#1902

NDSU Student Technology Fee Action Plan Request

I. Action Plan Introduction and Authorizations

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Office of the Vice President for Information Technology

NDSU ORGANIZATION OR UNIT Architecture & Landscape Architecture Computer Science Visual Arts Geoscience			
TITLE OF PROJECT **Custom 3D Scanner**			
Project Duration (3 years maximum)	**From: 5/19**	**To: 5/22**	
Type of Project (Check one)	**New X**	**Previously Submitted**	**Renewal**
Total Technology Fee Request $18,800.00			
Project Director **(Must be NDSU faculty or staff)** **Ben Bernard** **Jessie Rock** **Dr. Jeremy Straub** **David Swenson**	**Campus Address: Klai Hall 10A** **Phone: 701-793-9528** **Fax:** **E-mail: ben.bernard@ndsu.edu**		
Name (Type or Print)	**Signature**	**Date**	
Project Director **Ben Bernard** **Jessie Rock** **Dr. Jeremy Straub** **David Swenson**	[signatures]	**2/15/19**	
Unit Head **Michael Strand**	[signature]	**2/15/19**	
IT Division Consultant Steve Sobiech	**Signature** [signature]	**Date** **2/15/19**	

Executive Summary (maximum of 175 words)

Ben Bernard and Computer Science Doctoral Student Pann Ajjimaporn will design and build two 3D scanners for multidisciplinary design, teaching, and research use. One unit will be deployed in Renaissance Hall to be shared between Architecture, Landscape Architecture, and Visual Arts students and faculty. The other will be deployed in a campus makerspace. At the time of this proposal several different sites are being considered for deployment, including the Library's new Digital Fabrication Lab. The final design and software will be made available for any other campus labs that wish to create their own 3D scanner. Research faculty Jessie Rock (Geosciences), Dr. Jeremy Straub (Computer Science) and David Swenson (Visual Arts) will assist in testing the 3D scanner and incorporate the device in their teaching and research.

The Technology Fee Advisory Committee will only accept for consideration Student Technology Fee Action Plan Request forms which are fully completed and signed, and whose Project Directors have no past due reports on previously awarded projects as of the current submission deadline date, according to the guidelines listed in the Instructions, pages 1 and 2.

Technology Action Plan Request forms will be opened and reviewed after the submission deadline.

NDSU Student Technology Fee Action Plan Request

II. Project Overview

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1. How does this project meet student needs?

Students will be able to 3D scan their design models, artwork, prototypes to create a digital copy or a digital workflow that will allow them to take their 3D scan into virtual reality, edit their 3D scan using 3D design software, or make a new physical copy using 3D printing.

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2. What audience does this project directly serve? What audience is indirectly served? How many students are affected?

Over 400 students and faculty in the Architecture, Landscape Architecture, and Visual Arts programs will be the initial users and beta testers of the 3D scanner, because of the immediate need and proximity to existing digital fabrication and virtual reality assets. Once the 3D scanner has been fully developed and tested, a second 3d scanner will be deployed to a campus makerspace such as the Library's new Digital Fabrication Lab where all NDSU students, faculty, and staff could have access to a 3D scanner.

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3. For projects that target a subset of NDSU's students, please describe the possibility for broader application in the future.

Once the 3D scanner has been fully developed and tested, a second 3d scanner will be deployed to a campus makerspace such as the Library's new Digital Fabrication Lab where all NDSU students, faculty, and staff could have access to a 3D scanner.

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4. Describe both the immediate and long term impact of this project.

Immediately, the students and faculty in the Architecture, Landscape Architecture, and Visual Arts programs will benefit from having access to a 3D scanner. One immediate need is design and arts students create many physical models and sufficient storage space is not available for either student portfolio needs or department accreditation visits. Using a 3D scanner, students and faculty can digitally preserve the physical models, eliminating the need to store physical models over time and try to track down the rightful student owners after the accreditation visit. Another exciting opportunity is for students to be able to create a digital portfolio of objects they have created that can be viewed and manipulated using virtual reality.

Ajjimaporn has previously served as a co-author on published in three published conference papers on 3D scanning and will collaborate on further 3D scanner research with this project. Straub has published two journal articles and served as an author on four conference papers on this topic.

All students, faculty, and staff will have access to 3D scanning once the downtown beta testing is over and a campus site is selected for the second 3D scanner.

