Signoff Request - September 13th, 2022 - Navigation (HD Camera)

Friday, August 12, 2022 7:28 AM

Navigation Subsystem - HD Camera

Abstract: HD Camera Signoff Takeaways

This signoff request is for the high definition (HD) camera which will be used in the design for the Autonomous Crawl Space Inspection Robot. The HD camera will reside in the "Navigation Subsystem" on our block diagram and will be responsible for taking pictures and live streaming video from within the crawlspace. First, for this signoff request, the expectations or specifications of the HD Camera are explained in verbal terms. Then, analysis is performed so that the specifications of the HD Camera can be stated quantitatively as constraints and so that the quantitatively stated specifications can be justified. Finally, an HD Camera is chosen, examined, and analyzed to whether or not it can meet the specifications and constraints of the atomic subsystem.

Specifications:

1. *The device chosen for the HD Camera must allow a total frame area which would utilize the most amount of available lux from the flash hardware (determined by flash hardware)*
2. *The device chosen for the HD Camera must have a lens with a focal length with a wide enough angle that allows for the needed total frame area*
3. *The device chosen for the HD Camera must have a resolution that is large enough for good image and video resolution and must be able to record images and video at an appropriate fps*
4. *The device chosen for the HD Camera must generate images with a size which the wireless access point is capable of transmitting (determined by wireless access point)*

Constraints:

1. *The device chosen for the HD Camera must have a total frame area of **at least** 1 meter by 1 meter, which is the area that will utilize the maximum brightness emitted from the flash hardware. If the image has an area larger than 1 meter by 1 meter, then the emitted from the flash hardware will be enough for the surface to be properly lit and be bright within the pictures and videos.*
2. *The device chosen for the HD Camera must have a lens with a focal length with an angel of **at least** 57.3 degrees, which would allow for an image area of at least 1 meter by 1 meter when the camera and flash hardware (the robot) are 1 meter from the surface that is being recorded. This will allow for imaging of the crawlspace floors, walls, and sub-floor ceiling.*
3. *The device chosen for the HD Camera must have a frames per second (fps) speed of at least 2 fps on whatever resolution the camera is recording on. Due to the Nyquist rate (sampling at twice the frequency) and since the robot is estimated to move at a speed of roughly 1 foot per second, the live video feed would need to show at least 2 frames per second. Realistically, the fps of the video would be closer to 15 or 30 fps, which would drastically improve the quality of the video. Additionally, while there is not a minimum resolution required for the images, high definition (HD) images are preferred with a resolution of at least 720 by 1280.*
4. *The device chosen for the HD Camera must not generate and send files with a transmission speed over 290 Mbps, which would be the absolute maximum transmission speed allowed for live video feed while the operator is using the Remote Desktop Connection software.*

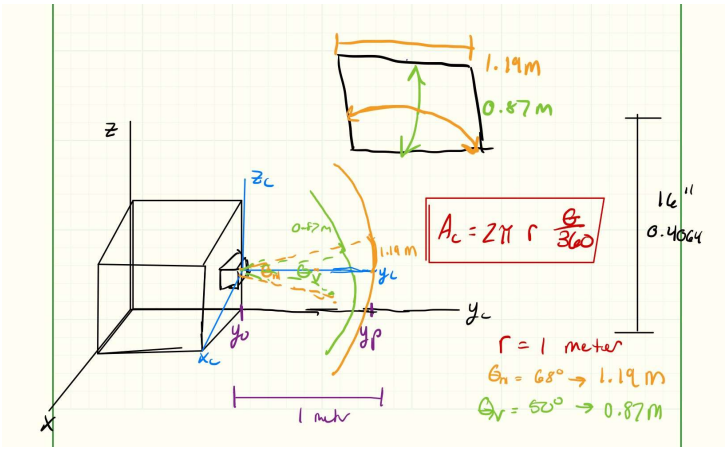
Analysis:

