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WAY-GO Torch :An intelligent flash light

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***Abstract*— Here the prototype of an intelligent flash light is presented which helps for outdoor navigation by projecting a directional arrow that guides a user from one point to another. The torchlight can be used for navigating in new campuses, can be used as a tool for search and rescue and also can be used for trekking and biking. By directly projecting the associated meta data like name of the place, distance to target and the heading information the torch eliminates the overhead involved in reading a map and comparing it with the surroundings to further decipher the map. It is an intelligent-ubiquitous flash light which over comes the limitation imposed by limited screen size of a GPS cell-phone, a GPS watch or a GPS navigating device used in a car.**

I. Introduction

This intelligent flashlight is primarily designed for the purpose of navigation. Currently GPS devices exist which provide navigation support outdoors for cars. Also navigation can be done by just manually reading a paper map but be it a digital GPS navigation aid or a paper map, map reading skills vary from person to person. Not every person can decipher all the information in a map. Understanding the symbols and annotations in a map and translating them to physical landmarks like buildings and roads is not a trivial task. Map reading induces an overhead in navigating new paths. So a device which would make this job easy and remove the overhead and burden associated with maps would greatly ease navigating new places. Also map reading is crucial in search and rescue scenarios where the time spent on understanding a map to plan a route for rescue could be an important factor in saving lives. The WAY-GO torch presented here also serves as a tool for search and rescue. This device is an improvement in basic flashlight design which ubiquitously combines GPS, AHRS (attitude heading reference system) and a pico projector in a single flashlight.

II. Related Work

The system tracks a person using a camera and uses a projector with a rotating mirror to project the interface on virtually any surface. Some approaches have combined the projected displays from several projectors and created a large scale display interface. Especially this idea has been used in virtual reality projects where an entire room or a passage is lit up with virtual worlds using projectors.

A. Indoor and outdoor tracking for hand held projectors

Almost in all the projects involving projected interfaces using a handheld projector an IMU or an accelerometer, a magnetometer or a compass has been used to get an idea of the orientation information. The use of an IMU is applicable both in indoor and outdoor environments to get heading information. However the location information for indoor and out door environments vary and in some cases it is challenging. Outdoor localization using GPS or cell phone signal strength is a simple solution but indoors it is not simpler to maintain a map of the physical surroundings and the objects just with the RFID tags and then further recalibrate the projected data to suit indoor environments with curved objects,

The work done by Ramesh Raskar [1] and his team on the geometrically aware projectors highlight how indoor location to projectors can be conveyed using RFiD tags. Localization in indoor environments is a tricky problem which requires redundant hardware. RFiD indoor positioning in iLamps is a solution which would stand as a bench mark in environments like shopping malls, libraries, and ware houses. Tracking of projectors can also be done externally by using IR tracking systems like The Vicon to get location information as discussed in the handheld projection research by Xiang Cao[2].

The paper on path light [3,4,5] also says that map reading skills differ from user to user but maps have the advantage of greater choice freedom. Guidance can be based either on visual landmarks or be decided from the current position. However the solution to group navigation even in indoors or outdoors is in the nascent stages. Path light project also discusses about using RFID tags for indoor positioning in museums for location and exhibit information like videos and presentations.

The project here[6] implements outdoor augmented reality using a GPS, a camera and a consumer laptop. The importance of this project is that AR applications were limited to indoor regions due to the lack of proper 6degree of freedom localization in outdoor environments but here tracking over large scale outdoors is done using a GPS. Here in Way-Go torch we use a GPS and an AHRS to obtain 6 d.o.f localization.

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Some forms of user triangulation [7] in indoor and out door environment don't use any markers. Multiple cameras are used to calculate the user's pose and position. This actually has a great implication in simplifying indoor tracking for assistive museum navigation by just using the security cameras, though its ethical implications are a wholly new topic of discussion. Outdoor environments to certain extent can also be equipped with cameras like street cameras for user tracking. Even the cellphone's signal strength can be used for tracking a user to provide location specific information outdoors.

This paper [8] on 3D GIS shows how one can use mobile displays like the HMDs to augment the physical world with virtual data and turn it into a GIS system. It also [8,pg39] throws light on how handheld devices like cell phones and palmtops be used for GIS applications. It still has the burden that one has to read the physical map, the VRML models and there are other UI burdens which act as a overhead in translating the virtual map into the user's understanding about the immediate physical world.

