How to construct an interactive museum exhibit that uses near-field communication technology

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1. INTRODUCTION

Please read the paper *Title To Be Determined* (Wiedemeier, 2024a) and then connect to the Internet the computer that will be used to create a near-field communication (NFC) museum exhibit. See Figure 1. This paper (Wiedemeier, 2024b) can be obtained from GitHub.

Figure 1: An operational NFC museum exhibit.

2. MATERIALS

As discussed in the paper *Title To Be Determined* (Wiedemeier, 2024a), three main pieces of hardware are required to construct an NFC museum exhibit,; a tower computer, an NFC read/write device, and one or more NFC tags. In addition, one or more video, audio, or image files must be created or obtained from a third party. An NFC museum exhibit, through use of a media player, will play a video or audio file or display an image file when an NFC tag is placed on an NFC read/write device. The required hardware components and the required video, audio,

and/or image files will be discussed in the following paper sections. Justification for purchasing one or more external speakers for the NFC museum exhibit will also be discussed.

2.1. Acquire a tower computer with an external monitor and detachable keyboard and mouse

The most expensive and important piece of hardware that must be acquired to construct an NFC museum exhibit is the computer. Reuse of older hardware is a preferred option, but if budget allow a new computer can be purchased. A tower computer with an external monitor and detachable keyboard and mouse is recommended.

The advantage associated with a tower computer is the ability to detach both the keyboard and mouse once the museum exhibit is placed into service. As such, museum patrons will be unable to directly interact with the computer's Linux operating system. In addition, when an NFC museum exhibit will be unused for a period of time, the external monitor can be powered off to prevent image persistence, which will be discussed in METHODS section of this paper.

The use of a laptop computer to construct an NFC museum exhibit is not recommended, as museum patrons will be able to interact with the Linux operating system using the attached keyboard and mouse pad. Additionally, it will be impossible to manually turn off the laptop screen. The use of an all-in-one computer to construct an NFC museum exhibit is also not recommended because, like a laptop, the screen cannot be turned off.

An NFC museum exhibit computer must possess minimally a 2 GHz dual core processor, 4 GB RAM, 25 GB hard disk, a video graphics array capable of 1024x768 screen resolution, and either a CD/DVD drive or a USB port (preferred) for the installer media. Initial Internet connectivity is also required for additional software installation. These hardware requirements are for Ubuntu Linux operating system ("Installation/System Requirements," n.d.) that will be installed on the NFC museum exhibit computer.

2.2. Acquire an NFC read/write device

The second piece of hardware that must be acquired to construct an NFC museum exhibit is an NFC read/write device. The recommended device is an Advanced Card System Ltd. ARC122U-A9 ("ACR122U USB NFC Reader," n.d.). This NFC read/write device operates at 5 V DC and 200 mA and is directly connected to the computer using a 3.5 feet universal serial bus cable. An additional USB male to female extension cable can be purchased when the NFC read/write device must be placed at a distance from the computer greater than the default 3.5 feet.

2.3. Acquire NFC tags

NFC tags come in many shapes, sizes, and costs. Three commonly used tags are key fobs, credit cards, and round adhesive stickers ("Common types of NFC tags," n.d.). Specifically, the ISO 14443-3A 1 inch round blank rewriteable NFC tags with adhesive backs work well with the NFC museum exhibit. These NFC tags are approximately the size of a US quarter dollar, can store 540 Bytes of data, and can be protected with a password.

The use of key fob or credit card types of NFC tags are not recommended, as experience proves they do tend to *walk off* in unsupervised environments. While NFC tag costs are often maximally US $1 per unit, accrued costs become prohibitive over time as NFC tags disappear.

2.4. Acquire videos, audio, and/or images files

The media player an NFC museum exhibit uses to play video files is also adept at playing audio files and displaying image files. The video, audio, and/or image files selected to be included in an NFC museum exhibit's playlist must either be created or obtained from third party sources. Many organizations offer open access to video, audio, and image files, including The Library of Congress ("Free to Use and Reuse Sets," n.d.), NASA ("A catalog of publicly available NASA datasets," n.d.), The Getty Research Institute ("Open Access Online Resources". (n.d.) and the Internet Archive ([The landing page for the Internet Archive Digital Library], n.d.).

2.5. Acquire plastic laminate sheets

Museum patrons interact with an NFC museum exhibit by placing a 11.5 inch by 9 inch plastic laminated sheet on the NFC read/write device. Each laminated sheet encapsulates two 8.5 inch by 11 inch sheets of papers and a single 1 inch round adhesive sticker NFC tag. A color picture of a museum artifact is printed on one sheet of paper. The 1 inch round adhesive sticker NFC tag is attached to the back of this sheet of paper. Information about the museum artifact is printed on the second sheet of paper. Both sheet of paper and the NFC tag are then encased in a plastic laminate sheet.

Purchase a package of clear thermal plastic 11.5 inch by 9 inch 3 mil laminate sheets. Access to a color printer, which will be used to print pictures of museum artifacts and their corresponding information, and a thermal rolling laminating machine are required.

2.6. Acquire one or more external speakers (optional)

While not required, consider attaching one or more external speakers to the computer designated as the NFC museum exhibit. The internal speakers that come standard with most computers produce acceptable audio, but the audio generated by external speakers will be far superior.

2.7. Build a plywood platform to hide and secure the NFC read/write device (optional)

As mentioned in paper section 2.2, the NFC read/write device will be connected to the tower computer's universal serial bus port via a 3.5 feet universal serial bus cable. The NFC read/write devices will be placed on a flat surface such as a table. Museum patrons will place the plastic laminate sheets with the embedded NFC tags on the NFC read/write device to play a specific media file. In this configuration, the NFC read/write devices is exposed and could possibly be damaged or stolen. We built a plywood platform to hide and secure the NFC read write device. A list of materials and basic instructions on how we constructed our plywood platform are found in the APPENDIX.

3. METHODS

Once the required hardware necessary to construct an NFC museum exhibit have been obtained, connect the monitor, keyboard, and mouse to the computer. Do not attach the NFC read/write device to the computer at this time. In the papers sections that follow, a discussion on how to (1) upgrade the computer's BIOS, (2) install a Linux operating system, and (3) configure said operating system to create an NFC museum exhibit will be presented. Some basic knowledge of the Linux operating system, as well as an understanding of the Linux commands necessary to move around the filesystem is required to understand the discussion presented in the following paper sections.

3.1. Upgrade the computer's BIOS

BIOS is the firmware used to perform hardware initialization during the booting process and to provide runtime services for operating systems and programs ("BIOS," n.d.). If the computer does not have the most current version of BIOS installed, now is the time for an upgrade to occur.

As stated, BIOS controls how the computer boots the operating system. To install a Linux operating system, which will be discussed later in this paper, either boot the computer from a USB memory stick or from a CD/DVD ROM disk.

It is assumed the computer's current operating system is some variant of Microsoft Windows and is connected to the Internet.

To upgrade the computer's BIOS, complete the following steps.

- Boot the computer.
- Log in using the Administrator account.
- Open a web browser window.
- Using a web search engine, identify and download the most recent BIOS for the computer.
- Use Microsoft Windows explorer to navigate to the Downloads directory associated with the Administrator's account.
- Double left-mouse-click on the downloaded BIOS file to upgrade the computer's BIOS.
- Reboot the computer and quickly press the F12 to enter Boot Sequence mode.
- The boot menu should now show a new option *USB Device*.

3.2. Download an Ubuntu Linux Desktop LTS operating system ISO file

To minimum development costs, the Linux operating system was chosen to control the computer's hardware. Specifically, the Ubuntu Linux operating system was chosen (Wiedemeier, 2024a) to control the hardware attached to the NFC museum exhibit computer.

The Ubuntu Linux operating system is available in two flavors; Desktop and Server.

The main difference between the two is the Desktop operating system provide a Gnome desktop environment and the Server operating system does not. The NFC museum exhibit uses an Ubuntu Linux Desktop operating system.