*In order analyze what the minimum requirements are for the HD Camera, two other components had to be considered in addition to the previously mentioned specifications for what the HD Camera needs to do. Since the HD Camera is present on the robot to, first, take pictures of the crawlspace to record its characteristics, and, second, provide live-video feed to operators who are manually controlling the robot; the HD Camera must have properly lit surfaces to take record of as well as utilize the maximum light available for illuminating images and video. Therefore, as designated by the flash hardware, the HD Camera must be able to take images of surface and include at least an area of 1 meter by 1 meter, which is where the maximum amount of lux will be present (light intensity per unit area) [1]. Therefore, in order to have the most amount of lux present in the unit area, the HD Camera and Flash hardware will need to be positioned roughly 1 meter away from the surface of which the image is being captured [2]. In order to maintain an image area of 1 meter by 1 meter and also be positioned 1 meter away from the surface, the HD Camera will need to have a lens angle that allows for an arc length of **at least 1** (since lens is semi-spherical it will have a vertical arc length of 1 meter and a horizontal arc length of 1 meter, therefore creating an image area of 1 meter by 1 meter). The lens angle needed to maintain an arc length of 1 when the radius from the lens to the surface equals 1, is approximately 57.3 degrees per the commonly used formula for arc length as shown in equation 1, where radius is the distance from the camera to the surface and theta is the lens angle. As the angle of the lens increases, the area that image encompasses will also increase to an area larger than 1 meter by 1 meter. Additionally, if the horizontal angle is larger than 57.3 degrees, it can offset a smaller vertical angle, as not all cameras have the same horizontal and vertical lens angles [3].*

$$Equation\ 1: Arclength\ (A_c) = (2\pi)(radius)\left(\frac{\emptyset}{360}\right)$$

In order to determine whether or not an arc length of 1 meter (or an image area of 1 meter squared) will be sufficient in the design of the inspection robot, the crawlspace and the position of the camera on the robot must be determined. Per the design phase 1 document and the constraints of the inspection robot, the device must be able to fit into a 16 inch tall crawlspace. If the height of the crawlspace is 16 inches, then it can be assumed that the sub-floor (crawlspace ceiling) would be roughly 16 inches above the crawlspace floor. If the camera was mounted roughly 4 inches above the crawlspace floor onto the robot chassis, then the camera would need to be able to see at least 12 inches above the center line of the lens and at least 4 inches below the center line of the lens, which would allow for an image to capture the crawlspace floor, walls, and sub-floor (ceiling). As shown in figure 1, if the camera was mounted at roughly 4 inches above the crawlspace floor and had a horizontal angle of 57.3 angles and a vertical angle of 57.3 degrees, the horizontal arc length would be roughly 1 meter and the vertical arc length would be 1 meter. Therefore, the horizontal and vertical arc lengths would be roughly 32 inches, meaning that the image taken by the camera, if the camera is roughly 1 meter from a subject surface, would be 36 inches by 36 inches. If the horizontal angle is 68 degrees and the vertical angel is 50 degrees, the overall image would still have an area of 1 m^2, with the vertical arclength being 0.87 meters and the horizontal arc length being 1.19 meters. Therefore, with the SVPro HD Camera, if mounted at 4 inches, the camera would be able to capture a vertical height of rouhgly 16 inches above the center lens angle and 16 inches below the center lens angle (which is more than enough to capture the floor, walls, and sub-floor or ceiling of the crawlspace). Additionally, the camera would be able to capture a horizontal width of roughly 21.42 inches on each side of the center angle, or a full horizontal arc length of 42.84 inches. Therefore, the SVPro HD Camera will be able to sufficiently capture the crawlspace floors, walls, and sub-floor (ceiling) if positioned at a distance of 1 meter away from the targetted surface (note as that distance increases the camera will see even more of the crawlspace).

Figure 1:



In order to determine the minimum frames per second (fps) of the HD Camera to be relevant in the design of the inspection robot, the Nyquist Rate of the ground must be considered. Since the robot is moving at roughly one foot per second, the HD Camera would need to be able to provide at least 2 frames per second at whatever resolution during live-video. As the frames per second available increases, the quality and smoothness of the image also increases, making the reaction time of the operator increase as well as the quality of the operator's experience navigating. While there is not a minimum image resolution, high definition (HD) images, 720 by 1280 pixel, are always welcomed as the provide more information. Finally, since the Raspberry Pi 4B is connected to the remote control via the wireless access point, there is a total transmission speed cap of 290 Mbps (the video feed is transmitted when the remote control protocol is initiated, thus the Remote Desktop Connection application is being used and utilizes 9 Mbps, leaving 290 Mbps free of the 300 Mbps provided by the wireless access point). A 720 by 1280 video, steaming at 30 frames per second would require roughly 60 Mbps (multiplying together 720, 1280, and recording for 60 seconds). With roughly 60 Mbps needed for the live video feed and another 9 Mbps for Remote Desktop Connection, the total needed bandwidth is still far below the available 300 Mbps.