What appears to be essential in all the outdoor and indoor navigation projects using projectors is a way of tracking them, having an idea of the surroundings, an intuitive interface which gives away with the un-necessary details but makes the users understanding easy and relevant to the context or scenario in hand. The pictorial representation especially the over-head view might be easy when seen on a large screen but when one is standing in that real world scene, in a totally new, unexplored environment trying to draw the simile between the physical world and the 2D map of symbols could be quite a task and it needs some experience.

B. Flashlight metaphor and projected arrow

Path light [3,4,5] uses a mobile projector along with a cell phone and serves as a mobile tool with a projected interface for navigating indoors in a museum. It assists in group navigation and group decision making about choosing which exhibits to see next. It uses a mobile pocket projector along with a cell phone. One advantage of the mobile projector is that it can be used as a collaborative space for planning a team's itenery in a museum.

Navi Beam [9] discusses about using projector cell phones with interfaces for shopping malls. The system discusses about using a projected arrow that rotates and guides a person from shop to shop with in a mall. For localization information they have suggested about using AR markers. The interaction with the projected UI from the projector mounted on the waist belt is done using the shadow of a finger.

The Microsoft "future productivity and vision" concept video [11] shows an interface that projects an arrow on the floor to guide the user towards his friend's position in an airport and towards the exit.

Another product named the Ecco GPS locator[12] helps locate ones car or any of the 3 stored positions. It shows the directional arrow using a GPS. The design of the GPS keychain is mentioned here.

The map-torch [20 ,pg3] light application uses synchronous projection to illuminate larger maps with several areas of interest

The flashlight metaphor has also been used in creating games like the flash light jigsaw puzzle [13] on large scale public displays. The game uses group collaboration and can also be played in ad-hoc mode. The player has to arrange a virtual projected puzzle using the movements of presentation controllers which are tracked in 6 degrees of freedom.

C. UI consideration in Pico projection research

This paper[20] stresses the importance of pico projectors being used in the research today. Since they are tiny and production costs have come down it is no longer fiction to include such engines in mobile devices. It mentions about several parameters that governs the UI design in pico projected displays. Here in the Way-Go torch the micro-controller generates a 120x90 display. The field of view versus the intensity of projection over distance was a judging parameter in considering the thickness of the projected arrow and even the font size.

Also the alignment of the projected screen as per the curvature of the object being projected at makes the projected data readable and usable. Some of the earlier works by Ramesh Raskar [14] involve stabilization by using fudicial markers on the wall which were then replaced by projected laser markers. The orientation of the projector with respect to the screen was estimated by knowing the distance between the projected markers and their relative angles. This was further used to adjust the projected screen.

UbiSketch[15] demonstrates projection while sketching on a large mobile. Some of applications of ubisketch involved projecting their own digital faces onto themselves. Some applications involve superimposing real world drawings with virtual paintings.

Handheld stabilization and projection onto moving hand-held surfaces is discussed in paper [17]. For this objects are embedded with light sensors which capture the temporal projected sequence and from that their location in the projection plane is known. With this the projected content is transformed accordingly.

The paper on the side by side multi user projected interaction is especially interesting because of the hardware modification of the projector. Interestingly they have modified the projection engine with IR Leds that help in uniquely identifying a projector and thus a user. The simplicity of this solution for shared projected workspaces is really appreciable.

III. SYSTEM DESCRIPTION

A. Hardware description

The WAY-Go torchlight system can be best implemented using a cellphone which has a pico projector embedded in it.