The Ubuntu Linux operating system also utilizes two different system support structures; Long Term Support (LTS) and Normal. An LTS operating system provides five years of guaranteed updates, whereas a Normal operating system only provides two years of updates. An Ubuntu Linux Desktop LTS operating system is installed on an NFC museum exhibit computer.

As of when this paper was written, the current version of the Ubuntu Linux Desktop LTS operating system is 24.04 Noble Numbat (Ubuntu 24.04, 2024). The size of the Noble Numbat ISO file is 5.7 GigaBytes and WILL NOT fit on a standard DVD, which can only hold 4.6 GigaBytes. This why USB memory stick ISO file installations are preferred, as the capacity of newer USB memory sticks are 32 GigaBytes and larger capacity sizes. That, and USB memory sticks are reusable. To install the Noble Numbat ISO file on a USB memory stick, an 8 GigaByte or larger USB memory stick must be used.

It is very easy to upgrade the current version of an Ubuntu Linux Desktop LTS operating system to the next version. Thus, if a smaller sized USB memory stick is available, then a previous version of an Ubuntu Linux Desktop LTS operating system ISO file can be installed a right-sized USB memory stick ("Old Ubuntu Releases," n.d.). Upgrading a current version of an Ubuntu Linux Desktop LTS operating system to the next version will be discussed later.

Table 1 displays the currently downloadable Ubuntu Linux Desktop LTS operating systems and their associated ISO file sizes.

Version	Code Name	Release Date	End of Standard Support	ISO File Size
24.04	Noble Numbat	2024, Apr. 25	2029, June	5.7 GB
22.04.4	Jammy Jellyfish	2024, Feb. 22	2027, June	3.4 GB
20.04.6	Focal Foosa	2023, Mar. 23	2025, April	2.5 GB
18.04.6	Bionic Beaver	2021, Sep. 17	2023, June	1.8 GB
16.04.7	Xenail Xerus	2020, Aug. 13	2021, April	1.4 GB
14.04.6	Trusty Tahr	2019, Mar. 7	2019, April	970 MB

Table 1: Currently downloadable Ubuntu Linux Desktop LTS operating systems

3.3. Burn the Ubuntu Linux Desktop LTS operating system ISO file to a USB memory stick

The downloaded Ubuntu Linux Desktop LTS operating system ISO file must now be burned to a USB memory stick. Rufus ("Rufus Downloads," n.d.) is one of many software packages that can be used to perform this task. This software is available for the Microsoft Windows operating system and provides a simple interface to create bootable USB memory sticks from an ISO file.

Please note the latest version of the Rufus software may not execute on older Microsoft Windows operating system. Rufus will, however, generate a message if it is unable to execute

on the current version Microsoft Windows operating system. It will also generate a message stating which version of Rufus should be installed.

To burn an ISO file to a USB memory stick using the Rufus software, first insert a USB memory stick into an available USB port. Then execute the Rufus software. Notice the USB memory stick is displayed in the Device pull down menu. If there are two or more USB memory sticks occupying USB ports, select the USB memory stick upon which the ISO file will be burned by selecting the correct item from the pull down menu.

Left-mouse click on the Select button and use the Microsoft Window explorer to find and select the downloaded ISO file. Once the ISO file has been selected, simply click the Start button. Hey Presto, an ISO file has been successfully burned to a USB memory stick.

Left-mouse click on the Microsoft Windows Start button, type computer in the text box, right-mouse click on the icon that represent the USB memory stick, and select the Eject menu option. Remove the USB memory stick from the USB port.

3.4. Backup data on the computer

If a new computer will be used to create the NFC museum exhibit discussed in this paper, then skip this step. However, if the computer was previously used for other work, then now is a good time to back up any data that must be retained because it will be erased once the new Ubuntu Linux Desktop LTS operating system is installed.

3.5. Install the Ubuntu Linux Desktop LTS operating system from a USB memory stick

To install the Ubuntu Linux Desktop LTS operating system ISO file that current resides on a USB memory stick, first insert the USB memory stick in an available USB port. Next, either reboot (i.e., restart) the computer or power down (i.e., shutdown) and then power on (i.e., turn on) the computer.

As the computer boots, quickly push the F12 key several times until the *Boot Device Menu* displays. A menu option *USB Device* will be available. Use the down/up arrow keys to select this menu option and press the Enter key to begin the Ubuntu Linux Desktop LTS operating system installation process. The installation process will present the user with seven installation windows.

The first installation window displays the title *Welcome*. Select a language from the menu located on the left side of the window. Left-mouse click the *Install Ubuntu* button to continue.

The second Ubuntu installation window displays the title *Keyboard layout*. Select the keyboard layout to use from the menu located on the left side of the window. The defaults selections are *English (US)* and *English (US)*. Left-mouse click the *Continue* button to continue.

The third Ubuntu installation window displays the title *Updates and other software*. Select option *Normal installation*. Select option *Download updates while installing Ubuntu*. Left-mouse click the *Continue* button to continue.

The fourth Ubuntu installation window displays the title Installation type. Select the option *Erase disk and install Ubuntu*. Left-mouse click the *Install Now* button to continue.

The firth Ubuntu installation window displays the title *Write the changes to disk?*. Left-mouse click the *Continue* button to confirm disk erasure and continue.

The sixth Ubuntu installation window displays the title *Where are you?*. Select the time zone where the NFC museum exhibit computer resides. Left-mouse click the *Continue* button to continue.

The seventh, and last Ubuntu installation window displays the title *Who are you?* Enter the string *NFC Museum Exhibit Project Administrator* in the *Your name:* textbox. Enter the string *nfc-mepa* in the *Pick a username:* textbox. Enter a password that can be easily remembered and is strong in the *Choose a password:* textbox. Enter the same password in the *Confirm your password:* textbox. Select the *Require my password to log in* option. Left-mouse click the *Continue* button to continue.

At this point, the Ubuntu Linux Desktop LTS operating system will be installed. Depending on the computer's processor and the speed of the Internet connection, the installation process may time some time. Once the installation has completed, a computer reboot is required.

3.6. Update and upgrade the software packages associated with the current version of the installed Ubuntu Linux Desktop LTS operating system

After the Ubuntu Linux Desktop LTS operating system has been successfully installed, a full software package update should be performed because during the time between when the ISO file was originally release and when the ISO file was downloaded many updates to the Ubuntu Linux operating system's software packages will have occurred. Here, a software package update essentially brings the currently installed software packages up to the latest update since the ISO file was released. It does not, however, install new software packages.

After all software packages have been successfully updated to the current version of the Ubuntu Linux Desktop LTS operating system, a software package upgrade should be performed. Here, a software package update installs new software packages that were added to the operating system distribution between the time the ISO file was released and now.

To update and upgrade the installed packages associated with the current version of the Ubuntu Linux Desktop LTS operating system, complete the following steps.

- Log in to the computer using the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

- Open a Linux terminal window and execute the following command.

  ```
  $ sudo apt update
  ```

  The `sudo apt update` Linux command brings the currently installed Ubuntu software packages up to the latest update. It does not install any new packages.

- In the same Linux terminal window, execute the following command.

  ```
  $ sudo apt upgrade
  ```

  The `sudo apt upgrade` Linux command installs new Ubuntu software packages that were added to the operating system distribution between the time the ISO was released and now.

- In the same Linux terminal window, execute the following command.

  ```
  $ sudo reboot
  ```

  The `sudo reboot` Linux command will (1) power off the computer, (2) power on the computer, and (3) reload the Ubuntu Linux operating system.

3.7. Upgrade the current version of the Ubuntu Linux Desktop LTS operating system to the next version.

If the current version of the Ubuntu Linux Desktop LTS operating system IS the latest version, then the following discussion can be skipped.

As was mentioned earlier in this paper, it is very easy to perform an upgrade of the current version of the Ubuntu Linux Desktop LTS operating to the next version. Here, upgrade means the process associated with migrating the current version of the Ubuntu Linux Desktop LTS operating system to the next version. Note the upgrade process does take considerable time (i.e., one or more hours) to complete.

To upgrade to the next version of the Ubuntu Linux Desktop LTS operating system, complete the following steps.

