The Digital Reconstruction and Simulation of Civil War Garments Recovered From the H. L. Hunley

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Abstract

Costumes are a crucial element in the representation of historical figures. Beyond reflecting aesthetic trends, clothing is closely intertwined with culture, economics, and the personal history of the individual who wore them. Fabric simulation allows for the digital creation and animation of garments too fragile or incomplete to be used directly in film or education. This thesis demonstrates the digital reconstruction of the clothing worn by H. L. Hunley crew member James Wicks.

The H. L. Hunley is a submarine from the Civil War. It was the first in history to successfully sink an enemy ship, but never returned from the mission. It and its crew were lost for more than a century. Maritime archaeologists and conservators working on the Hunley have to grapple with the cumulative damage caused by 136 years submerged in the ocean. Many inorganic objects can be cleaned up for museum display, but the fabric of the crew’s clothing is significantly decayed. The scraps remaining are not enough to quickly provide the public with a clear idea of their appearance when worn by the crew the day the submarine sank.

Details of James Wick’s clothing construction can be gleaned through analysis of its remnants, the study of better-preserved Civil War garments, and comparison to 1850’s and early 1860’s sewing practices. Findings inform the pattern-drafting, assembly, and simulation of realistic production-ready digital counterparts.
Acknowledgments

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Chapter 1

Introduction

Physically based animation allows for the simulation of complex systems, like cloth. It can achieve lifelike results with greater flexibility and ease than an animator trying to replicate realistic cloth motion by hand. With the advancement of cloth simulation techniques, it has become convincing enough for use in realistic settings. It is increasingly composited into live action film, used in educational material, and employed as an aid in the development of real clothing.

In this thesis, I perform cloth simulations on a reconstruction of a historical garment from the *H. L. Hunley*. The *Hunley* was an early submarine that sank after becoming the first one to sink an enemy ship. It was raised in 2000, after over a century submerged in the waters of Charleston Harbor. Since then, it has been the subject of extended study, conservation, and education efforts at Clemson University’s Warren Lasch Conservation Center. Among the materials discovered inside the *Hunley* were remnants of the crew’s clothing. The outfit reconstructed and simulated in this thesis belonged to James Wicks.

The project is part of a growing interdisciplinary collaboration between the Warren Lasch Conservation Center and Clemson University’s Digital Production Arts program. Kayla Rutherford previously reconstructed *Hunley* captain George Dixon’s clothing in a similar project, and others in Digital Production Arts are performing facial reconstructions based on the crew’s skulls.

In order to represent James Wicks’s historical garments as faithfully as possible, I consulted the expertise of maritime archaeologist Nicholas DeLong and conservator Johanna Rivera-Diaz. The two work on the *Hunley* at the Warren Lasch Conservation Center and were able to share a wealth of knowledge that made the project possible.
I additionally conducted extensive research into Civil War era garments. Wherever there were gaps in the archaeological evidence for James Wicks's clothing construction, I endeavored to fill them with well-informed and period-appropriate design choices.

Once the garments were constructed, I used Maya’s nCloth to simulate their movement with character animations. I aimed for a realistic depiction of their appearance and behavior when worn by James Wicks in life, such that the resulting renders would be suitable for use in exhibits in the Hunley museum or for publications about the Hunley.
Figure 1.1: The reconstruction of James Wicks’s garments
Chapter 2

Historical Background

2.1 Civil War Naval Strategy

Economics quickly became a key component of Union strategy during the Civil War. Southern states’ economies were driven primarily by agricultural exports and slavery that made them vulnerable in wartime. Although the South produced the majority of the world’s cotton, for example, it relied on other regions to purchase and process it. The region was similarly dependent on imports of goods from areas like the North, where manufacturing was more prominent. [2] If the South were unable to trade, the economic impact would be devastating—perhaps enough to drive the Confederacy to surrender.

One of the ways the Union strove to make this a reality was through the blockading of Confederate waterways and ports, like Charleston Harbor. The strategy, suggested by General Winfield Scott, was known as the Anaconda Plan. Much like the constrictor snake for which it was named, the idea was to encircle the South to restrict its movements and exert pressure from all sides.

The blockades greatly hampered the Confederacy’s ability to import and export supplies. Many naval conflicts during the Civil War revolved around Confederate efforts to break the blockades and aid blockade runners that sought to import or export goods despite the immense obstacles. The Confederacy announced a bounty for any captured or sunken Union ships that encouraged costly, inventive, and desperate innovations. [43]
2.2 The Advancement of Naval Technology

Ironclad warships were developed in the decades leading up to the Civil War. Unlike their wooden predecessors, these steam-powered ships were coated in armor plates that protected them from enemy shells. The necessity for new strategies and technologies to combat them was demonstrated early on in the war.

In March of 1862, ironclads met in combat for the first time at the Battle of Hampton Roads. The ironclad CSS *Virginia* set out to break the Union blockade there. It devastated wooden Union ships on the first day of the battle, but the USS *Monitor* arrived on the second. The two ironclads were unable to defeat each other after hours of combat, and both claimed victory when they assumed the other had given up the fight. None of the ships present possessed the heavy firepower required to sufficiently damage their tough metal hulls. [13]

Among the naval warfare innovations inspired by the threat of ironclads were a wide variety of underwater explosives. While lighter impacts would merely bounce off ironclads’ hulls, a powerful concentrated blast could cause significant damage. The devices used to deliver these blasts were referred to as torpedoes at the time, but generally lacked the ranged capabilities that distinguish
modern torpedoes from other marine explosives. By present-day definitions, they bear more resemblance to contact mines. They allowed for powerful destructive force at low cost, were flexible in their use, and required the enemy to proceed with caution.