The torch light uses a 60 channel San jose GPS receiver, an AHRS from Sparkfun, an Atmega128, a 3M LCOS modified pico-projection engine. It has a 2 degree of freedom servo setup that can make the projection head move in 2 directions. The Atmega128 parses the roll, pitch and yaw sent from the AHRS and the GPS data. Currently the torch light is run with a 1100 mAH 7.4V Li-Po battery. It gives about 15 minutes of run time with the servos of and about 8 minutes with the servos on. The LCOS projector initially came with an inbuilt driver on the projection board but it got burnt during experimentation. A more reliable constant power driver was designed using TI's constant power

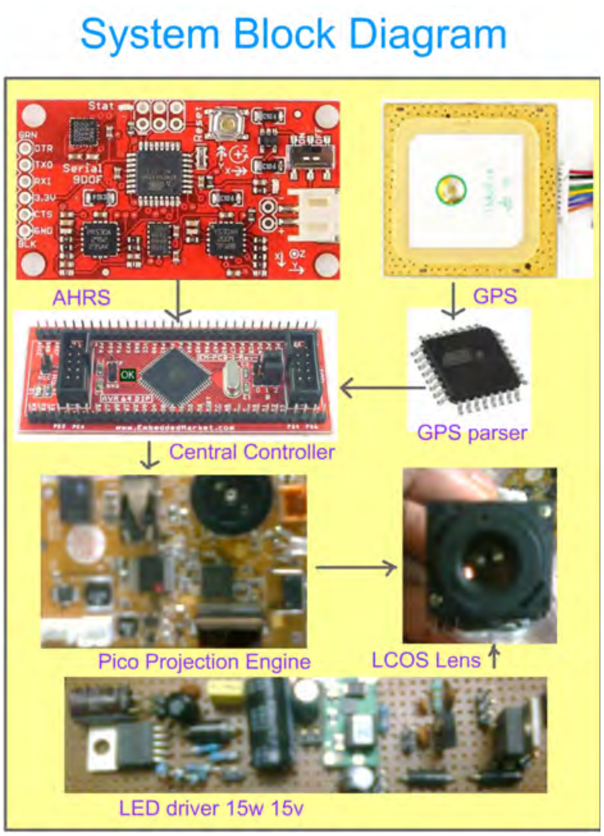

Fig. 1. Figure showing the electronics of the torch light (electronic block diagram).

modules. Driving the Led with separate driver boards rather than the projection engine's driver improved the life of the projection engine and also reduced the heat produced in the board itself.

To improve the luminosity the default CREE LED was replaced with a more powerful CREE Led. CREE LEDs are widely used in hand held pico projectors and long distance focusable flash lights. To further improve the luminosity several LEDs from different manufacturers were experimented with in the design. Parameters of the LED like the drive current, operating voltage, power consumption, luminosity per watt were taken into consideration to decide the best LED for projection. Though, some of the LEDs provided very high luminosity there was no sufficient place to put in a cooling mechanism using a fan and a heat sink. Some LEDs did not have the proper bin structure and a lens profile to be fit into the LCOS pico projection engine. Lasers were another option and mono-chromatic green lasers of 20mW showed good contrast ratio in the projected data. Unlike ultra-violet and read lasers the human eye is 20 times more sensitive to green color than red or blue and hence green lasers were chosen. Though higher the power of he laser more will be the intensity of the projected data and its visibility in day light. The problem is higher the intensity more quickly the lasers get heated and it requires the installation of bulky cooling mechanism. 5mw-20mW lasers were sufficient enough to conduct eye safe experiments wearing goggles and turned out to be a good choice because they generated less heat, had a sufficient on time and had low power consumption.

The pico projector setup had two half silvered mirrors with a convex lens setup. It was difficult to diverge the entire beam on the LCD aperture. So to sufficiently illuminate the aperture 4 lasers were used and precision aligned using a custom designed laser holder

Different lens setups were also tried out using a combination of diffusing plastic sheet, Fresnel lens and convex lens. The diffusing plastic sheet spread the luminosity but the projected image did not have good intensity. Later the lasers were directly mounted on top of the half silvered mirror in the projector.

Today phones are equipped with mobile projection engines can serve the purpose of such applications in indoor environments with moderate ambient illumination. However such projectors do not have sufficient luminosity in their projecting LED to form a high luminosity high contrast ratio image.

Some of the DIY projects show how a high powered laser can be used to get projection over a long distance with a good contrast ratio. Nowadays PICO projectors from microvision use a laser with a MEMs reflector to achieve a high contrast display. These also do not require focusing optics because the image is actually a laser dot being swept vertically and horizontally at high speeds.