- Log in to the computer using the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

- Open a Linux terminal window and execute the following command.

  ```
  $ sudo do-release-upgrade
  ```

  The `sudo do-release-upgrade` Linux command upgrades the current version of the Ubuntu Linux Desktop LST operating system to the next version. Multiple version

upgrades do not occur due to the execution of `sudo do-release-upgrade`. As such, **it may be necessary to execute the command two or more times** to upgrade the current version of the Ubuntu Linux Desktop LST operating system to the latest version. The `sudo do-release-upgrade` Linux command will display a message when it is unable to upgrade the current version any further.

As of June 2024, the Ubuntu Linux operating system upgrade path currently stops at version 22.04 Jammy Jellyfish. It is not possible to upgrade to 24.04 Noble Numbat because Ubuntu has yet to release the upgrade path to this version.

- The upgrade process will ask the user to reboot the computer when the Ubuntu Linux operating system upgrade has completed.

- Log in to the computer using the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

- Open a Linux terminal window and execute the following command.

  ```
  $ lsb_release -a
  ```

  The `lsb_release -a` Linux command displays the version of the Ubuntu Linux Desktop LTS operating system that is currently installed on the computer.

3.8. Download and install the Ubuntu software packages needed to manually compile and install the `nfc-eventd` software package

The software package `nfc-eventd` controls the museum exhibit and is used to direct a media player to play a video or audio file or display an image file when an NFC chip is placed on the NFC read/write device. A discussion on how to download and manually compile and install the `nfc-eventd` software package will occur later in this paper.

To compile and install the software package `nfc-eventd` seven required Ubuntu software packages must first be downloaded and installed using the advanced package tool (`apt`), which is a free-software user interface comprised of several Linux executables, including `apt`. "The advanced package tool works with core libraries to handle the installation and removal of software on Debian and Debian-based Linux distributions" ("APT," n.d.), including Ubuntu.

The first software package to download and install is GNU `gcc`, which is "a collection of compilers from the GNU Project that support various programming languages, hardware architectures and operating systems" ("GCC Compiler Collection," n.d.).

The second software package to download and install is GNU `automake`, which is "a GNU programming tool to automate parts of the compilation process. It eases usual compilation problems" ("Automake," n.d.). The installation of `automake` will automatically download and install several additional software packages, including, `autoupdate` and `autoreconf`.

The GNU "`autoupdate` program updates a `configure.ac` file that calls Autoconf macros by their old names to use the current macro names" ("Using autoupdate to Modernize configure.ac," n.d.).

The GNU "`autoconf` is an extensible package of M4 macros that produce shell scripts to automatically configure software source code packages. These scripts can adapt the packages to many kinds of UNIX-like systems without manual user intervention. Autoconf creates a configuration script for a package from a template file that lists the operating system features that the package can use, in the form of M4 macro calls" ("Autoconf," n.d.).

The third software package to download and install is GNU `libtool`, which is a "generic library support script that hides the complexity of using shared libraries behind a consistent, portable interface" ("GNU Libtool," n.d.).

The fourth software package to download and install is GNU `libtool-bin`, which includes the `libtool` binary.

The fifth software package to download and install is GNU `pkg-config`, which is a "computer program that defines and supports a unified interface for querying installed libraries for the purpose of compiling software that depends on them. It allows programmers and installation scripts to work without explicit knowledge of detailed library path information" ("pkg-config," n.d.)
The sixth software package to download and install is Apache `subversion`, which is a "free/open-source version control system" (Collins-Sussman, 2007). It manages files and directories, and the changes made to them, over time and allows the recovery of older versions of data, or examine the history of how the data changed.

The seventh software package to download and install is GNU `make`, which is "a tool which controls the generation of executables and other non-source files of a program from the program's source files" ("GNU Make," n.d.).

To download these Ubuntu software packages, complete the following steps.

- Open a Linux terminal window and execute the following commands.

```
$ sudo apt install gcc
$ sudo apt install automake
$ sudo apt install libtool
$ sudo apt install libtool-bin
$ sudo apt install pkg-config
$ sudo apt install subversion
$ sudo apt install make
```

3.9. Download and install the Ubuntu software packages to permit the Ubuntu Linux Desktop LTS operating system to communicate with the NFC read/write device

To allow the Ubuntu Linux Desktop LTS operating system installed on the computer to interact with an attached NFC read/write device, four additional Ubuntu software packages must be downloaded and installed. Each software package is discussed below.

The first software package to download and install is `libnfc-bin`, which is a library for Near Field Communication. "It abstracts the low-level details of communicating with the devices away behind an easy-to-use high-level API and supports most hardware based on the NXP PN531, PN532 or PN533 controller chips" ("Package: libnfc-bin (1.8.0-3.1)," n.d.).

Included with the `libnfc-bin` software package is the `nfc-poll` program, which is a utility for polling any available NFC tags that use ISO14443-A, FeliCa, Jewell, and ISO14443-B modulations ("nfc-poll," n.d.).

The second software package to download and install is `libnfc-dev`, which contains the header and development files needed to build programs and packages that use `libnfc` ("Package: libnfc-dev (1.8.0-3.1)," (n.d.).

The third software package to download and install is `libnfc-examples`, which provides `libnfc` examples for debugging and/or educational purposes (`nfc-anticol`, `nfc-emulate`, etc.) ("Package: libnfc-dev (1.8.0-3.1)," n.d.).

Included with the `libnfc-examples` software package is the `nfc-list` program, which is "a utility for listing any available tags like ISO14443-A, FeliCa, Jewel or ISO14443-B (according to the device capabilities). It may detect several tags at once thanks to a mechanism called anti-collision, but all types of tags don't support anti-collision and there is some physical limitation of the number of tags the reader can discover" ("nfc-poll," n.d.).

The fourth software package to download and install is `libnfc-pn53x-examples`, which provides `libnfc` examples for hardware based on PN53X controller chips ("Package: libnfc-pn53x-examples (1.8.0-3.1)," n.d.).

To download these Ubuntu software packages, complete the following steps.

- Open a Linux terminal window and execute the following commands.

```
$ sudo apt install libnfc-bin
$ sudo apt install libnfc-dev
$ sudo apt install libnfc-examples
$ sudo apt install libnfc-pn53x-examples
```

3.10. Configure the Ubuntu Linux Desktop LTS operating system to unload device drivers `nfc`, `pn533`, and `pn533_usb` at boot

The installation of various `libnfc-*` software packages discussed in the previous paper section installed the device driver necessary to allow the Ubuntu Linux Desktop LTS operating

system to communicate with the Advanced Card System Ltd. ARC122U-A9 NFC read/write device. The specific device driver used by Linux to communicate with the ARC122U-A9 NFC read/write device is named `arc122_usb`.

By default, Linux provides generic drivers to communicate with attached NFC hardware, but these drivers, specifically `nfc`, `pn533`, and `pn533_usb`, are outdated and interfere with the `arc122_usb` device driver ("Linux NFC Device Driver Installation," n.d.; Stocker, 2018). As such, the Ubuntu Linux operating system must be instructed to unload (i.e., blacklist) outdated device drivers when the it boots.

To unload device drivers `nfc`, `pn533`, and `pn533_usb` at boot, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ tail /etc/modprobe.d/blacklist-libnfc.conf
  ```

  The Linux tail command should display the following output.

  ```
  blacklist nfc
  blacklist pn533
  blacklist pn533_usb
  ```

- If these three lines are not displayed, or the file does not exist, then, from the same Linux terminal window, execute the following Linux command.

  ```
  $ sudo echo 'blacklist nfc
  > blacklist pn533
  > blacklist pn533_usb' >> /etc/modprobe.d/blacklist-
  libnfc.conf
  ```

3.11. Test whether the Ubuntu Linux Desktop LTS operating system recognizes the NFC read/write device

At this point of NFC configuration, the `arc122_usb` device driver has been installed to support correct communication between the Ubuntu Linux operating system and an NFC read/write device.

To determine whether the Ubuntu Linux operating system recognizes an NFC read/write device, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ lsusb
  ```

You will see displayed in the Linux terminal window a list of all attached USB devices recognized by the Ubuntu Linux operating system, including, but not limited to, the mouse and keyboard.