Chosen Component:

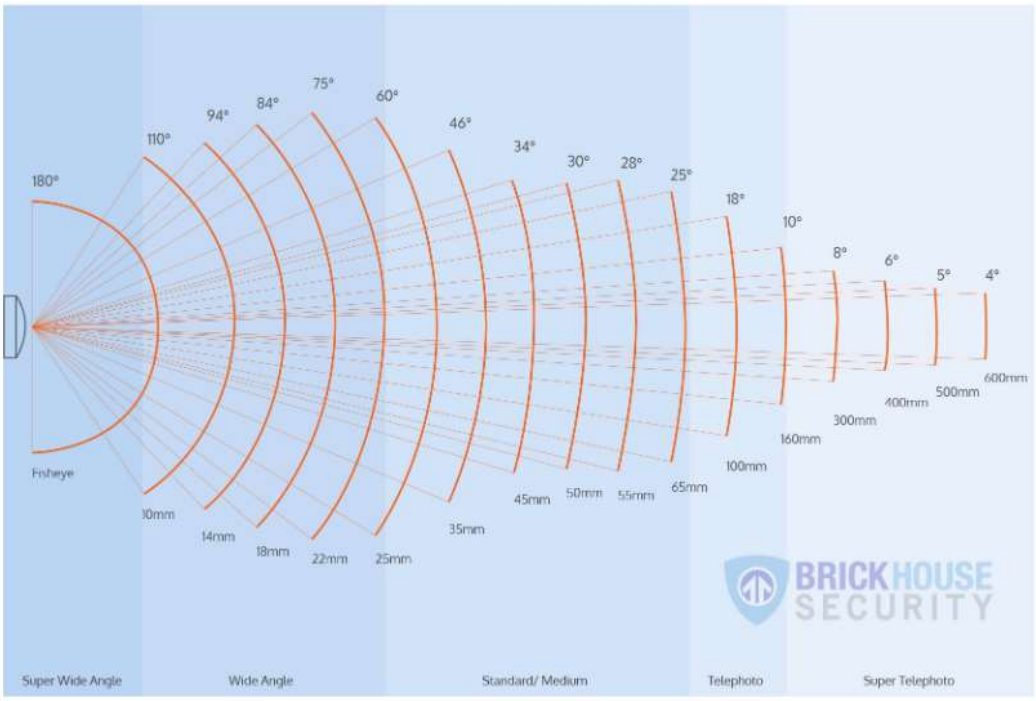
SVPRO - 60 Degree Autofocus HD USB Camera - $60.99/Unit - 1 Unit Needed - $60.99 BOM

SVPRO 60 Degree Autofocus HD USB Camera

The 60 Degree Autofocus HD USB Camera, manufactured by SVPRO, is shown in figure 2 [5]. The SVPRO HD camera features a 5 megapixel (MP) lens with a maximum image capture resolution of 2592(H)x1944(W) pixels [6]. The SVPRO HD camera supports numerous video resolutions with a variety of frames per second (FPS) classifications, shown in table 1, which include 1920x1080 at 15 fps and 1280x720 at 30 fps [6]. The lens on the SVPRO HD camera supports mechanical autofocus, which allows for automatic adjustments to occur onboard in order to ensure that clear images and video feed are obtained. As previously stated, the lens on the SVPRO HD camera is a 60-degree, wide angle, lens which enables the camera to capture images with a wider viewing aspect of an environment, as shown in figure 3 [7]. The SVPRO HD camera requires a constant voltage of 5 Volts and has a working current of 150 mAmps and can be connected to and powered from a device via the USB 2.0 connections [5, 6]. Additionally, the camera features an aluminum weatherproof case that shields the internal electronic components and camera from exposure to an environment. The SVPRO 60 Degree Autofocus HD USB Camera is available via multiple online commerce websites, such as amazon, for an average price of $60.99 [5].