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5. Who will pay for ongoing expenses following the technology fee funded portion of this project (e.g., who will replace hardware or software after it has reached its end of life)?

The Architecture & Landscape Architecture and Visual Arts departments will maintain the 3D scanners following the technology fee funded portion of the project.

6. Describe how this project will follow NDSU's best practices in information technology. (Please make sure the NDSU IT Division staff you consulted signs in Part I of this form.)

Computer Science PhD Candidate Pann Ajjimaporn will be writing the software that will operate the 3D scanner. The design, creation, and operation of the 3D scanner will not require any NDSU IT Division resources.

Ben Bernard recently completed the NDSU Cybersecurity Graduate Certificate and has served on a number of successful TFAC projects, including the highly successful Augmented Reality Sandbox collaboration between Architecture & Landscape Architecture and the Geosciences departments. Bernard is currently working towards his Master's degree in Computer Science and has been serving at the Architecture & Landscape Architecture Department Computer Services Specialist since 2004.

Jeremy Straub will provide project management expertise to this project. Jessie Rock and David Swenson will provide relevant input from their respective user communities.

7. What service on campus is most similar to the one proposed here? How does this project differ?

At this time, there are no large, high resolution 3D scanners available on campus.

Architecture, Landscape Architecture, and Visual Arts students and faculty often create large design models and artistic works that could be digitally preserved with a 3D scanner. A 3D scanner also creates a digital workflow in which a user can take the 3D scanning data into 3D design software to further enhance the design, just as a user may draw, sketch, and then utilize a flatbed scanner to create a digital workflow to output the work on printers or publish the work online or on social media.

Bernard and Ajjimaporn are particularly interested in collaborating with the students and faculty currently utilizing 3D printing and virtual reality to provide creative workflows for custom 3D scanning. Bernard has assisted the Memorial Union Gallery and the Library with the development and deployment of their virtual reality labs based on five years of experience working with virtual reality technologies within the Architecture & Landscape Architecture department. Bernard has seven years of experience operating a 3D printing lab that serves Architecture, Landscape Architecture, and Visual Arts students while collaborating across campus to spread this important technology. Successful collaborations include Classroom Technologies, Interior Design, Psychology, Facilities Management, the College of Engineering, and founding a 3D printing lab in the Library.

Ajjimaporn previously built a 3D Scanner while completing his B.S in Computer Science at the University of North Dakota. He has co-authored articles such as "Impact of lighting and attire on 3D scanner performance", "The use of 3D scanning for sporting applications" and "The use of 3D scanning for wellness assessment purposes" using this technology.

III. Project Description (5 pages maximum)

Include information on the background of this project: how did it come to fruition?

The goal is to develop a modified Large, Low-Cost, Instant 3D-Scanner based on the work describe by Straub and Kerlin (2014) with the focus being toward a highly-detailed and more accurate scan of a smaller object approximately 1 cubic meter in size [1]. The following components are estimation derived from the larger version. The amount required might be smaller as the purpose of the 3D-Scanner in this project would be smaller scans and more compact

There is significant demand for large 3D scanning at NDSU. 3D scanning can be used for digital preservation and modeling, rapid prototyping, and a number virtual reality applications – all of which can be used to fuel research and teaching. The first 3D Scanner will be tested in Renaissance Hall with the Project Directors Ben Bernard (Architecture & Landscape Architecture), Jessie Rock (Geoscience), Dr. Jeremy Straub (Computer Science), and David Swenson (Visual Arts). In the testing stage, the Project Directors estimate that between the academic departments represented, over 500 undergrad and graduate students will be involved. The second 3D Scanner will be housed in a campus makerspace that will be accessible to all NDSU students, faculty, and staff. Several options for that space are in development currently.

Process of construction

The phase of construction of the 3D scanner can be divided into 3 main phases:

1. Physical Structure
2. Electrical Components
3. Software

Physical Structure:

The physical structure of the 3D scanner is composed of 1.5-inch polyvinyl chloride (PVC) pipe and associated connectors.