- Now plug an NFC read/write device into an available USB port.

- From the same Linux terminal window, execute the following Linux command.

  ```
  $ lsusb
  ```

  You will see a list of all attached USB devices, including the following line displayed in the Linux terminal window.

  ```
  Bus 00# Device 00#: ID hhhh::hhhh Advanced Card Systems,
  Ltd ARC122u
  ```

  Where `#` represents any integer number in the range `[0-9]` and `h` represents any hexadecimal number.

  The Ubuntu Linux operating system recognizes the NFC read/write device.

3.12. Test whether the NFC read/write device can recognize an NFC tag

Given the Ubuntu Linux operating system now recognizes the NFC read/write device, a determination as to whether the NFC read/write device can recognize an NFC tag must occur.

To make this determination, complete the following steps.

- From the Linux terminal window, execute the following Linux command.

  ```
  $ nfc-poll
  ```

  The Linux `nfc-poll` command is available because the `libnfc-examples` software package was previously installed.

- Place any NFC tag on the NFC read/write device.

- Remove the NFC tag from the NFC read/write device.

  You should see the following lines displayed in the Linux terminal window.

  ```
  NFC reader: ACS / ARC122U PICC Interface opened
  NFC device will poll during 36000 ms (20 pollings of 300 ms
  for 6 modulations)
  ISO/IEC 14443A (106 kbps) target:
      ATQA (SENS_RES):  00 44
  ```

```
       UID (NFCID1):  hh hh hh hh hh hh hh
      SAK (SEL_RES):  00
Waiting for card removing…nfc_initiator_target_is_present:
Target released
done.
```

Where `hh hh hh hh hh hh hh` represents the fourteen (14) hexadecimal character userid of the NFC tag that was placed on the NFC read/write device.

- *ALTERNATIVELY,* place any NFC tag on the NFC read/write device
- From the Linux terminal window, execute the following Linux command.

  ```
  $ nfc-list
  ```

  The Linux `nfc-list` command is available because the `libnfc-bin` software package was previously installed.

  You should see the following line displayed in the Linux terminal window.

  ```
  NFC device: ACS / ARC122U PICC Interface opened
  1 ISO14443A passive target(s) found:
  ISO/IEC 14443 (106 kbps) target:
      ATQA (SENS_RES):  00 44
         UID (NFCID1):  hh hh hh hh hh hh hh
        SAK (SEL_RES):  00
  ```

  Where `hh hh hh hh hh hh hh` represents the fourteen (14) hexadecimal character userid of the NFC tag that was placed on the NFC read/write device.

- Remove the NFC tag from the NFC read/write device.

3.13. Download and install the git Ubuntu software package

GitHub is a software "developer platform that allows developers to create, store, manage and share their code. It uses Git software, providing the distributed version control of Git plus access control, bug tracking, software feature requests, task management, continuous integration, and wikis for every project" ("GitHub," n.d.). It is commonly used to host and distribute open source software development projects. The GitHub application will be used to download open source software projects used to create the museum exhibit.

To download and install the `git` Ubuntu software package, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ sudo apt install git
  ```

3.14. Download and install the VLC media player Ubuntu software package

The VLC media player is a free and open-source, portable, cross-platform media player software and streaming media server. The VLC media player will be used to play videos or audio files or display images.

To download and install the VLC media player Ubuntu software package, complete the following steps.

- Open a Linux terminal window and execute the following command.

```
$ sudo apt install vlc
```

3.15. Download the open source `nfc-eventd` software package

Having previously installed the GitHub suite of software, now is the time to download the open source `nfc-eventd` software. The `nfc-eventd` software is an "NFC monitor daemon that is able to launch modules (libraries) on action (tag inserted or removed)" (Conty, n.d.) This software is what controls the museum exhibit. After download, the `nfc-eventd` software will be manually compiled and installed.

To download and install the `nfc-eventd` software package, complete the following steps.

- Open a Linux terminal window and execute the following command.

```
$ sudo git clone https://github.com/nfc-tools/nfc-
eventd.git /usr/local/src/nfc-eventd-master
```

  This Linux command downloads a copy of the `nfc-eventd` software and places it in the directory `/usr/local/src/nfc-eventd-master` within the local Linux filesystem.

- ALTERNATIVELY, a copy of the `nfc-eventd` software package can be retrieved by executing the following commands in a Linux terminal window.

```
$ cd /usr/local/src
$ sudo wget
https://github.com/nfc-tools/nfc-eventd/archive/refs/heads/
master.zip
$ sudo mv master.zip nfc-eventd-master.zip
$ sudo unzip nfc-eventd-master.zip
```

  These Linux commands specifically …
  (1) change the present working directory to be `/usr/local/src`

(2) download a copy of the ZIP archive file `master.zip` and places it in the directory `/usr/local/src` within the local Linux filesystem
(3) rename the ZIP archive file `master.zip` to be `nfc-eventd-master.zip`, and
(4) uncompressed the contents of the ZIP archive file `nfc-eventd-master.zip` and copies the contents into the directory `/usr/local/src/nfc-eventd-master`

3.16. Manually compile and install the open source `nfc-eventd` software

The `nfc-eventd` software package has now been downloaded. To manually compile and install the `nfc-eventd` software package complete the following steps.

- Open a Linux terminal window and execute the following commands.

```
$ cd /usr/local/src/nfc-eventd-master
$ sudo autoupdate
```

The `autoupdate` Linux command will generate WARNINGS, but it is OK to continue.

```
$ sudo autoreconf -vis
```

The `autoreconf` Linux command will generate WARNINGS, but it is OK to continue.

```
$ sudo ./configure
```

```
$ sudo make
```

The `make` Linux command will generate WARNINGS, but it is OK to continue.

```
$ sudo make install
```

3.17. Verify the `nfc-eventd` software was installed correctly.

The `nfc-eventd` software has now been manually compiled and installed.

To verify the `nfc-eventd` software was installed correctly, complete the following steps.

- Log in to the computer using the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

- Open a Linux terminal window and execute the following command.

```
$ which nfc-eventd
```

You should see the following line displayed in the Linux terminal window.

```
/usr/local/bin/nfc-eventd
```

The `nfc-eventd` daemon has been installed in the correct Linux directory.

- From the same Linux terminal window execute the following command.

  ```
  $ ls /usr/local/etc/nfc-eventd.conf
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  /usr/local/etc/nfc-eventd.conf
  ```

  The `nfc-eventd.conf` configuration file has been installed in the correct Linux directory.

3.18. Reboot the computer

All required software packages have now been installed. Only the Ubuntu Linux operating system configurations necessary to construct the museum exhibit remain.

To reboot the computer, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ sudo reboot
  ```

3.19. Execute the `nfc-eventd` daemon in the background

The `nfc-eventd` software was successfully installed.

To execute the `nfc-eventd` daemon in the background, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ /usr/local/bin/nfc-eventd &
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  [1] XXXX
  Nfc-eventd 0.1.7
  Connected to NFC device: ACS / ACR122U PICC Interface
  ```

  Where `XXXX` represents the process identification number associated with the executing `nfc-eventd` daemon.

This command executes the `nfc-eventd` daemon in the background as the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

- From the same Linux terminal window execute the following command.

  ```
  $ pidof nfc-eventd
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  XXXX
  ```

  Where `XXXX` represents the process identification number associated with the executing `nfc-eventd` daemon.

3.20. Test the functionality of the `nfc-eventd` daemon

The `nfc-eventd` daemon is now executing in the background.

To test the functionality of the `nfc-eventd` daemon, complete the following steps.

- Place any NFC tag on the NFC read/write device.
- Open a Linux terminal window and execute the following command.