Figure 2 [5]:

Figure 3 [7]:



Adhering to the Given Specifications of the Autonomous Crawl Space Inspection Robot

An HD USB camera is needed in the design of the Autonomous Crawl Space Inspection Robot so that images of the crawl space environment can be recorded for technicians and home owners as well as live video feed for manually operating the robot. In order to be sufficient for the design of the inspection robot, the HD USB camera will need to be capable of providing high-definition (HD) quality pictures and videos of a resolution of at least 720p. The HD USB camera will need to be able to be powered by the power subsystem of the inspection robot for at least two hours, which will is the estimated operation time of the inspection robot. The HD USB camera will need to require a voltage of 3.3 Volts or 5.0 Volts and will need to have an operating current of 200 mAmps or less so that the total current supplied used by the Raspberry Pi 4B and its connected devices does not exceed 3 Amps. The Raspberry Pi 4B uses on average 1.5 Amps under normal operation, the ultrasonic sensors will use an estimated 32 mAmps, the Lidar sensor will uses an estimated 0.6 Amps, the HD Camera will use no more than 0.2 Amps, and the flash hardware will use an estimated 0.6 Amps, totaling roughly 2.9 Amps, which Is within the maximum current draw of the Raspberry Pi 4B [8, 9, 10, 11, 12]. The HD Camera will need to have a lens rated at a value of at least 2 mega-pixels (MP) since high definition images are defined as at least 1280x720 pixels (921,600 pixels) with a max quality of 1920x1080 pixels (2,073,600 pixels) [4]. While the angle of the lens does not necessarily matter, a wide-angle lens will allow for more information coverage within the captured images, therefore, a wide angle lens is suggested for the design of the inspection robot. Finally, the HD USB camera will need to have a protective case which will help with preventing possible damage from the crawl space environment, as well as an USB cable for a secure, fast, and sturdy connection to the Raspberry Pi 4B. After considering all requirements and specifications of the autonomous crawl space inspection robot, it can be seen that the SVPRO 60 Degree HD USB Camera is an acceptable camera for this capstone project. The SVPRO HD USB Camera electrical connections to the Raspberry Pi 4B are shown in figure 4. The proposed physical connections of the camera to the inspection robot are shown through a proposed Solid Works model in figures 5 and 6 [13].

Figure 4: [8, 9, 10, 11, 12]