The strategy, while effective, was not perfect. The mines posed a risk to all ships traversing their waterways, would not always explode at the correct time, and could be removed or disabled by enemy ships. Submarines were developed to fulfill the desire for stealthy on-demand underwater explosives that could be directed to specific targets, relied upon to detonate at the correct moment, and leave the waterways clear for friendly ships. [41]

2.3 The H. L. Hunley

Horace Lawson Hunley was among those who sought out new ways to sink enemy ships. His varied exploits as a slaveholding plantation owner, lawmaker, and New Orleans deputy chief of customs left him with the funds to invest in bold new ideas and enough ambition to tackle the problem of Union blockades. If it went well, there was money to be made through the bounty on Union ships. He teamed up with James McClintock and Baxter Watson to develop a boat that could dive underwater.

The first submarine the team constructed was a small vessel called the Pioneer. It was destroyed after a few tests to avoid falling into Union hands as the trio fled from New Orleans, Louisiana to Mobile, Alabama in 1862. In Mobile, the group used what they learned during the Pioneer’s brief test period to construct the American Diver. Although the American Diver was
slower than desired, it was sent out on two unsuccessful missions. On the second of these, in February of 1863, the submarine sank. [43]

Around this time Hunley, McClintock, and Watson joined the Singer Secret Service Corps, which shared their interest in developing novel naval warfare technology. The group was led by Edgar Collins Singer, nephew of Isaac Merritt Singer, who invented the Singer sewing machine in 1850 with some assistance from Edgar. They decided to construct a third submarine. One third of the cost was split across a few investors from the group, while another third was contributed by Singer. The final share was paid for by Horace Hunley, for whom the submarine would eventually be named. [33]

The *H. L. Hunley* performed well in tests, and managed to sink a test barge in the Mobile River. After the impressive display, it was shipped up to Charleston to help combat the Union blockade of Charleston Harbor. Initial attempts to use the submarine there were disastrous.

On August 29th, 1863, the *H. L. Hunley* was still docked when it abruptly sank with seven of its eight crew members already inside. Five of them drowned. The submarine was raised from the seafloor and prepared to resume operations.

Horace Hunley captained the submarine’s second crew. In a demonstration on October 15th, the *Hunley* dove beneath the CSS *Indian Chief* and failed to resurface. Weeks later, the submarine was found and brought back up to the surface. All eight crew members had drowned, including
Horace Hunley.

After these two catastrophes, confidence in the *Hunley* was low. Many opposed further attempts to use it. Among those who still believed in its potential was Lieutenant George E. Dixon, who secured permission to assemble a crew of volunteers for further missions.

On February 17, 1864, the *Hunley* and its volunteer crew set out to attack the USS *Housatonic*, a Union sloop-of-war. The submarine was armed with an explosive attached to a spar on the front of the vessel. In light of previous casualties, the crew intended to avoid submerging. By the time those aboard the *Housatonic* saw it, they were too late to prevent the *Hunley* from blasting a hole in their ship. The USS *Housatonic* sank, killing five, and the *H. L. Hunley* became the first submarine to sink an enemy ship. The *Hunley* and its eight crew members never returned from the mission. [12]

### 2.4 James A. Wicks

James A. Wicks was born in North Carolina around 1819. In 1850, he enlisted in the United States Navy and was stationed in Brooklyn, NY. The same year, he married a young girl named Catherine Kelly who had been born in England in 1836. The pair had four children together, Mary, Josephine, Eugenia, and Laura Jane.
When the Civil War began, Wicks’s wife and children were living in Fernandina, FL. Florida was among the first states to secede from the Union and join the Confederacy, while Wicks’s U. S. Navy service continued for the Union.

Wicks fought for the Union aboard the USS Congress in the famous Battle of Hampton Roads, where ironclad ships engaged each other in combat for the first time. The conventional wooden Congress was sunk by the CSS Virginia. Wicks seized on the opportunity afforded by the ship’s defeat to betray the Union Navy and defect to the Confederate side. He enlisted in the Confederate Navy approximately one month later on April 7th, 1862.

Upon joining the Confederates Wicks was stationed in Charleston, SC, where the Union Navy was blockading Charleston Harbor. Many of the Confederate naval efforts there were launched in pursuit of breaking the blockade. Among those were the missions of the H. L. Hunley.

The second time the Hunley sank, it had failed to resurface after a dive below Wicks’s assigned boat, the CSS Indian Chief. In light of the accidents, many Confederates believed that the “Murder Machine” should be retired. Lieutenant George E. Dixon felt it should be given another chance, and secured permission to recruit a volunteer crew. James Wicks was one of five Hunley crew members from the Indian Chief who accepted the dangerous invitation.

James Wicks’s role in the Hunley was to operate the sixth crank, and release the aft keel block in the event of an emergency. On February 17th, 1864, Wicks and the crew made history by sinking the USS Housatonic, the first time a submarine had ever sunk an enemy ship. Although the mission was a success, they did not return from it. The Hunley remained at sea until the year 2000,
when it was lifted for study and conservation efforts. 140 years after their deaths, in 2004, Wicks and the rest of the crew were buried in Charleston, SC. The service was attended by thousands, including Wicks’s descendants. [28]

2.5 Maritime Archaeology

The *H. L. Hunley* was brought back to the surface in 2000, about 136 years after it last sank. Maritime archaeologists and conservators at the Warren Lasch Conservation Center began working to uncover its secrets while taking steps to ensure its longevity.

