modelled file. The masks were machined in two separate passes with the router over wooden blocks – A first rough machining pass, and a second finer ball-nose machining pass, as seen above in Figure 9.

After the second pass was completed, the masks resembled their virtual model counterpart with the exception of having slightly less detail. The masks could be taken to further completion with successive iterations of the routing pass, but with diminishing returns – at this point, the masks could be finished quicker, and with unique detailing, by hand carving.

The last procedure, which lends itself to maintaining the traditional skills of a carver, is hand finishing, as seen below in Figure 10. The hand finishing aspect of the process allows the artist to utilize their traditional, fine-grained carving skills, while leaving the rougher wood removal and symmetry determination for the router, similar to current chainsaw techniques used on larger wood sculptures.

Figure 10. Hand Finishing Details by Andrew Pershin. By maintaining a hand-finishing step, significant value can be added, through unique detailing that often determines the level of an artist's quality

The completed Moon Mask and Human-Frog Morph Mask are proof of concepts for developing a design in using 3-D modelling from start to finish. The quality of the masks, along with the ease of modeling in Z-Brush highlights the potential for higher education for NWC Indigenous artists. In addition, the higher proportion of artist involvement, in the place of scanners, along with the preservation of traditional carving skills, through the hand finishing process, further support this process as being a better alternative to scan-based reproduction.

6.0 CONCLUSION

As technology spreads globally, the reach of computer automated design and manufacturing will become increasingly accessible to artists and communities looking to tackle modern economic opportunities in their respective contexts. Over the turbulent history, Indigenous communities and artists of BC's Northwest Coast have adapted the production methods and applications of their designs to reflect the current times, as illustrated by the thriving print and jewellery markets.

Various avenues exist in transferring Northwest Coast Native design into the digital environment, including scanning and several modeling applications. Though scanning can reproduce existing pieces, significant technical and cost barriers limit the feasibility in many applications. Leaning on 3D modeling advances made in the Film and Video Gaming Industries, the computer design of original artwork, using programs such as Z-brush, shows significant promise for development.

Native interest regarding CNC carving exists, as illustrated by the community initiatives such as that of Laxgalts'ap's Cultural Spaces Project and independent Native Artists, though significant cultural and educational barriers prevent a seamless integration between traditional hand carving and CNC production.

Regardless of the technology utilised, Indigenous awareness and education of the methods and implications are essential for the Northwest Coast Native Community to adopt CAD/CAM technology in a culturally relevant and ethical manner.