The initial version was made from a flashlight shell available off the shelf. The version 1.0 and 2.0 were CAD designed and printed using a rapid prototyping machine. This helped us print parts with precision alignment for the laser diodes. The model was designed to accommodate all the electronics in the standard form factor of a flashlight. This was important because the flashlight would look more ubiquitous in design.

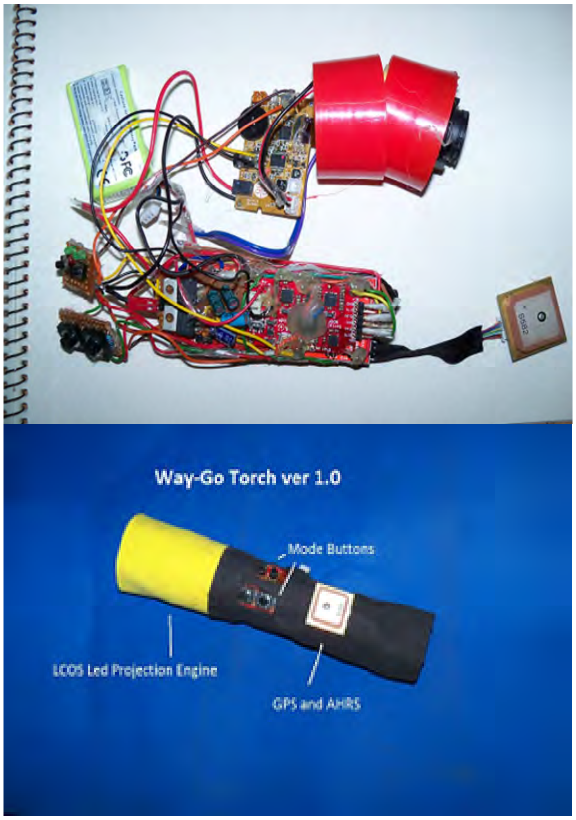

Fig. 2. Figure showing the prototype-1 of way-go torch and the disassembly of the torch.

TABLE I

S.no	LED Model	Lumens	Power	Current-Voltage
1.	CREE XLamp XRE	107		1000mA
2.	CREE XLamp MCE	430	4	700mA
3.	LedEngine LZ4-00CW	703	15	1500-14.5
4.	Seoul Semi Conductor	900	10	900
5.	Green Laser		20mW	60-3.5

IV. Software Description

The WAY-GO flash light uses an AVR atmega128 running at 16 mHZ. The technical challenge was to store the entire campus map in the form of 25 GPS waypoint where each point was two units of floating point data, parse the GPS data and calculate distances correct to 4th decimal point, parse the IMU data at the same time, decide the heading and distance information and also generate a PAL video signal for the projector. The micro-controller also handles the geometric transformation from the IMU frame to ground frame and then to the projector's reference frame. The AVR controller also uses error control techniques to identify faulty GPS and IMU packets. Coming to the computational requirements it is possible to handle several instruments and sensor data with the localization data and command the onboard actuation module using such minimally computational micro-controllers. For example, the recent Mars Exploratory Rover [20] uses a computer that runs at just 20 Mhz but handles several instruments and precisely control them.

A. Program flow code

1) On boot calculate all possible Dijkstra paths from source to destination way points in the map.
2) Select mode.
3) Select user source, default = Main gate.
4) Select user destination.
5) Select the path from generated look up table for the given pair of source and destination.
6) Calculate distance to next way-point in path mode. Calculate the heading to the next way-point.
7) Do transformation from compass frame to campus map frame and then to the projector frame.
8) After reaching a waypoint increment way point flag, display way-point meta data and calculate distance and heading to next way-point.
9) When way-point flag equals number of way points +1, set reached flag.

Fig. 3.Figure showing various functional threads in the torch software.

The software threads mentioned above include the threads for generating PAL video signal for the LCOS projector,Dijkstra shortest path finding, parsing the IMU and GPS data to find the next closest point on the way. The controller used a computationally minimal micro-controller and so it was a challenge to do calculation upto the 4th place after the decimal point especially with the GPS data and the IMU data. The algorithm for running the torch is mentioned in the program flow code.