  ```
  $ tail -f /tmp/nfc-eventd.log
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh), inserted at: WEEKDAY MONTH DAY
  TIME TZ YEAR
  ```

- Remove the NFC tag from the NFC read/write device.

  You should see the following line displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh), inserted at: WEEKDAY MONTH DAY
  TIME TZ YEAR
  Tag (uid=hhhhhhhhhhhhhh) removed at: WEEKDAY MONTH DAY TIME
  TZ YEAR
  ```

  Where `hhhhhhhhhhhhhh` represents the fourteen (14) hexadecimal character userid of the NFC tag that was placed on the NFC read/write device.

- From the same Linux terminal window execute the following command.

```
$ ^c (i.e., ctrl-c)
```

*3.21. Terminate execution of the **nfc-eventd** daemon executing in the background*

The nfc-eventd daemon is functioning correctly.

To terminate the execution of the nfc-eventd daemon, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ pidof nfc-eventd
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  XXXX
  ```

  Where XXXX represents the process identification number associated with the executing nfc-eventd daemon.

- From the same Linux terminal window, execute the following command.

  ```
  $ kill -9 XXXX
  ```

  Where XXXX represents the process identification number associated with the executing nfc-eventd daemon.

  You should see the following line displayed in the Linux terminal window.

  ```
  [1]+  Killed                 /usr/local/bin/nfc-eventd
  ```

  This command terminates the execution of the nfc-eventd daemon executed earlier.

*3.22. Configure the Gnome desktop environment to automatically execute the **nfc-eventd** daemon in the background when Linux account **nfc-mepa** logs in*

The VLC media player cannot be executed by the Linux root user. This implies the nfc-eventd daemon cannot be executed by the Linux root user because the nfc-eventd daemon will direct the VLC media player to play a video or audio file or display an image file when an NFC chip is placed on the NFC read/write device. Placing an entry in root's crontab file to execute the nfc-eventd daemon at boot or using the Linux systemctl service manager to start, restart, and stop the nfc-event daemon will not work.

To execute the nfc-eventd daemon as the Linux account nfc-mepa add an entry to the account's Gnome Startup Applications Preference file. In this way, the nfc-eventd daemon will automatically be started when the Linux account nfc-mepa logs in to the computer.

To start execution of the `nfc-eventd` daemon as the Linux account `nfc-mepa` and when this account logs in, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ gnome-session-properties
  ```

- Left-mouse click Add

- Enter the following content is the appropriates text boxes.

  Name: `nfc-eventd` Startup
  Command: `/usr/local/bin/nfc-eventd`
  Comment: Start the `nfc-eventd` daemon at log in

- Left-mouse click Add

- Left-mouse click Close

- From the same Linux terminal window, execute the following Linux command.

  ```
  $ gnome-session-quit
  ```

- Left-mouse click the Log Out button to log out.

- Log in to the computer using the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

- Open a Linux terminal window and execute the following command.

  ```
  $ pidof nfc-eventd
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  XXXX
  ```

  Where `XXXX` represents the process identification number associated with the executing `nfc-eventd` daemon.

  The `nfc-eventd` daemon is now executing in the background when the Linux account `nfc-mepa` logs in.

3.23. Test the functionality of the `nfc-eventd` daemon

The `nfc-eventd` daemon is now executing in the background.

To test the functionality of the `nfc-eventd` daemon, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ tail -f /tmp/nfc-eventd.log
  ```

- Place any NFC tag on the NFC read/write device.

  You should see the following line displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh), inserted at: WEEKDAY MONTH DAY
  TIME TZ YEAR
  ```

- Remove the NFC tag from the NFC read/write device.

  You should see the following lines displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh), inserted at: WEEKDAY MONTH DAY
  TIME TZ YEAR
  Tag (uid=hhhhhhhhhhhhhh) removed at: WEEKDAY MONTH DAY TIME
  TZ YEAR
  ```

  Where `hhhhhhhhhhhhhh` represents the fourteen (14) hexadecimal character userid of the NFC tag that was placed on the NFC read/write device.

- From the same Linux terminal window, execute the following command.

  ```
  $ ^c (i.e., ctrl-c)
  ```

3.24. Configure the Gnome desktop environment to disable screen lock

By default, the Gnome desktop environment, which is the default desktop environment used by the Ubuntu Linux Desktop LTS operating system, will lock the user's screen after a certain period of time has elapsed. The default time is 300 seconds, or 5 minutes. When a user's screen has been locked, the user's session is active, but suspended, and the user is required to reenter their password to access the operating system. This is to prevent image persistence, which may occur with liquid crystal or plasma display screens.

Image persistence, or image retention, is the LCD and plasma display equivalent of screen burn-in. Unlike screen burn, the effects are usually temporary and often not visible without close inspection. Plasma displays experiencing severe image persistence can result in screen burn-in instead" ("Image persistence," n.d.).

To disable screen lock and address the image persistence issues, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ gsettings get org.gnome.desktop.session idle-delay
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  uint32 300
  ```

- From the same Linux terminal window, execute the following command.

  ```
  $ gsettings set org.gnome.desktop.session idle-delay 0
  ```

- From the same Linux terminal window, execute the following command.

  ```
  $ gsettings get org.gnome.desktop.session idle-delay
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  uint32 0
  ```

3.25. Configure the Gnome desktop environment to disable screen dim

By default, the Gnome desktop environment, which is the default desktop environment used by the Ubuntu Linux Desktop LTS operating system, will dim the monitor after a certain period of time to prevent image persistence.

However, when a key is pressed on the keyboard or the mouse is moved, then the monitor is reawakened. For security reasons, the keyboard and mouse from the museum exhibit computer must be detached and stored in a secure area of the museum. As such, there is no way to reawaken the monitor.

To disable screen dim and address the image persistence issues, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ gsettings get org.gnome.settings-daemon.plugins.power
  idle-dim
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  true
  ```

- From the same Linux terminal window, execute the following command.

```
$ gsettings set org.gnome.settings-daemon.plugins.power
idle-dim false
```

- From the same Linux terminal window, execute the following command.

  ```
  $ gsettings get org.gnome.settings-daemon.plugins.power
  idle-dim
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  false
  ```

3.26. Configure the Gnome desktop environment to use a custom background image (optional)

The default background image associated with all non-root Linux accounts, administrator or otherwise, is image of the code name of the Ubuntu Linux Desktop LTS operating system. Bionic Beaver is an image of a beaver. Focal Foosa is an image of a cryptoprocta ferox (i.e., a foosa). An alternative image that displays the simple text *Please place an NFC chip on the NFC read/write device* can be created and saved in the `~/Pictures` directory.

To define a custom background image for the Linux account `nfc-mepa`, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ gsettings get org.gnome.desktop.background picture-uri
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  'file:///usr/share/backgrounds/warty-final-ubuntu.png'
  ```

- From the same Linux terminal window, execute the following command.

  ```
  $ gsettings set org.gnome.desktop.background picture-uri
  'file:///home/nfc-
  mepa/Pictures/NewBackground.[jpg,png,gif]'
  ```

- From the same Linux terminal window, execute the following command.

  ```
  $ gsettings get org.gnome.desktop.background picture-uri
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  'file:///home/nfc-
  mepa/Pictures/NewBackground.[jpg,png,gif]'
  ```

- From the same Linux terminal window, execute the following command.

  ```
  $ gnome-session-quit
  ```

- Left-mouse click the Log Out button to log out.

- Log in to the computer using the non-root administrator Linux account `nfc-mepa`, which was created when the Ubuntu Linux Desktop LTS operating system was installed.

  You should now see the new desktop background image displayed.

3.27. Acquire an open source video file

As mentioned in the Materials section of this paper, one or more video, audio, and/or image files, which the VLC media player will play or display when an NFC chip is placed on the NFC read/write device, must be obtained.

To acquire an open source video file, complete the following steps.

- Open a Linux terminal window and execute the following commands.

  ```
  $ cd ~/Videos
  $ wget
  https://archive.org/download/CEP_00_054_WS/CEP_00_054_WS_51
  2kb.mp4
  $ mv CEP_00_054_WS_512kb.mp4 RedwingedBlackbird.mp4
  ```

  Each Ubuntu Linux account has defined a Video directory. Placing all video files in the provided `~/Video` directory is recommended.