Over a century submerged in the ocean wore on the submarine and its contents. The hull was covered in concretion, a solidified shell of sediments and barnacles. Salt water caused chemical changes over time that could threaten the structural integrity of the vessel and objects inside. Exposure to the air after these changes could cause another series of chemical reactions. Organic materials had been decaying and deteriorating all along. These challenges and more required people on the project to move slowly, carefully, and thoughtfully.
As they cleared the submarine of sediments and sifted through them, scientists found artifacts to study and preserve. Submarine parts cast light on the workings of the vessel, details of which had been uncertain due to the project’s secretive nature during the Civil War. Skeletal remains helped identify unknown crew members through DNA testing. A story about a gold coin that saved George Dixon from a bullet was given credence through the discovery of a dented gold coin with his remains. Buttons and delicate scraps of fiber have revealed some information about the crewmembers’ outfits.

The mystery that remains unsolved is the cause of the Hunley’s sinking. Ever since the submarine sank, people have had theories to explain what happened to it. Early on, a popular one was that the Hunley sailed into the hole it created in the USS Housatonic and was dragged down with it. [41] This is no longer considered a possibility. Some more recent ideas were that the concussive force of the explosive killed the crew or that small arms fire damaged the port hole in the forward conning tower. Both theories have since been disproven. While the question remains unanswered, there is still work to be done that may reveal more clues.

Aside from the archaeological and conservation efforts, the Warren Lasch Conservation Center hosts a Hunley museum, where the submarine and a selection of artifacts are on display. The public can visit to see these objects in person, learn about their history, and learn about the work being done to study and preserve it.
Chapter 3

Design

3.1 Art Direction

This project is based on a real historical figure and archaeological discoveries made about him. To reflect this, I decided that it would be most appropriate to use an art style grounded in reality. Wherever creativity was required to fill in the gaps in our understanding of James Wicks’s clothing, I would base design choices on research about Civil War era clothing. To the extent possible, I would prioritize primary sources from the time.

3.2 Civil War Era Clothing

3.2.1 Civil War Navy Uniforms

Union and Confederate forces both had uniform regulations during the Civil War. Adherence was strictest at the war’s start and declined over time, especially in the South.

Much like the Confederacy itself was an offshoot of the United States, Confederate uniforms were a direct descendent of US uniforms. Their similarity caused dangerous and unwanted confusion. Additionally, the increasing scarcity of supplies made it difficult to provide forces with uniforms. This was more pronounced in the South, where there was abundant cotton but few mills to turn it into cloth. Forces often ended up sourcing clothes from elsewhere in order to stay clothed, leading to a distinct lack of uniformity. [36] Extensive repairs helped keep clothing serviceable for longer
periods of time under heavy use, and piecing garment pieces together helped make use of precious fabric scraps.

James Wicks was a member of the US Navy when the war started. He enlisted in the Confederate Navy in April of 1862, approximately one year into the war. Archaeological evidence indicates that he kept his Union peacoat when he joined the Confederate forces. Some inferences about his other clothing can be made assuming a desire to adhere to some semblance of uniformity as supplies were becoming limited. Both Union and Confederate Navy regulations called for a black silk neckerchief, with fits the description of the neckerchief found with Wicks’s remains. His shirt and trousers may have been the blue dictated by Union regulations, [35] or the gray of Confederate ones. [34]

3.2.2 The State of Sewing and Sewing Patterns

I started off with a goal to find sewing patterns for Civil War uniforms and quickly learned that sewing patterns as we recognize them today were not yet in widespread use during the 1850’s and 1860’s. They were popularized for home use, which was only starting to take off with the spread of the sewing machine. It took a few more decades for the format we use today to gain prominence.

The Singer sewing machine was patented by Isaac Singer in 1851. His nephew, Edgar Singer, assisted in the invention and manufacturing. [33] This, and other sewing machines at the time, were not yet practical. They were clunky, prohibitively expensive, prone to malfunctions, and incapable of delicate work. Leading up to the Civil War, the technology improved and machines by all manufacturers became more reliable. The Singer Company, however, achieved market dominance by marketing their machines heavily to women, dramatically decreasing production costs in order to sell them at an attainable price for the middle class, and offering payment plans. Sewing machine sales were low in the early 1850’s, and increased exponentially through the 1860’s and 1870’s. [9] That success helped enable Edgar Singer to invest heavily in naval warfare innovations, including the H. L. Hunley.

Tailors were hesitant to adopt sewing machines, both out of fear that their adoption would render their jobs obsolete and objections that the devices produced low-quality garments. Many, however, took advantage of the opportunity to publish drafting systems for use by the growing numbers of home seamstresses. [8] Unlike modern sewing patterns, which are available in several graded sizes based on a standard set of body proportions, these were instructions on how to draw
out pattern pieces based on measurements taken from the eventual wearer for a custom fit. They tended to include minimal detail on garment assembly and detailing. These systems were the closest thing to sewing patterns that I was able to find for Wicks's clothing, and they served the purpose well. Critical factors people rely on in sewing instructions (such as seam direction, stitch type, the side of the fabric used, and assembly order) are relatively inconsequential, if they exist at all, in digital sewing.