- 17x 10-foot pieces of 1.5-inch PVC pipe;
  - $5.00 per each / $85
- 68x T-joint pieces;
  - $2.50 per each / $170
- 5x Unions;
  - $3.50 per each / $17.50
- 8x 90° corner pieces.
  - $2.00 per each / $16

Total : $288.50

During the construction of the foundation phase, the PVC pipes are cut to specific length and are put together along with the T-joint pieces, unions, and corner pieces to form a base. The structure is an octagon comprised of eight 36-inch-long sides with 157.5° between the adjacent walls. From the base, the frame will be built upon upward layers by layers with one of the sides of the octagon being left open as a doorway. The top layer of the structure includes the roof which shape similarly to a dome to ensure complete coverage of the object scanning. The ideas were to make the frame as close to circular as practical as cameras can be mounted on both vertical and horizontal bars. The cameras were placed equidistantly around the octagon frame, facing inward at a specific angle toward the middle of the structure. Since the software utilized image point-matching technique, the system does not need to be maintaining precise camera positions.

At each layer of the frame, cameras were spaced at regular intervals around the structure. There were 12 camera locations at 4 different heights of layers, with the sides alternating between one and two cameras mounted. At the top piece, there were two additional cameras position in the non-edge section of the frame.

The door side and the one opposite were cut at halfway point to allows for pluming unions to be inserted in between. This allows the structure to be detached and transported in two equally-size pieces. One union was over the doorway and the rest were located on the opposite side.

Once the structure was built, desired color can be spray painted to make it more stylish. Panels made from cardboard were hung using zip-ties in the open spaces between beams to exclude background from the image which can also be painted to match the frame.

Electronic Components:

The major variable component in the 3D-Scanner would be the Raspberry Pi computers and cameras whereas the amount of Raspberry Pi and the type of the cameras would play major role in determining the quality of the scans.

- 1x File Server, running the FTP protocol;
- 2x 48-port Ethernet switches;
  - $400 per each / $800
- 1x User console workstation;
- 50x Raspberry Pi computers;
  - (based on Pi 3 model B) $35 per unit / $1750
- 50x Raspberry Pi cameras;
  - (based on V2, 8MP) $25 per unit / $1250
- 50x 8GB SD cards;
  - $5 per unit / $250
- 3x Adjustable power supplies.
  - $100 per unit / $300

Total : $4350.00

The electrical components phase of the construction comes down to wiring the Raspberry Pi to the server which connected to the workstation. Most of the components are connected via the Ethernet switch through the category 5e Ethernet cable. Two wire pairs in the Ethernet cable connect the Raspberry Pi units and are used for data transmission. An additional pair are used to transmit power to the Raspberry Pi from the adjustable power supply.

A camera is connected directly into each of the Raspberry Pi via a ribbon cable provided with the camera unit. An 8GB SD card inserted into the Raspberry Pi acts as the hard drive for the operating system and is used as temporary storage for the captured images prior to the transmission to the file server.

Other Components:

The other components suggested for the 3D-Scanner might not be directly attached to the structure but would often help in making the result scan being more detailed and accurate.

- High contrast background wallpaper;
- Diffused light sources;
- High contrast stickers for markers.

The prices estimation for the entire setup is approximately $5000 if every part of the system is brand-new.

Software:

The software that operates the 3D scanner system is designed to support the capture of a single 3D scan, or a 3D scanned video. Since the hardware was the limiting factor in this case, the software can be made to fit the necessary usage and a more developed GUI can be made if needed. A software would begin with a command to perform a single scan command along with asking for the name of the file. The instruction will then be transmitted to the server process which generates "capture-now" message for each of the Raspberry Pi. The capture message is received at approximately the same time by each of the Raspberry Pi, which then take the image capture action, and sends the images back to the file server. Once the files are all collected, the images are now ready to be used by the 3D rendering program.

Digital files generated by the 3D scanner can be scaled to fit smaller 3D printers located in various labs and makerspaces across campus, or can be 3D printed at full scale utilizing the Human Scale 3D printer, located in the Quentin Burdick building (QBB).

Problems found during the usage and construction of the Large, Low-Cost, Instant 3D-Scanner and proposal changes:

There were a few problems encountered during the construction of the original Scanner that will taken into account in the construction of this new unit.

1. The power problem. As during the moment that the object was being scanned, the power surges up for all 50 of the Raspberry Pi. This issue was corrected using voltage regulators near the Raspberry Pi units. This approach will be used.

2. The background of the images problem. The panels used as backgrounds for the 3D-Scanner was dark grey, which doesn't contrast too well with the skin colors and many scanned objects. If the background panels will changed into something high contrast such as neon green. This will make the edges of the object more defined and should produce a more accurate scan. The best result was when there is a big contrast between the background and the target object such as shown in figure 1.