  The above commands simply (1) enter the directory `~/Videos`, (2) obtains the open source video file `CEP_00_054_WS_512kb.mp4` from the server `archive.org`, and (3) renames the file as `RedwingedBlackbird.mp4`.

- From the same Linux terminal window, execute the following command.

  ```
  $ cvlc --play-and-exit --fullscreen --video-title-show
  RedwingedBlackbird.mp4
  ```

  The VLC media player will begin playing the video file `RedwingedBlackbird.mp4`. Notice the VLC media player displays the Title metadata *Redwing Blackbird\'s Song 2\(Wide Screen\) – http://www.archive.org/details/CEP_00_054_WS*.

3.28. Modify an mp4 video file's Title metadata

The VLC player will, by default, display the Title metadata associated with a video file when the video first begins playing. If no Title metadata exists, then the VLC player will display the name of the video file.

To modify an mp4 video file's Title metadata, complete the following steps.

- Open a Linux terminal window and execute the following commands.

  ```
  $ cd ~/Videos
  $ vlc RedwingedBlackbird.mp4
  ```

  The VLC media player will begin playing the video file `RedwingedBlackbird.mp4`. Notice the VLC media player displays the Title metadata *Redwing Blackbird\'s Song 2\(Wide Screen\) – http://www.archive.org/details/CEP_00_054_WS*.

- Left-mouse click on the Pause button in the lower left hand corner of the VLC media player window.

- Press the `^i` (i.e., `ctrl-i`) keys to modify the video's Title metadata.

- Modify the current value in Title metadata textbox to be *Red-winged Blackbird – Agelaius phoeniceus*

- Left-mouse click the Save Metadata button.

- Left-mouse click the Close button.

- Press the `^o` (i.e., `ctrl-o`) keys to exit the VLC media player

- From the same Linux terminal window, execute the following command.

  ```
  $ cvlc --play-and-exit --fullscreen --video-title-show
  RedwingedBlackbird.mp4
  ```

  The VLC media player will begin playing the video file `RedwingedBlackbird.mp4`. Notice the VLC media player displays the Title metadata *Red-winged Blackbird – Agelaius phoeniceus*.

3.29. Acquire an open source audio file

To acquire an open source audio file, complete the following steps.

- Open a Linux terminal window and execute the following commands.

  ```
  $ cd ~/Music
  ```

```
$ wget
https://archive.org/download/birdsongjukebox/audio/6_nuthat
ch.mp3
$ mv 6_nuthatch.mp3 Nuthatch.mp3
```

Each Ubuntu Linux account has defined a Music directory. Placing all audio files in the provided `~/Music` directory is recommended.

The above commands simply (1) enter the directory `~/Music`, (2) obtains the open source audio file `6_nuthatch.mp3` from the server `archive.org`, and (3) renames the file as `Nuthatch.mp3`.

- From the same Linux terminal window, execute the following command.

```
$ cvlc --play-and-exit Nuthatch.mp3
```

The VLC media player will begin playing the audio file `Nuthatch.mp3`.

3.30. Acquire an open source image file

To acquire an open source image file, complete the following steps.

- Open a Linux terminal window and execute the following commands.

```
$ cd ~/Pictures
$ wget https://archive.org/download/dsc-2118_the-little-
nuthatch/DSC_2118\ 2020-09-09\ edit1-2020-12-17.jpg
$ mv DSC_2118\ 2020-09-09edit\ t1-2020-12-17.jpg
RedBreastedNuthatch.jpg
```

Each Ubuntu Linux account has defined a Pictures directory. Placing all video files in the provided `~/Pictures` directory is recommended.

The above commands simply (1) enter the directory `~/Pictures`, (2) obtains the open source image file `DSC_2118\ 2020-09-09edit\ t1-2020-12-17.jpg` from the server `archive.org`, and (3) renames the file as `RedBreastedNuthatch.jpg`.

- From the same Linux terminal window, execute the following command.

```
$ cvlc --play-and-exit --fullscreen --image-duration 5
--meta-title="Red-breasted Nuthatch - Sitta canadensis"
RedBreastedNuthatch.jpg
```

The VLC media player will begin displaying the image file `RedBreastedNuthatch.jpg` for 5 seconds. Notice the VLC media player displays the Title metadata *Red-breasted Nuthatch - Sitta canadensis*

3.31. Associate an NFC tag's userid with a video, audio, or image file

Each NFC tag is uniquely identified by a fourteen (14) hexadecimal character user identification number (i.e., userid). The userid of an NFC tag can be easily obtained using the Linux commands `nfc-poll` or `nfc-list`.

To associate and NFC tag's userid with a video, audio, or image file, complete the followings steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ tail -f /tmp/nfc-eventd.log
  ```

- Place any NFC tag on the NFC read/write device.

  You should see the following line displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh), inserted at: WEEKDAY MONTH DAY
  TIME TZ YEAR
  ```

- Remove the NFC tag from the NFC read/write device.

  You should see the following line displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh), inserted at: WEEKDAY MONTH DAY
  TIME TZ YEAR
  Tag (uid=hhhhhhhhhhhhhh) removed at: WEEKDAY MONTH DAY TIME
  TZ YEAR
  ```

  Where `hhhhhhhhhhhhhh` represents the fourteen (14) hexadecimal character userid of the NFC tag placed on the NFC read/write device.

- From the same Linux terminal window, execute the following command.

  ```
  $ ^c (i.e., ctrl-c)
  ```

This NFC tag's fourteen (14) hexadecimal character userid (i.e., `hhhhhhhhhhhhhh`) will soon be associated with either a video, audio, or image file.

Repeat the above steps, associating an NFC tag with a video, audio, or image file, for as many video, audio, and image files that exist.

3.32. Create the Bourne shell script nfc-eventd.sh

The `nfc-eventd` daemon will execute the Bourne shell script `nfc-eventd.sh`, which directs the VCL player to play a video or audio file or display an image file based on the NFC tag that was placed on the NFC read/write device.

To associate an NFC tag's userid with a video file, complete the following steps.

- Open a Linux terminal window and execute the following commands.

```
$ cd ~nfc-mepa
$ echo '#!/bin/sh
>
> TAG_UID=$1;
>
> (echo -n "Tag (uid=$TAG_UID) inserted at " && date) >>
/home/nfc-mepa/nfc-eventd.log;
>
> case $TAG_UID in
>
> # Video: RedwingedBlackbird.mp4
> vvvvvvvvvvvvvv)
> exec cvlc --play-and-exit --fullscreen --video-title-show
/home/nfc-mepa/Videos/RedwingedBlackbird.mp4
> ;;
>
> # Audio: Nuthatch.mp3
> aaaaaaaaaaaaaa)
> exec cvlc --play-and-exit
/home/nfc-mepa/Music/Nuthatch.mp3
> ;;
>
> # Image: RedbreastedNuthatch.jpg
> iiiiiiiiiiiiii)
> exec cvlc --play-and-exit --fullscreen --image-duration 5
--meta-title="Red-breasted Nuthatch - Sitta canadensis"
/home/nfc-mepa/Pictures/RedBreastedNuthatch.jpg
> ;;
>
> *)
> esac' > /home/nfc-mepa/nfc-eventd.sh
```

  Where the fourteen (14) hexadecimal character userid (i.e., `vvvvvvvvvvvvvv`) represents the NFC tag associated with the open source video file downloaded previously.

Where the fourteen (14) hexadecimal character userid (i.e., `aaaaaaaaaaaaaa`) represents the NFC tag associated with an open source audio file downloaded previously.

Where the fourteen (14) hexadecimal character userid (i.e., `iiiiiiiiiiiiii`) represents the NFC tag associated with the open source image file downloaded previously.

- From the same Linux terminal window, execute the following commands.