3.3 Peacoat

3.3.1 Archaeological Findings

Maritime archaeologists working on the Hunley believe James Wicks had a Union peacoat. Among his remains, they found seven large 34.5mm Goodyear patent 1851 rubber buttons stamped with U. S. N. (United States Navy). These match buttons that were found by archaeologists excavating the USS Monitor, one of the ships involved in Battle of Hampton Roads. This was the battle in which Wicks’s ship, the USS Congress, sank and he used the opportunity to defect to the Confederacy. A slightly smaller mismatched button appears to be a substitution for the final button in eight button Union peacoats. Archaeologists also found several scraps of felted kersey wool fabric that matched the type used for peacoats at the time.

Union peacoats were high-quality, and it would have cost Wicks roughly half his monthly salary to replace his upon joining the Confederate Navy. Keeping his coat when he went turncoat was the easier option for Wicks. Analysis of the other Hunley crew members’ garments indicates that Wicks was not an outlier in wearing non-regulation clothing.

3.3.2 Research and References

The earliest peacoat pattern drafting system that I was able to find was published in the December, 1867 volume of the Gazette of Fashion and Cutting Room Companion. I used this as my starting point for Wicks’s peacoat, and allowed additional research to inform my work as I fit and detailed the garment.

The November, 1869 edition of The Cutter’s Monthly Journal mentioned that “pea jackets” used to have a squarer cut. [10] I noted that the side seam edges on the diagram I was using for
Wicks’s coat curved slightly inward, which may create more of an hourglass shape or flare at the bottom.

The National Civil War Naval Museum did not have any peacoats in their holdings, but I was able to glean information about general Civil War coat construction during a visit. The collars on coats in their collection, for example, were all made in halves connected by a seam along the center back. I also observed that the seam along the back of sleeves is generally connected to the bodice at the narrow section of the armscye formed by the back panel of coats (The small curved section next to point F on “Dia. 15” in the peacoat cutting diagram).

Photographic references further contributed to my understanding of the appearance to aim for with Wick’s peacoat. This was especially useful when establishing simulation settings later on, because photos gave a clearer and more intuitive impression of Civil War peacoat fabric behavior than cloth descriptions or the wrinkle-free drawings in fashion plates from the era.

### 3.4 Shirt

Most of the archaeological information on James Wicks’s shirt comes from its buttons. Four two-hole mother-of-pearl buttons were found near his scapula. Two of these are estimated to have been attached to the shirt’s placket, the opening at the neck. The remaining two were likely attached to the shirt cuffs.
Figure 3.2: An 1867 peacoat cutting diagram [32]
Figure 3.3: An 1867 fashion plate in which the center figure is wearing a peacoat [32]
While I’d been able to track Civil War era pattern systems for civilian shirts, those for sailor shirts eluded me. Civil War photographs gave an impression of the finished shirts’ appearance, but were not helpful in uncovering the ways they were construction. Seam lines were hidden by layers of clothing, camera angles, people’s poses, and the clarity of the images. To fill in the gaps, I ended up leaning heavily on practical reference.

The National Civil War Naval Museum graciously allowed me to study a shirt in their collections. Gentle handling of the delicate garment gave me a firm understanding of the way it was constructed. The top of the shirt body consisted of a single rectangular piece of fabric, with a hole cut into the center for the head. The base of the sleeves were the same length as this piece, and attached directly to its sides. The bottom half of the shirt was made of two rectangular panels. The large distinctive collar was also made of a simple rectangle of contrasting fabric. [24]

This rectangle-based pattern aligns with the popularity of block pattern shirts during the 1860’s. Shirts of this type had minimal tailoring for shape. [36] Their consistency and simplicity made them relatively easy to produce, and suited for manufacturing as ready-to-wear items. [15]

I made small adjustments to accommodate the button placement described by archaeologists. Instead of two on each cuff, I placed one per cuff and added two to the shirt placket.
Figure 3.5: A shirt in the collections of the National Civil War Naval Museum [24] and my notes on its construction
3.5 Neckerchief

3.5.1 Archaeological Findings

Archaeologists found James Wicks’s neckerchief nearly intact. The partially concreted fabric was covered in iron stains and sediments. Once it was cleaned up, the neckerchief’s square knot and some decorative stitching on the remainders of the tassels became clearly visible. Its current pinkish hue is a byproduct of chemicals used to remove iron corrosion. The silk would have been dark blue or black when Wicks wore it into the Hunley.

3.6 Other Garments

James Wicks wore leather brogan shoes that stayed relatively intact to the present day. They show signs of extensive wear and repairs.

Some felted material and silk ribbons were likely part of Wick’s hat, but the other fabrics that survived to the present day were too degraded to provide substantial information about the garments they came from. In one of his woven fabrics, for example, the warp was lost while the weft still remains.

Five four-hole buttons made of bone provide the bulk of the information we have about Wicks’s trousers. Two of them are larger than the others, and probably fastened the waistband while the smaller ones closed the fly. A prosser button completes Wicks’s collection, and resembles those used for drawers in the Civil War era.
3.7 James Wicks

James Wicks was 44, among the oldest on the crew of the *Hunley*. Analysis of his remains indicate that he was about 5’9” tall and weighed an estimated 179 lbs. Records show that he had blue eyes, light brown hair, and a florid skin complexion. Facial reconstruction based on his skull is in progress. No known photographs of James Wicks exist.
Chapter 4

Cloth Simulation

4.1 Overview

There is often a need for cloth animation in 3D media. Characters wear clothes, curtains billow in the wind, couch cushions compress under weight, and so on. Animators primarily work with rigs to bring digital objects and characters to life, but cloth moves in complex ways. It can stretch and bend in all directions, and each type of fabric does so differently according to the properties of its materials and weave. Rigs would need to be complex to allow for the full range of cloth behaviors in a realistic style. Manually 3D animating this behavior is a difficult and tedious task that tends to produce unconvincing results.