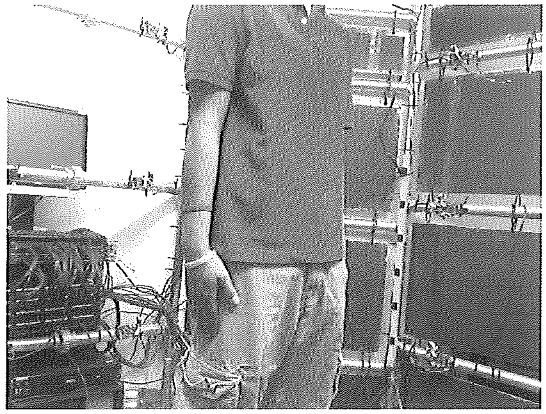

Figure 1. Scanning of a person with high contrast shirt

3. The lighting problem. As the scans required relatively strong diffused light to help defined the edges and lessen the shadow from the object. The lighting scenarios that should be avoided are: Dim lighting, Shadows, and unevenly lit environment [2]. Additional lighting will be incorporated in this new design.
4. The lack of focus in the camera problem, which the complex structures in the background usually plays part in complicating the model quality. Markers on the object have been used to help with differente the target object from the background.

References

[1] J. Straub and S. Kerlin, "Development of a Large, Low-Cost, Instant 3D Scanner," *Technologies,* pp. 76-95, May 2014.

[2] Artec 3D, "Lighting conditions and specific 3D-scanning scenarios," 2018. [Online]. Available: https://artecgroup.zendesk.com/hc/en-us/articles/360005149174-Lighting-conditions-and-specific-3D-scanning-scenarios.

[3] P. Ajjimaporn, D. Feist, J. Straub and S. Kerlin, "Impact of lighting and attire on 3D scanner performance," in *Three-Dimensional Imaging, Visualization, and Display 2015*, 2015.

[4] P. Ajjimaporn, K. Friel, J. Straub and S. Kerlin, "The use of 3D scanning for wellness assessment purposes," in *Three-Dimensional Imaging, Visualization, and Display 2015*, 2015.

[5] K. Friel, P. Ajjimaporn, J. Straub and S. Kerlin, "The use of 3D scanning for sporting applications," in *Three-Dimensional Imaging, Visualization, and Display 2015*, 2015.

[6] J. Straub, B. Kading and A. Mohammad, Characterization of a Large, Low-Cost 3D Scanner, MDPI-Technologies, 2015.

[7] J. Straub, "The use of a low-cost visible light 3D scanner to create virtual reality environment models of actors and objects," in *SPIE Modeling and Simulation for Defense Systems and Applications X*, 2015.

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IV. Milestones

List the date for each project milestone. These milestones should represent the ***significant*** accomplishments that will be associated with the action plan. For each milestone, please indicate its expected outcome and the means for assessing that outcome. (The table may be extended as needed.)

	Date	Milestone	Expected Outcomes	Means of Assessment
1.	5/19	Successfully Funded	Project Launches	Funds Released
2.	9/19	First prototype built	Software development begins	Prototype Operational
3.	1/20	Device testing	Testing with ALA/VA students / faculty	Successful scans of acceptable quality
4.	5/20	Build second 3D scanner	Deploy at campus makerspace	Recruit campus partner
5.	9/20	Second 3D scanner deployed	Hardware & software components complete	Complete documentation on hardware and software development available

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V. Supporting Documentation

The following describe previous efforts to construct and use a large-format 3D scanner.

[1] J. Straub and S. Kerlin, "Development of a Large, Low-Cost, Instant 3D Scanner," *Technologies,* pp. 76-95, May 2014.

[2] Artec 3D, "Lighting conditions and specific 3D-scanning scenarios," 2018. [Online]. Available: https://artecgroup.zendesk.com/hc/en-us/articles/360005149174-Lighting-conditions-and-specific-3D-scanning-scenarios.

[3] P. Ajjimaporn, D. Feist, J. Straub and S. Kerlin, "Impact of lighting and attire on 3D scanner performance," in *Three-Dimensional Imaging, Visualization, and Display 2015*, 2015.

[4] P. Ajjimaporn, K. Friel, J. Straub and S. Kerlin, "The use of 3D scanning for wellness assessment purposes," in *Three-Dimensional Imaging, Visualization, and Display 2015*, 2015.

[5] K. Friel, P. Ajjimaporn, J. Straub and S. Kerlin, "The use of 3D scanning for sporting applications," in *Three-Dimensional Imaging, Visualization, and Display 2015*, 2015.