  ```
  $ chmod u+x nfc-eventd.sh
  ```

  The `chmod` command gives the non-root administrator Linux account `nfc-mepa` execute permission on the Bourne shell script `nfc-eventd.sh`.

3.33. Test the execution of the Bourne shell script `nfc-eventd.sh`

To test the execution of the Bourne shell script `nfc-eventd`, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ ./nfc-eventd.sh hhhhhhhhhhhhh
  ```

  Where the fourteen (14) hexadecimal character userid (i.e., `hhhhhhhhhhhhh`) represent the NFC tags associated with the video, audio, or image file.

  The VLC media player *should* play the video or audio file, or display the image file.

3.34. Modify the `nfc-eventd.conf` file

The execution of the `nfc-eventd` daemon is controlled by the `nfc-eventd.conf` file, which defines the actions of the `nfc-eventd` daemon when certain events occur. This file specifically defines what actions occur when an NFC tag is placed on the NFC read/write device.

Once the `nfc-eventd` daemon restarts and rereads the `nfc-eventd.conf` file, placing an NFC tag that was associated with the video, audio, or image file on the NFC read/write device will result in the VLC media player playing a specified media file.

To modify the `nfc-eventd.conf` file, complete the following steps.

- Open a Linux terminal window and execute the following commands.

  ```
  $ sudo nano /usr/local/etc/nfc-eventd.conf
  ```

  NOTE: Any Linux editor can be used to edit this file.

- Find the line …

  ```
  action = "(echo -n 'Tag (uid=$TAG_UID), inserted at : ' &&
  date) >> /tmp/nfc-eventd.log";
  ```

- Place a # in front of this line.

- Add the line …

  ```
  action = "/home/nfc-mepa/nfc-eventd.sh $TAG_UID";
  ```

- Press the ^o (i.e., ctrl-o) keys to save the contents of the file.

- Press the ^x (i.e., ctrl-x) keys to exit the nano file editor program.

3.35. Direct the nfc-eventd daemon to reread the file nfc-eventd.conf

The file nfc-eventd.conf has been successfully modified.

To direct the nfc-eventd daemon to reread the file, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ pidof nfc-eventd
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  XXXX
  ```

  Where XXXX represents the process identification number associated with the executing nfc-eventd daemon.

- From the same Linux terminal window, execute any one of the following Linux commands.

  ```
  $ kill -SIGHUP XXXX
  $ kill -HUP XXXX
  $ kill -1 XXXX
  ```

  Where XXXX represents the process identification number associated with the executing nfc-eventd daemon.

  The kill -HUP XXXX command directs the nfc-eventd daemon to reread the nfc-eventd.conf file.

If for some reason the `kill` Linux command actually terminates the `nfc-eventd` process, then simply log out using the `gnome-session-quit` Linux command and then log in again using the `nfc-mepa` Linux account. Use the `pidof nfc-eventd` Linux command to determine whether the `nfc-eventd` process is running in the background.

3.36. Test whether the newly updated `nfc-eventd.conf` file correctly executes the Bourne shell script `nfc-eventd.sh`

To test the execution of the `nfc-eventd` daemon and ensure it has read the newly updated `nfc-eventd.conf` file, complete the following steps.

- Place the NFC tag associated with the open source video, audio, or image file on the NFC read/write device.

  VLC media player *should* play the open source video or audio file, or display the open source image file.

- Open a Linux terminal window and execute the following command.

  ```
  $ tail /home/nfc-mepa/nfc-eventd.log
  ```

  You should see the following line displayed in the Linux terminal window.

  ```
  Tag (uid=hhhhhhhhhhhhhh) inserted at WEEKDAY MONTH DAY TIME
  TZ YEAR
  ```

  Where the fourteen (14) hexadecimal character userid (i.e., `hhhhhhhhhhhhhh`) represents the NFC tag associated with the open source video, audio, or image file.

4. RESULTS

To display a list of the unique days the NFC read/write device read at least one NFC tag AND the number of times an NFC chip was placed on the NFC read/write devices on that day, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ cat /home/nfc-mepa/nfc-eventd.log | awk -F ` ` `{printf
  "%04d-%02d-%02d\n", $11,
  (index("JanFebMarAprMayJunJulAugSepOctNovDec", $6)+2)/3,
  $7}' | sort | uniq -c
  ```

  You should see output similar to what is shown below displayed in the Linux terminal window. The output format is INSTANCES DATE.

  ```
   7 2024-05-23
  ```

```
 1 2024-05-24
 3 2024-05-26
10 2024-05-27
11 2024-05-28
```

To display a list of unique NFC tag hexadecimal character userids that have been placed on the NFC read/write device AND the number of times each NFC tag userid has been used, complete the following steps.

- Open a Linux terminal window and execute the following command.

  ```
  $ cat /home/nfc-mepa/nfc-eventd.log | awk -F ` ` `{print
  $2}' | awk -F `=' `{print $2}' | sed s/\)// | sort |
  uniq -c | sort -n
  ```

  You should see output similar to what is shown below displayed in the Linux terminal window. The output format is INSTANCES USERID.

  ```
   5 040342ead56481
   7 04034942d96481
  11 042ac61ad96480
  ```

5. REFERENCES

Wiedemeier, P. D. (2024a, DATE). *Title To Be Determined*. DOI To Be Determined

Wiedemeier, P. D. (2024b, June 7). *How to construct an interactive museum exhibit that uses near-field communication technology*. GitHub. https://github.com/wiedemeierp/nfc_mep/blob/main/NFC_Museum_Exhibit_Project_Paper_HowToConstruct.pdf

"Installation/System Requirements". (n.d.). In Ubuntu Documentation. Retrieved from https://help.ubuntu.com/community/Installation/SystemRequirements

"ACR122U USB NFC Reader". (n.d.). In Advanced Card Systems Ltd.. Retrieved from https://www.acs.com.hk/en/products/3/acr122u-usb-nfc-reader/

"Common types of NFC tags". (n.d.). In serialio.com. Retrieved from https://serialio.com/support/common-types-of-nfc-tags/

"Free to Use and Reuse Sets". (n.d.). In Library of Congress. Retrieved from Retrieved June 18, 2024, from https://www.loc.gov/free-to-use/

"A catalog of publicly available NASA datasets". (n.d.). In National Aeronautics and Space Administration. Retrieved June 18, 2024, from https://data.nasa.gov

"Open Access Online Resources". (n.d.). In The Getty Research Institute. Retrieved from Retrieved June 18, 2024, from https://getty.libguides.com/openaccess/getty

[The landing page for the Internet Archive Digital Library]. (n.d.). The Internet Archive. Retrieved June 18, 2024, from http://archive.org/

"BIOS". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/BIOS

Ubuntu 24.04 (Noble Numbat). (2024, April 25). *24.04 Noble Numbat* [Linux Operating System]. Ubuntu Website. Retrieved from https://releases.ubuntu.com/noble/

"Old Ubuntu Releases". (n.d.). In Ubuntu. Retrieved from http://old-releases.ubuntu.com/releases/

"Rufus Downloads". (n.d.). In Rufus. Retrieved from https://rufus.ie/downloads/

"APT". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/APT_(software)

"GCC Compiler Collection". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/GNU_Compiler_Collection

"Automake". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/Automake

"Using autoupdate to Modernize configure.ac". (n.d.). Gnu Operating System Free Software Foundation. Retrieved from https://www.gnu.org/software/autoconf/manual/autoconf-2.60/html_node/autoupdate-Invocation.html

"Autoconf". (n.d.). Gnu Operating System Free Software Foundation. Retrieved from https://www.gnu.org/software/autoconf/

"GNU Libtool". (n.d.). Gnu Operating System Free Software Foundation. Retrieved from https://www.gnu.org/software/libtool/

"pkg-config". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/Pkg-config

Collins-Sussman, B., Fitzpatrick B. W., & Pilato, C. M. (2007). *Version Control with Subversion*. Retrieved from https://edoras.sdsu.edu/doc/svn-book-html-chunk/svn.intro.whatis.html

"Package: libnfc-bin (1.8.0-3.1)". (n.d.). Debian The Universal Operating System. Retrieved from https://packages.debian.org/sid/libnfc-bin