Cloth simulations are a form of physically based animation that uses the properties of the cloth, environment, and objects the cloth can collide with to calculate fabric behavior over time. Simulation artists are able to art direct the cloth by manipulating physical traits like its weight and resistance to stretching. The process allows for more lifelike digital cloth performances with greater flexibility for change as productions demand.

Cloth simulations are widely used for 3D animation, games, and even in the development of real-world garments. In this thesis, cloth simulations are used to create the motion of H. L. Hanley crew member James Wicks’s clothing.
### 4.2 History

Some of the earliest cloth simulations were geometric approaches that replicated the appearance of cloth rather than its behavior over time. The first of these published was Jerry Weil’s 1986 approach to approximating the shape of cloth suspended by user-defined constraint points. It created the appearance of wrinkled fabric by relaxing cloth along curves between constraints, but did not support its animation and was limited in its use cases. [42]

Around the same time, others in computer graphics were working on the development of cloth models that accounted more for its physical properties. Also in 1986, Carl Feynmann published a technique in which cloth was a grid with energy at each intersection, and moved to the position that minimized that energy. [11] In 1987, Terzopoulos et al. published another energy-based approach using elasticity. This method supported the animation of cloth. [39]

In 1992, Breen, House, and Getto used force-based particle systems to incorporate more of cloth’s structural properties in simulations. [16] Four years later, Eberhardt, Weber, and Strasser increased the speed of particle system cloth simulations and allowed for the influence of external forces, like wind, by modeling the forces acting on particles as differential equations. [6] Baraff and Witkin further improved simulation times without sacrificing simulation stability in their 1998 paper on a system that allowed for larger time steps through the use of implicit integration and triangulated cloth. [3] Baraff and Witkin’s method was implemented in many cloth simulation engines, including Maya’s nCloth. [38]

### 4.3 Related Work

The digital reconstruction of historic garments is a growing field whose range of applications and advantages in comparison to physical reconstructions are still being explored. The majority of these projects completed so far focus on creating visual representations of the garments.

In 2005 and 2006, the Seoul National University created digital reconstructions of donated costumes. These demonstrated that reconstructions were possible, but also that improvements in fabric simulation technology were necessary to make the fabric behave more realistically and handle complex construction techniques such as those seen in historic clothing collections. [21]

In 2015, Young et al. created reconstructions of two dresses in the collections of the Museum of London. They used patterns and garment measurements to create and adjust physical mockups,
then used the refined patterns to create digital counterparts in DC Suite 3.0. Once complete, they conducted a survey in which people analyzed the digital garments. Participants generally reviewed them favorably and enjoyed the interactivity the format allowed, showing that the presentation held promise for exhibition of and education about historic garments. [19] Museum curators appreciated the ability to show the garments in motion, the potential to visually restore damaged garments, and ability to allow the study of reconstructed collection items without physical touch. Some, however, felt that the physical presence of garments or physical reconstructions held irreplaceable value that could not be replaced by a digital counterpart. [18]

In the 2020 reconstruction of an evening gown work by suffragist Carrie Chapman Catt, Villarreal et al. noted that the selection of fabric properties and materials were subjective processes. Reconstructions of the same garment could have different appearances depending on interpretations made by their creators. [40]

Kayla Rutherford completed a digital reconstruction of H. L. Hunley captain George Dixon’s garments in a 2021 collaboration between Clemson University’s Digital Production Arts program and Warren Lasch Conservation Center, similar to this project. Dixon’s outfit was the best-preserved of the crew, however his assemblage was made more complex by the presence of suspenders and a vest.

Moskvin et al. recently demonstrated the use of digital reconstructions as research tools in their study of the costume of 2nd–4th century AD Germanic warriors. The team performed their reconstruction of archaeological garments in Clo3D, and then used the digital costumes to test hypotheses about the outfit.

Calculations revealed that the assemblage’s belt reduced the chain mail’s moment of inertia and helped to split its weight between the shoulders and waist. Analysis of the space between the avatar’s body and the chain mail showed ample room for padded undergarments, which have not survived to the present day. Strain maps of the garments on an avatar in poses corresponding to different types of warfare indicate that the outfits allowed their wearers to move freely for many forms of combat. The process provided visual representations of the garments, and went beyond them to increase understanding of the clothing’s function. [23]
4.4 nCloth

The fabric simulation system used in this thesis is Autodesk Maya’s nCloth. It works by allowing users to shape the behavior of a network of particles it creates from object meshes. Each vertice in the mesh is assigned a particle, and each edge corresponds to a link between particles. If the faces in the mesh are quadrangles, cross-links are also created to connect particles across the diagonals of the face. Links are used to manage the distance between particles, while cross-links maintain the angles between them.

nCloth objects have several adjustable properties that can be used to change the behavior of the system of particles, links, and cross-links. For example, if the user increases the stretch resistance parameter, links will more powerfully resist tension pulling particles apart in effort to return to their rest lengths. Similarly, increases to the bend resistance will cause cross-links to more powerfully resist deviations from the rest angle between particles.

nCloth properties can be adjusted to make the simulated cloth behave similarly to different types of real fabrics. Maya includes several presets that can be applied to quickly mimic materials like silk and burlap. Others, such as lava and soft sheet metal, are more suitable for non-cloth materials. These presets can be blended together, or used as convenient starting points for the fabric. Users can also save their own presets for further use.