[6] J. Straub, B. Kading and A. Mohammad, Characterization of a Large, Low-Cost 3D Scanner, MDPI-Technologies, 2015.

[7] J. Straub, "The use of a low-cost visible light 3D scanner to create virtual reality environment models of actors and objects," in *SPIE Modeling and Simulation for Defense Systems and Applications X*, 2015.

NDSU Student Technology Fee Action Plan Request
VI. Budget

(double-click on the form to begin entering data)

1.	NDSU ORGANIZATION OR UNIT Architecture & Landscape Architecture
2.	PROJECT DIRECTOR(S) (Must be NDSU faculty or staff) Ben Bernard & Pann Ajjimaporn

3.	SALARIES AND WAGES			
	Personnel description	Number employed	Number of months	Funds Requested
	A. Staff B. Graduate students C. Undergraduate students	1	18	$8,000.00
4.	TOTAL SALARIES AND WAGES			$8,000.00
5.	FRINGE BENEFITS			$0.00
6.	TOTAL SALARY, WAGES AND BENEFITS			$8,000.00
7.	EQUIPMENT			$8,800.00
	Describe Equipment specifics in the Budget Justification section			
8.	MATERIALS AND SUPPLIES			$1,000.00
	Describe Materials and Supplies specifics in the Budget Justification section			
9.	TOTAL TECHNOLOGY FEE REQUEST			$18,800.00
10.	MATCH (Describe in Match Section)			$10,050.00
11.	TOTAL PROJECT EXPENDITURE			$28,850.00

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VII. Budget Justification

Describe how you arrived at the budget totals in Section VI, Budget.

You are expected to follow all applicable university policies and procedures regarding salary expenditures.

You are expected to follow the state-approved purchasing guidelines when purchasing materials and supplies.

- Equipment: List name, estimated cost and quantity of each item and explain why it is important to the project. Include installation and maintenance costs in your estimates.
- Materials and Supplies: List name, estimated cost and quantity for each non-equipment items and explain why it is important to the project.

Each 3D Scanner will require the following electronic components:

- 1x File Server, running the FTP protocol – ALA budget match
- 2x 48-port Ethernet switches;
  - $400 per each / $800
- 1x User console workstation – ALA budget match
- 50x Raspberry Pi computers;
  - (based on Pi 3 model B) $35 per unit / $1750
- 50x Raspberry Pi cameras;
  - (based on V2, 8MP) $25 per unit / $1250
- 50x 8GB SD cards;
  - $5 per unit / $250
- 3x Adjustable power supplies.
  - $100 per unit / $300

Each 3D Scanner will require an assortment of 1.5-inch polyvinyl chloride (PVC) pipe and associated connectors, estimated at less than $500 per 3D scanner.

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VIII. Budget Match

1. Attempted Budget Matches:

Will attempt to obtain 48-port Ethernet switches from IT Division or Department of Computer Science surplus.

2. Actual Budget Matches:

Bernard's time commitment to the project will be donated. This is estimated at a value of $2,500 for each of the three years of the project. Jeremy Straub's time will be donated. This is estimated at a total of $1,500. Guy Hokanson and Demitrius Fenton's time will be donated at a value of $300 and $750 respectively. Additional time from Straub, Hokanson and Fenton is available, if needed. The budgetary figure represents an estimate of project requirements. The file server and user console workstations will be surplus Architecture & Landscape Architecture design workstations. The Department of Computer Science will also provide spare aluminum tubing and PVC that is left over from a previous project. The approximate value of this is $500 to $800.

3. Additional Budget Match information:

N/A

NDSU NORTH DAKOTA STATE UNIVERSITY

2/15/2019

Dear Reviewers,

It is my pleasure to confirm the commitment of Department of Computer Science resources in support of a TFAC proposal entitled "Large, Low-Cost, Instant 3D-Scanner." Specifically, this confirms the commitment of 25 hours of Dr. Jeremy Straub's time in support of project management and student mentoring for the Computer Science graduate student who will work on the project. Further, we commit 10 hours of department systems administrator Guy Hokanson's time and 50 hours of junior systems administrator Demitrius Fenton's time. Please do not hesitate to contact me if I can provide any additional details in support of this proposal.

Sincerely,

Kendall E. Nygard

Kendall E. Nygard
Professor & Chair

DEPARTMENT OF COMPUTER SCIENCE
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