Last updated on Thursday, June 20, 2024 at 9:25 AM

"nfc-poll". (n.d.). ArchLinux. Retrieved from https://man.archlinux.org/man/extra/libnfc/nfc-poll.1.en

"Package: libnfc-dev (1.8.0-3.1)". (n.d.). Debian The Universal Operating System. Retrieved from https://packages.debian.org/sid/libnfc-dev

"Package: libnfc-examples (1.8.0-3.1)". (n.d.). Debian The Universal Operating System. Retrieved from https://packages.debian.org/sid/libnfc-examples

"nfc-list". (n.d.). ArchLinux. Retrieved from https://man.archlinux.org/man/nfc-list.1

"Package: libnfc-pn53x-examples (1.8.0-3.1)". (n.d.). Debian The Universal Operating System. Retrieved from https://packages.debian.org/unstable/utils/libnfc-pn53x-examples

"Linux NFC Device Driver Installation". (n.d.). GoToTags. Retrieved from https://gototags.com/linux/nfc/drivers#generic

Stocker S. H. (2018, May 7). *Blacklisting modules in Linux*. Networkworld. Retrieved from https://www.networkworld.com/article/965682/blacklisting-modules-on-linux.html

"GitHub". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/GitHub

Conty, R. & Teuwen, P. (n.d.). nfc-eventd [software]. Retrieved from https://github.com/nfc-tools/nfc-eventd

"Image persistence". (n.d.). Wikipedia The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/Image_persistence

6. APPENDIX

As stated paper section 2.7, we built a plywood platform to secure and hide the NFC read/write device from public view. The large platform area allows children to easily place the plastic laminate sheets that contain the pictures of the birds and embedded NFC tags on the hidden NFC read/write device. The materials necessary to construct our plywood platform are listed below and a simple assembly drawing of our plywood platform is shown in Figure A1.

- 4 foot by 8 foot by ¾ inch plywood sheet
- Phillips, star, or square head #8 1-5/8 inch wood screws
- Wood glue
- Wood filler
- Cordless drill
- 1/16 inch drill bit
- ½ inch countersink drill bit
- 5/8 inch large diameter spade drill bit

- Four (4) 2 inch L bracket right angle corner braces
- Assorted grit (60, 80, 120, 220) sandpaper
- Rust-oleum protective enamel oil paint
- 2 inch paint brushes
- 3 foot single port USB 3.0 male to female AUX flush mount extension cable for car, truck, boat, or motorcycle dashboard panel.

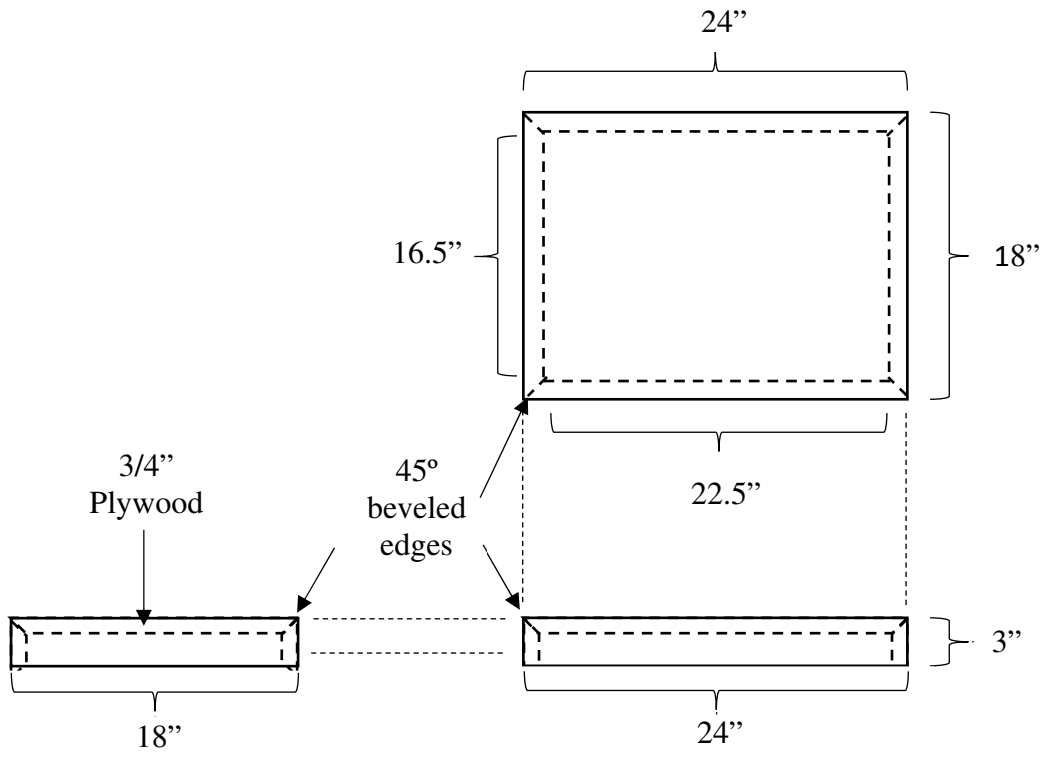

Figure A1: A simple assembly drawing of the plywood platform we built.

Cut the plywood to the dimensions shown in Figure A1. Drill a 5/8 inch hole using the 5/8 inch spade bit through one 24 inch by 3 inch by ¾ inch plywood pieces. This piece serves as the back of the plywood platform and the newly drilled hole will accept the 3 foot single port USB 3.0 male to female AUX flush mount extension cable. See Figure A2.

Figure A2: 3 foot single port USB 3.0 male to female AUX flush mount extension cable.

Once all pieces are cut and drilled, sand piece starting with the 60 grit sandpaper. Continue to sand each piece, gradually increasing the grit of sandpaper used. Finish with the 220 grit sandpaper.

Connect one 24 inch by 3 inch by 3/4/ inch plywood side piece to one 18 inch by 3 inch by ¾ inch plywood side piece using one 2 inch L bracket right angle corner brace. See Figure A3. Place wood glue on the connected beveled edges before attaching the L brackets.

Figure A3: L bracket supports on the inside of the plywood platform for support.

For added support, drill a 2.5 inch hole through one of the 24 inch plywood piece, 1 inch from the bottom and 3/8 inch from the outside side of the piece, into one of the 18 inch plywood piece using the 1/16th inch drill bit. Continue this process, connecting one side piece to another, until all sides of the plywood platform are connected. When drilling a counter sink hole through an 18 inch plywood piece into a 24 inch plywood piece, the hole drilled should be 2 inches from the bottom and 3/8 inch from the outside of the piece.

For each hole drilled, use the ½ inch countersink drill bit to create 45° countersink holes so the wood screw head will be flush with the surface of the wood. Use the drill and associated bit to drive the necessary number of #8 1-5/8 inch wood screws into each drilled hole.

Glue top of the plywood platform to the bottom we just constructed. Drill holes through the plywood top into the side pieces using the 1/16th inch drill bit. Again, use the drill and associated bit to drive the necessary number of #8 1-5/8 inch wood screws into each drilled hole.

Apply two coats of the oil based enable paint to the plywood platform. The enamel paint provides a long lasting high quality finish lasts for years and is easy to clean and disinfect.

Affix the NFC read/write device to the underside of the top of the plywood platform. See Figure A4.

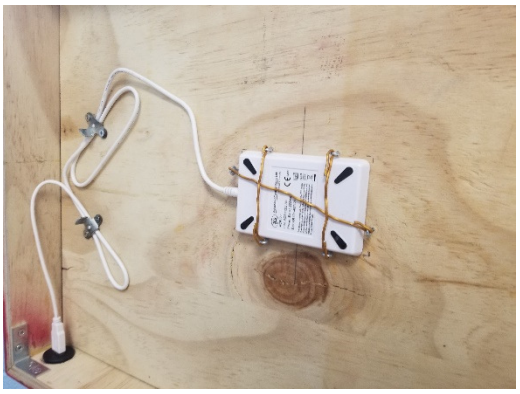

Figure A4: NFC read/write device affix to the underside of the top of the plywood top.