Applying properties evenly across nCloth objects is not always suitable. There may be cases where more than one material needs to be represented by the same mesh, or the desired settings are not providing the desired results in specific parts of the cloth. For scenarios like these, it is possible to paint variable property values to maps. nCloth supports both vertex maps and texture maps, although the latter requires the mesh to be cleanly UV mapped. The values from the painted maps are used as a multiplier or weight for the properties they are assigned to.

The behavior of nCloth particle systems is further shaped by the Nucleus solver it is assigned to. The Nucleus dictates the properties of the environment, such as wind and gravity. If multiple nCloth objects are assigned to the same Nucleus, it allows them to interact with each other.

When the nCloth object is simulated, the Nucleus solver will perform the calculations to determine its behavior. Each particle of the system moves according to the net influence of all of the forces acting upon them. Their updated positions are used in the resulting output mesh, which is the visible representation of the nCloth’s object mesh as altered by the simulation. Although the
user may only see frame-by-frame results, multiple substeps are usually calculated between frames in order to increase the simulation’s accuracy and stability.

Performing the calculations for nCloth fabric simulations can be slower than is appropriate for viewport playback. Rather than running the simulation every time the user wants to view the results, nCloth allows the results to be cached. This allows Maya to read the nCloth objects state at each frame from a file instead of taking the time to compute it. Its uses include playing the simulation back from multiple angles, jumping to different frames in the timeline, and mixing the results of multiple simulations.

The combination of these features and more allow nCloth users to simulate an expansive range of fabric types, both realistic to the physically impossible.
Chapter 5

Implementation

5.1 3D Models

It was necessary to obtain and prepare a model to represent James Wicks before creating clothing for him. A base mesh by Vincent Ménier was chosen for the purpose. [25] This model has a realistic style, suitable for depicting the estimated appearance of a historic figure. It also has clean topology and tidy UV layouts, which aid achieving a smooth rigging and surfacing experience. Furthermore, it was used in Kayla Rutherford’s reconstruction of Hunley captain George Dixon’s garments. The use of a consistent base mesh across Hunley crew member reconstructions could increase the efficiency of future projects that build on them.

Before beginning, the model was adjusted to better fit what we know of Wicks’s physical build. These changes were made in ZBrush, a powerful digital sculpting program. The base mesh’s crisp muscle definition was softened with the smooth brush, and then the overall form was thickened for a stockier and more powerful appearance. This altered model was exported for use with the topology and UV layout from the original left intact. Once the base mesh was imported to Maya, I scaled it to match James Wick’s estimated height.

From there, I created some clothing elements that are not made of fabric. Each of Wick’s button types were poly-modeled in Blender. I imported reference images of his buttons, and then scaled them to match the button’s size to the scene scale. I modeled the buttons directly over the photo reference to ensure a close match, then UV unwrapped the buttons for texturing later on.

Wicks’s brogan shoes were modeled in Maya, directly around the foot of his edited base
Figure 5.1: Vincent Ménier’s original base mesh (left) and the adjusted version for James Wicks (right)
mesh. I consulted photo references to aid in the process and took care to maintain clean topology with good edge flow for smooth deformations. The shoes were also UV unwrapped for surfacing.

Figure 5.2: Buttons modeled directly over reference images [12]

Figure 5.3: Reference of one of James Wicks’s shoes [12] (left) and the shoes’ 3D models (right)

5.2 Rigging

Rigs are systems of joints and controls that give animators the ability to manipulate models’ deformations. The base mesh chosen for James Wicks did not include one, so it had to be created. I
utilized the AdvancedSkeleton [37] plugin for Maya with a workflow described by David Mattock [22] to quickly generate a high quality rig.

The first step was to run a check to make sure the mesh did not contain any problems that would interfere with rigging. The only issue the tool found was slight asymmetry on a handful of vertices. Maya’s symmetrize tool corrected these asymmetries, and the next check passed.

After that, AdvancedSkeleton’s biped FitSkeleton was added to the scene and adjusted to fit Wicks’s model. The knee joint was moved to sit inside his knee, the elbow joint in his elbow, and so on. With the joint system in place, building a robust set of working controls for its movement was as simple as clicking the Build AdvancedSkeleton button.

At this point, the controls did not move Wick’s mesh. A skin cage was used in order to help AdvancedSkeleton move the correct parts of the mesh with each control. The skin cage is a lightweight mesh built over the joint system. Each part was scaled to encompass the mesh geometry that its section of the joint chain should influence. Skin weights, a measure of that influence, are then copied from the skin cage and applied to the mesh. From there, weight painting allowed for the refinement of the mesh deformations through the manual adjustment of joining influences on the mesh.

5.3 Animation

With a rig set up, I was enabled to create animations of James Wicks to use with cloth simulations. I decided to create two animations for three simulations. I’d use a walk cycle animation for simulations of Wicks’s outfit both with and without his peacoat, and an animation of Wicks operating the Hunley’s hand crank for a simulation without his hand crank (archaeological evidence indicates that he removed it). Each animation begins with several frames of the base mesh’s initial pose in order to give the cloth time to settle into place. This is followed by several frames to transition into the action’s starting pose.