Pesudo code:

```
Const float distancemap[30][3]
{1,2,3,13, 2,3,1,55…..}
Const char positionlist[][13]
{"entrance,main block,parking,cafeteria…}
Const float gpspo[24][2]
(17.4459,78.3514…}
Func distance_between(lat,long…)
Void printpath( )//pal signal out
Void dijkstra( ) //on position tags
Void graphic routine( )//for LCOS display
```

V. Operating Modes

The torch operates in the following modes

A. *Show path mode*

Initially when the torch is booted it finds all the possible paths from the entrance gate as its source to other destinations in the map. During this process it sets up the look up tables for each path containing the intermediate way points. One can select the source in source selection mode and the destination respectively. It would then chose the appropriate look up table or calculate again if necessary. While navigating in a chosen path it would show the nearest intermediate way point considering the current GPS location. During this the user has to proceed in the direction of forward projected arrow. If the user tends to rotate or move away the arrow changes its direction with appropriate correction. After reaching a waypoint it calculates the heading to the next way point and the distance to it. When ever the user is in about 1.5 m radius from the waypoint it sets a reached flag. The GPS accuracy of 1 m was achieved in the flash light with the current GPS device.

B. *Diagnostic mode*

This mode projects the meta-data from the IMU-AHRS (yaw, pitch, roll) data, the GPS latitude, longitude and signal strength. The microcontroller calculates if it is a valid IMU packet or a GPS packet using cyclic redundancy checking and this helps in diagnosing if the WAY-GO torch is working properly or is showing the wrong direction. The diagnostic mode can be used especially for indoor environments where getting is GPS fix is impossible. One can still get an idea as to where the magnetic north is from the IMU data. This in turn can be used to identify blocks in a hostel building say if it is the north block or the extended block. It can also be used to get an idea as to where a room with a particular room number can be, say if one is new to campus and wants to meet a friend. Generally the first time experience to find a particular hostel or a block or even a room in it can be pretty tiring, but this diagnostic mode

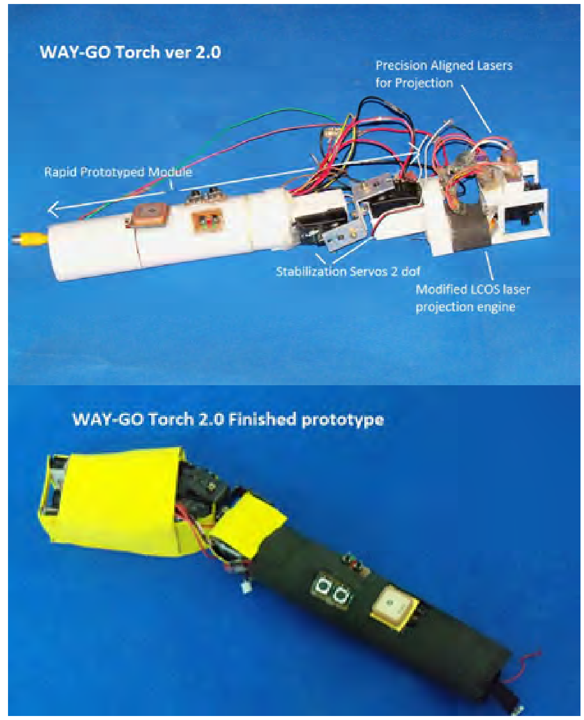

Fig. 4 Figure showing prototype2 of the way-go torch

coupled with classifying the 3D space with directional data from the IMU solved the problem.

C. *Flash light mode*

The torch can also be used as a basic flash light in the full lit mode. The LCOS projector uses an LED as a source of illumination, so with the entire pixels set to white it would function as a flashlight.

D. *Wander mode*

The user need not set the path in this mode but can just move around the campus and the torch would project him info about the nearest position. Especially if one has to use this for hiking, for exploring a new place, touring a new campus this mode will be helpful. People who are new to a particular locality say a college campus can be given this torch light to go around and explore new places in the campus. One more use of such a tool is in shopping malls where the buyer is directed to the appropriate stall. The meta data can be used to know the direction of nearest exit say in a shopping mall or an airport.

E. *Biking mode*

Blaze[1] is another product designed by Emily brighton which projects a static laser image onto the road in front of the bike. As she says about 80% of the accidents occur when cyclists are traveling straight are hit by motorists driving into them. The bright green share lane symbol would help motorists see the symbol and get an indication that a cyclist is near by even if he or she is in the blind-spot. Some of the products [2] create a virtual bike lane to give a visual indication for other bikers on roads to join when there is no physical divider. This also warns other high speed vehicles.