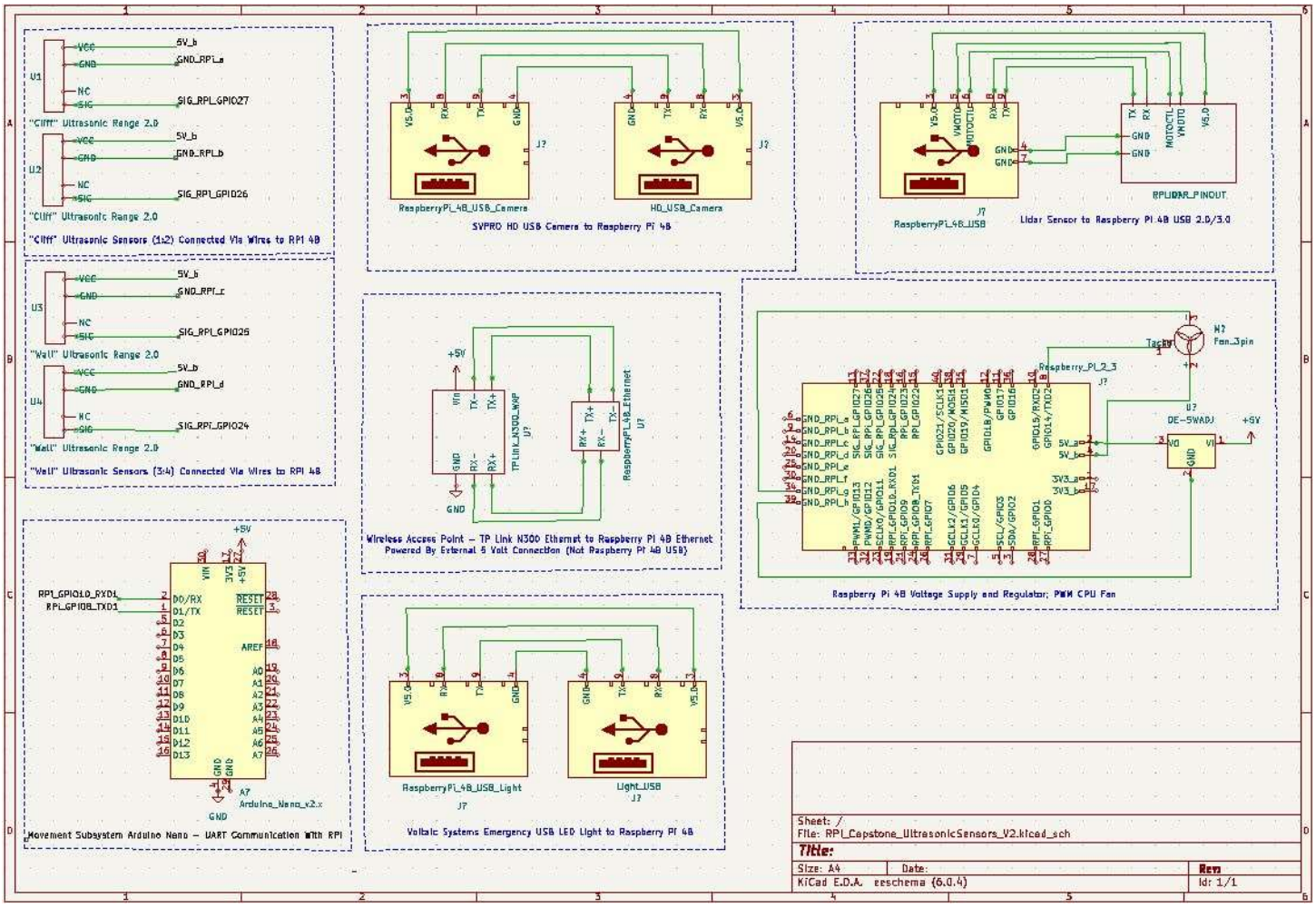


Figure 5 [13]:

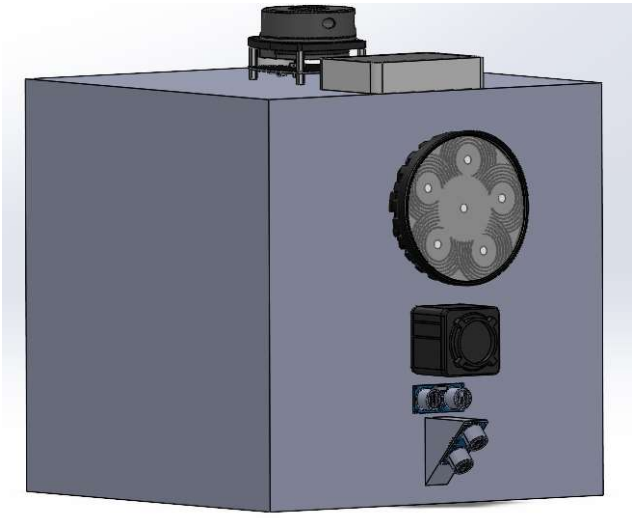
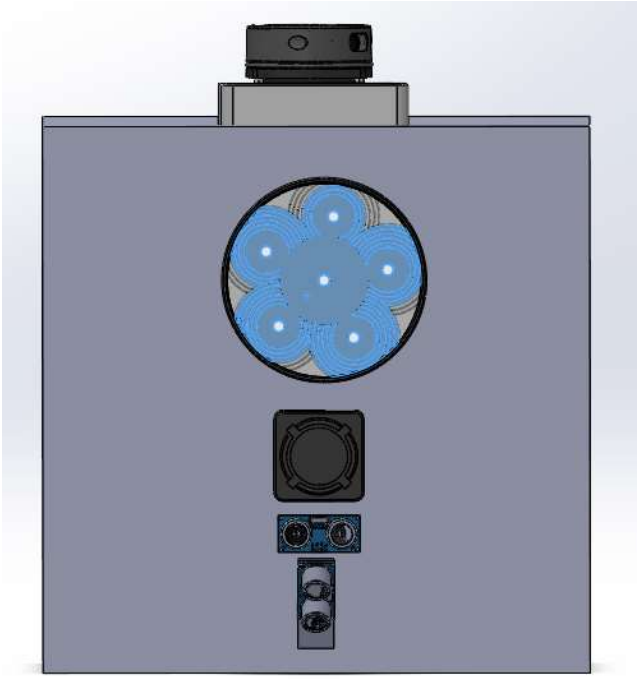


Figure 6 [13]:



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[13] 3D CAD Model
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