I animated the action by using the rig to move the Wicks model into key poses for one iteration of the repetitive motion. I set keyframes on the rig controls at each of these poses, then adjusted the timing as necessary. To refine the animation, I added some additional keyframes and used Mayas graph editor to adjust the interpolation from keyframe to keyframe. Once I was happy with my single iteration of the action, I looped it to repeat as many times as desired.
Figure 5.4: A rig allowed the James Wicks model to move for the walk cycle animation
5.4 Drafting and Draping

James Wick’s clothing was created in Marvelous Designer, [17] a digital sewing program. It functions similarly to sewing in the real world. Users flat draft two-dimensional pattern pieces, connect them to one another, drape them over the model in 3D space, check how well they fit, and make adjustments as necessary.

Character models in Marvelous Designer are called avatars. I imported the James Wicks mesh at real world scale, and enabled the option to automatically create arrangement points. These points hover at a slight distance from the avatar, on the surface of bounding volumes that wrap around features like the arms and legs. Pattern pieces can be placed on these arrangement points to quickly move them into a good starting position for the sewing simulation.

I started constructing the majority of Wicks’s garments by tracing over a background image of an 1850’s or 1860’s drafting system. In cases where I was unable to track down suitable patterns, I relied more heavily on other references. The shirt pattern, for example, was largely based on my in-person analysis of the construction of a shirt held in the collections of the National Civil War Naval Museum. Handling the shirt allowed me to glean information that could be difficult to determine from photographs or stationary exhibits of layered clothing, such as the lack of a seam on top of the shoulder and the placement of seams in the armpit area. Once the pattern panels were
created, I used arrangement points to place them around the Wicks avatar in 3D space and added sewing lines to indicate which parts should be connected to each other.

In Marvelous Designer’s sewing simulation, pattern pieces react to gravity, collide with the avatar as well as each other, and are drawn together along sewing lines. While the simulation is running, users can interact with the cloth to help tug it into position. After simulating the initial draft of a garment, I assessed the fit and made adjustments as necessary. Loose areas are clearly visible through things like falling pants or gaping fabric, while tension maps help identify strain on tight ones.

Once each garment was nearly complete, I added them to a single Marvelous Designer file to dress the Wicks avatar in his full outfit. Layers were an essential tool in ensuring that his clothing overlapped properly. His shirt, for example, was tucked in and needed to lie beneath his trousers. Setting the shirt to layer 0 and the trousers to layer 1 helped Marvelous Designer keep the shirt from trying to explode out of the pants when I simulated them into position. Fully dressing the avatar in Marvelous Designer helped save time in nCloth simulation when I exported the garments in Maya, because each outfit was already in an appropriate starting position and respecting the space occupied by other pieces of fabric.
5.5 Retopology and UV Mapping

To prepare the clothing I created in Marvelous Designer for export to Maya for simulation, I retopologized and UV mapped it. Marvelous Designer uses triangulated meshes for its simulations by default. Maya’s nCloth, however, needs quad-based meshes in order to utilize both links and cross-links between particles. A quadrangulated mesh with relatively even spacing helps nCloth perform most effectively. Surfacing relies on UV mapping to apply two-dimensional images onto three-dimensional objects.

I performed my retopology within Marvelous Designer using the techniques described in their VFX Pipeline Tutorial. [5] The patch retopology tool allowed me to rapidly fill swathes of pattern pieces with evenly spaced rectangles. The ability to see internal lines on the pattern made it easy to plan topology around button placements and deformations like the lapel fold in the peacoat. Once pieces were retopologized, I UV mapped them. A benefit to flat drafting patterns is that the process inherently completes goals of UV unwrapping. The pattern pieces are already flattened and split into islands across seam lines. Once their parts were straightened and scaled appropriately in the UV editor, I exported the retopologized garments for use in Maya.
5.6  Simulation

5.6.1  Preparation

In Maya, I imported my retopologized and UV mapped clothing files. I merged the vertices at the edges of adjacent pattern pieces to hold them together during simulation. The same garment sometimes used multiple materials across its parts. For example, the felted top of Wicks’s hat, the hat band, and the decorative silk pieces were all different fabrics. I kept their geometry separate in order to more easily assign appropriate dynamic properties to each.

Creating my first nCloth object also created a Nucleus solver. By default, the solver’s space scale is set to meters. My scene and the objects in it were set up in centimeters. This mismatch caused fabric in test simulations to appear to fall very slowly. I adjusted the Nucleus’s space scale to 0.01 to align with the scale of the scene, and my test fabric began falling as expected.

At this point, nCloth objects could pass through the models of Wicks and his shoes as if they did not exist. I turned these objects into passive colliders, which attached them to the Nucleus solver. This allowed it to calculate collisions between them and the fabric.

5.6.2  Constraints

Initial simulations before showed the necessity of constraints. As mentioned in the Preparation section, I used separate pieces of geometry for parts of the hat. This caused them to behave as if they were not sewn together. The Weld Adjacent Borders constraint links adjacent borders between objects to make them behave more like a single piece of fabric. Adding this constraint to the hat’s band and top held them together.

The Point to Surface constraint was helpful in situations where parts of nCloth objects had to be held in place to prevent unwanted behavior. This constraint links a selection of components on an nCloth object to the surface of another object. Users can adjust properties like the strength of the connection and its rest length. Placing these constraints between the trousers’s waistband and Wicks’s body helped prevent the trousers from slowly sliding to the floor.