This projector can also be used on bikes to project the desired heading information on the road ahead. The biker always looks on the road that is directly in front of him. At a distance of 8-10 feet holds the decision making region. Say if there are any pits on the road ahead the biker can actively use this information to maneuver his bike around or apply brakes. If a hand-held GPS device is installed on the dashboard of the bike it would be difficult for the biker to change his foveal attention from the road and onto the screen again several times. This change in foveal attention would be tiring, inconvenient, distracting and could also cause accidents. On the other hand if the relevant information is projected on the immediate path ahead the biker can effortlessly drive and make decisions as to where he should turn, especially if the projected meta data falls in the portion of the road which is conventionally illuminated by the bike's head light. If it is a car the information can be displayed on a transparent and flexible OLED display attached to the front wind shield or the data can even be projected using a roof mounted flashlight.

F. Biologically inspired head lock stable mode

Some of the birds exhibit head lock mechanism such that even if the rest of their body moves their head stays fixed to a particular position in space. Some de-blurring techniques for cameras estimate the direction or motion and remove the photo blur after it has been shot. Some of them even use accelerometers to change the orientation and align it properly after the shot has been taken. Optical flow can also be used to remove the video shake and stabilize the it. Well if we extend the same idea on output video devices like the projector it can also help in stabilizing the projected data. Here the torch's roll and pitch were measured using the IMU and the same were used to counter the change using a two degree of freedom servo setup. Here the stabilization using the 2 degree of freedom servos does not take place at video frequencies but the mechanism can also be used to bring robotic animated features in the torch's behavior.

VI. MORE USAGE SCENARIOS

GPS aided navigation in cars is achieved using hand held devices with LCD displays fitted to the dash board that show the path with an arrow and give audio cues about direction. If the vehicle driver has to look at the road and then change his focal attention on the tiny LCD screen on the dash board for details about the position and landmarks could be inconvenient and in effect could be dangerous. It would be better if the road itself is augmented with necessary driving guidelines. This is done to some extent using traffic lights, sign board which show meta-data like how far a landmark is, if there is a sharp bend or a speed breaker ahead.

One need not have a co-driver when the data is projected on the road ahead or the front wind shield. This is especially useful for people traveling in cars over mountainous roads and there is no proper street lighting, for bikers who are riding up a hill and for people who go on trekking. Many people take minimal gear with them when they go for hikes. If equipment like the WAY-GO torch is facilitated ubiquitously, then people would never forget nor require specialized equipment like a compass, or a professional GPS device with a map or a GPS enabled watch.

The beauty of this device is that one need not limit one self to the limited screen-size that the GPS devices in cars, cell phones, or watches offer. One can project the data any where they want to, be it on the road ahead, their palm, or the wall of a building. Map reading skills are varied among people, not every one can decipher the symbols in the map and relate them to the physical surroundings with ease. This device gives away with such a limitation as the map itself is stored and related useful information is projected ahead. It is an overhead to read the map, learn how information is represented in it and then use it. This especially induces a delay in navigations. Probably for this reason the GPS devices in the cars come with assistive voice messages which tell how far a way point is, where and when one has to take a turn. Mostly people set their source and destination in the GPS device before they start their journey and listen to the voice messages. If one has a friend sitting in an adjacent seat he can look into his phone and guide the driver accordingly. In case of small size vehicles like bikes traveling on roads with less traffic density the WAY-GO torch would be useful. It projects a directional arrow to the next pit stop and gives the distance-heading information.

Imagine a search and rescue scenario. Say there is an earth quake or a tornado and people are stuck under the debris. All the houses and buildings around are collapsed; there are no clear road ways as they are covered with debris. Typically a rescue worker looks up a map, identifies possible locations of homes as they are the places where people could be stuck. Then he takes a team and spends time in understanding the surrounding, looks into his handheld GPS aided device or a printed map , tries to identify the possible landmarks from the collapsed structures and then sorts a plan out. The planning and search process is slow. It can be speeded up by using these torch lights which directly project the landmark information giving away with the over head in reading the maps and identifying the places. The search and rescue personnel can use the same torch to search for people in dark areas but also navigate in the night. The cost involved in Search and rescue scenarios is too high that one cannot wait for daylight and it needs to progress with the same speed as could in the daylight. The flashlight proposed here would greatly aid a rescue worker.