Component to Component constraints create links between selected components, and have adjustable properties similar to those of Point to Surface constraints. They helped in areas where greater precision or linking within an nCloth object was required, such as holding buttoned areas together.
Occasionally, constraints helped to shape fabric behavior when adjusting properties did not suffice. The silk ribbons decorating Wicks’s hat were attached using a Point to Surface constraints with a line of vertices across their center. When I adjusted dynamic properties, they would either bend too much on either side of the attachment points or rock around like a stiff piece of plastic stapled to the hat. I ended up adding weak Point to Surface constraints between the top of the hat and the vertices at the top of the ribbons. These gave the ribbons enough support to stay upright but allowed some movement for a natural performance.
5.6.3 nCloth Properties

nCloth objects have several collision and dynamic properties, which shape the way they behave and interact with each other. Adjustments to these properties can be made across the entire object and on specific parts of them, through vertex and texture maps. These can be used to make them act like the desired type of fabric and refine their performance. Maya includes several presets which can be used as starting points for the fabric.

For the trousers, I started with the burlap preset. This came relatively close to the desired behavior, and I adjusted presets until I achieved the desired performance. Finding dynamic properties that fit the garments took several iterations. As I ran simulations I would observe the fabric’s behavior, take note of the dynamic properties, compare the performance to earlier iterations, and adjust the properties to approach the desired performance.

Properties sometimes had to be adjusted to fit the action of a shot. The shirt’s properties in the walk cycle, for example, caused significant strain across the back when Wicks leaned forward and reached out to turn the Hunley’s hand crank. In this case, I used property maps to allow additional stretching across the back of the shirt.
5.6.4 Caching

Once I was satisfied with the cloth simulations, I followed the process outlined in Karabo Legwaila’s nCloth tutorial [20] to transfer the performance onto high poly versions of the garments. Creating caches for the nCloth objects saved the fabric’s movement and allowed it to be played back without recalculating the simulation. A wrap deformer allowed the performance of the nCloth objects to be applied to their high resolution counterparts, which had thickness and seam details. I used point to poly constraints to attach buttons to these meshes. Once the deformers were applied, geometry caches saved the movement of these meshes.

5.7 Surfacing

Materials gave the costume its color and texture, adding to the illusion that the geometry is made of cloth. The materials for Wicks’s clothing were created in Substance Painter. I used a variety of fabric smart materials for their base, and edited the attributes to suit each garment. For example, in felted materials like the peacoat and top of the hat, I reduced the visibility of the fabric’s warp and weft. Once complete, I exported the texture files, attached them to materials in Maya, and assigned the materials to the clothing.

5.8 Rendering

The scenes were lit with an Arnold SkyDome light and an HDRI from Poly Haven. [14] This mapped the photographic image data from the HDRI to the scene’s illumination to make it look as if the objects were in that environment. I created a simple neutral backdrop for the scene to make Wicks’s clothing the focal point of the renders. I used multiple cameras to capture a variety of angles and shot compositions. The renders were made with the Arnold renderer.
Figure 6.1: A comparison of a reference image to the completed reconstruction
Figure 6.2: Outfit without peacoat, front, frame 0
Figure 6.3: Walk without peacoat, front, frame 883

Figure 6.4: Walk without peacoat, back, frame 312
Figure 6.5: Walk without peacoat, closeup, frame 883

Figure 6.6: Walk with peacoat, front angle, frame 228
Figure 6.7: Walk with peacoat, back angle, frame 228

Figure 6.8: Operating the *Hunley’s* hand crank, side angle, frame 173
Figure 6.9: Operating the *Hunley*’s hand crank, side angle, frame 239

Figure 6.10: Operating the *Hunley*’s hand crank, closeup, frame 290
Chapter 7

Conclusion and Future Work

7.1 Conclusion

The clothing remnants of H. L. Hunley crew member James Wicks are too delicate and incomplete for display. This project draws on prior work in 3D production, maritime archaeology, naval history, and fashion history to create digital reconstructions and simulations of the historically significant garments. The result is a piece that utilizes Civil War era garment construction to evoke the proper silhouette for the specific pieces of clothing depicted. The images and videos produced can provide the public with a clearer picture of what James Wicks’s outfit looked like the night the Hunley sank than the artifacts themselves.

The use of digital clothing reconstruction based on archaeological findings is a field with room for much more exploration. I hope this project will encourage further work in the area, which is rife with possibilities for benefits in research and education.

7.2 Future Work

Going forward, there is a great deal of additional work that could be performed on this project. I personally intend to continue refining the fabric simulations to fix areas I am not yet satisfied with, such as a strange motion caused by the peacoat riding the shirt beneath it like a raft as it slides too freely across the body. The addition of features such as rolled up cuffs, tears, wrinkles, and the peacoat laid on the bench of the Hunley could make the clothes feel more lived in.
While this project focused on the construction and movement of James Wicks’s clothes, it could be expanded to a more comprehensive reconstruction. Once facial analyses are complete, a better approximation of Wicks’s head could be attached to the model. More rigorous surfacing could represent the specific fibers found by archaeologists, include garment trims and linings, show repairs, more closely mimic the surface of buttons in Wicks’s assemblage, and approximate the appearance of his skin. A digital groom and dynamic hair simulations could help further bring the digital reconstruction to life.

This work could also be completed for the other crew members of the H. L. Hunley, and a detailed recreation of the submarine itself could be made and utilized for additional simulations and renders. Analysis of the simulated cloth as it moves could potentially contribute to our understanding of factors like the physical strain on crew members as they operated the H. L. Hunley.

This project and future contributions to it could be used in H. L. Hunley publications and museum exhibits for education and entertainment. The digital garment patterns could additionally be used as a starting point for physical recreations of the garments. As archaeologists learn more about the Hunley and its crew, updates to the project would help to more accurately represent the history depicted.
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English costumes, plate 2, February 1867.