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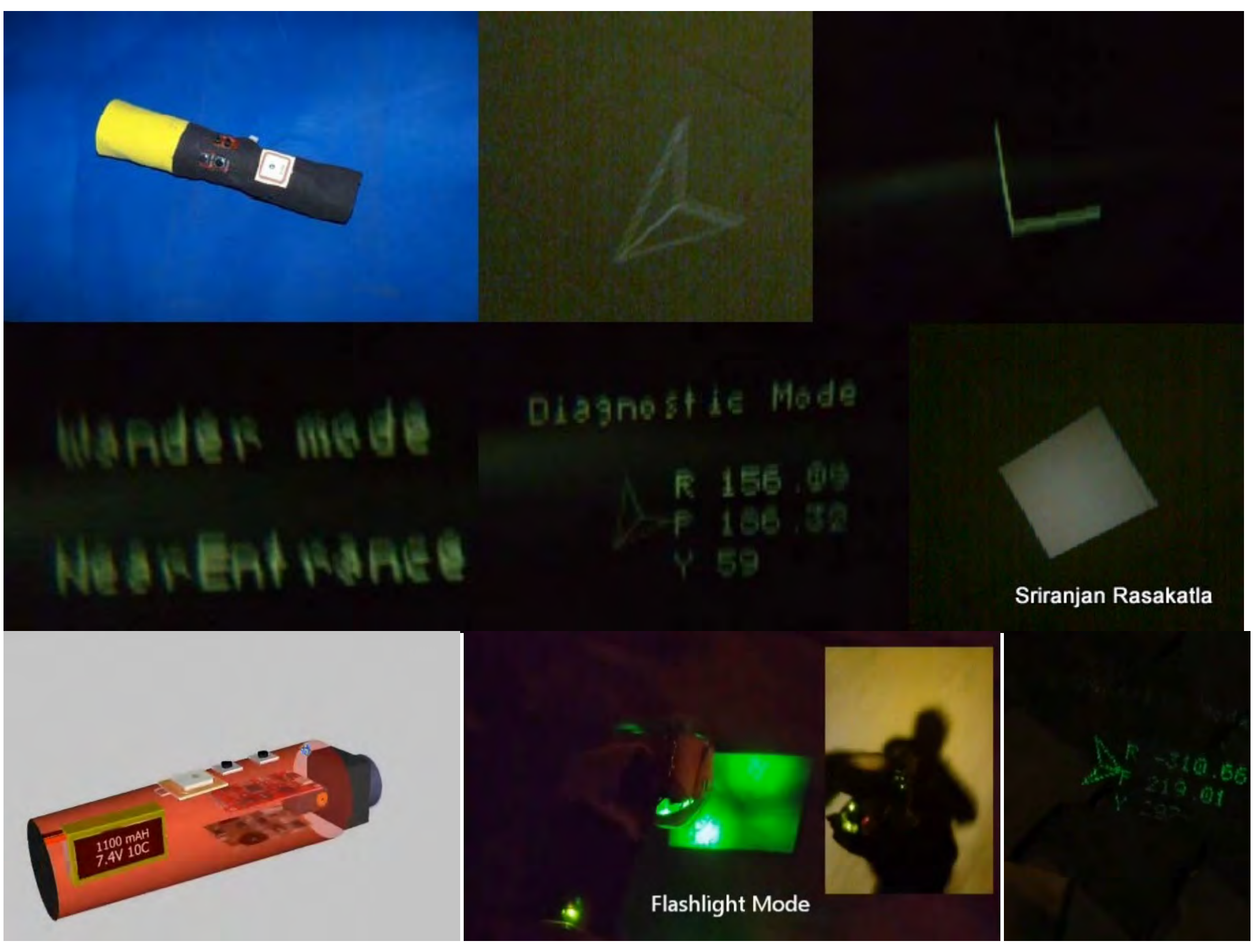

Fig. 5. Figure showing the projected interface of the torchlight in several modes