Finding Flood Survivors During Rescue Operations by Applying Deep Learning Technique on Aerial Radiometric Thermal Imaging

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Abstract: During search and rescue operations in flood disaster, application of deep learning on aerial imaging is pretty good to find the humans when the environmental conditions are favorable and clear but it starts failing when the environmental conditions are adverse or not supporting. During our findings we realized that generally rescue teams stop their rescue work in night time because of invisibility .When orientation of sun comes at front, the drone aerial picture quality starts decaying. It does not work in different types of fog. Also it is difficult to find people when they are somehow hidden in vegetation. This study explains about infrared cameras potentially very useful in disaster management especially in flood [6]. It takes deep learning networks that were originally developed for visible imagery [1], [2] and applying it to long wave infrared or thermal cameras. Most missions for public safety occur in remote areas where the terrain can be difficult to navigate and in some cases inaccessible. So the drone allows you to fly high above the trees see through gaps of foliage and locate your target even in the darkness of night through thermal cameras and then applying deep learning techniques to identify them as human. Creating accurate machine learning models capable of localizing and identifying human objects in a single image/video remained a challenge in computer vision but with recent advancement in drone, radiometric thermal imaging, deep learning based computer vision models it is possible now to support the rescue team to a bigger extent.

Index Terms*: Flood, rescue, deep learning, thermal imaging, drone*

I. INTRODUCTION

In June 2013, a multi-day cloudburst fixated on the North Indian province of Uttarakhand caused crushing floods and avalanches turning into the nation's most noticeably terrible catastrophic event. 16-Jun-13 and 17-Jun-13 were those terrifying days where nothing was visible at a distance of 4 meter in Kedarnath due to heavy rain and fog. The Indian Air Force, the Indian Army, and paramilitary troops emptied in excess of 110,000 individuals from the flood desolated territory. In spite of the fact that, starting at 16 July 2013, as indicated by figures given by the Government of Uttarakhand, in excess of 5,700 individuals were 'assumed dead'. 'Assumed dead' because rescue team were helpless to rescue victims just because of the adverse environment all around [3]. There was full rain and fog during 3rd week of Jun-13 in Kedarnath area. We also have taken this granted in general that Rescue is only possible in clear sky and day light time. But in the ground reality, whenever any disaster happens, the people who are stuck with their families and kids just expect high that some god man will come and will save them from these kinds of disasters to a safer zone especially in hilly areas.

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In the past decade much research has focused on search and rescue operations in clear sky and day light time only [5]. It remains unclear that why we are not equipped with those technologies, which can work day and night with adverse environmental factors as well like rain, fog, extreme front sunlight during search and rescue operations of human body. The purpose of this study was to get better results when we fly drone with thermal cameras in flood disaster areas during rescue operations and simulate the deep learning thermal models to it to find the living bodies that are laid, stuck or running in some regions.

II. LITERATURE SURVEY: THERMAL IMAGING CAPABILITIES

We started digging the thermal camera's generated infrared images and found very good capabilities to work in adverse environmental conditions in rescue operations [4] as below.

A. Color Palettes

Next we're going to look at some color palettes so thermal imaging cameras take energy that radiates from every physical object in the world and translate it into either at an estimated temperature value viewed as data or a visible image. The visible image depicts a range of temperatures within the scene and cast them in different shades and colors depending on the palette that's being used. So clear thermal imaging cameras offer a range of these palettes to make your job easier but some of the missions can be made more difficult with using the wrong palette so understanding the justification you had using the certain palette or selecting a palette is important for any user. The white-hot and black-hot would be the most two basic palettes as indicated by the name as shown in Fig. 1.

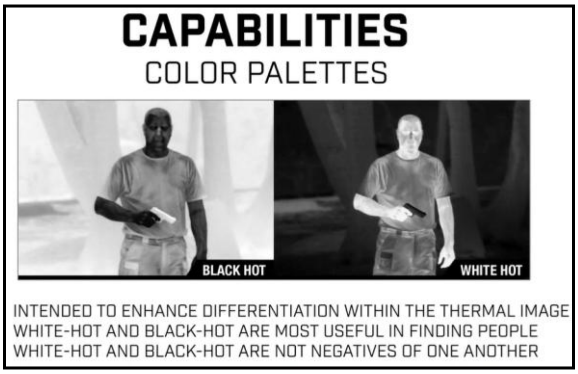

Fig. 1.Capabilities Color Palettes (White Hot, Black Hot)

If you're fine trying to find a person with these polished palettes it could be extremely difficult unless there is a difference between the temperature of the person that you're trying to locate and the surrounding area of more than 30 degrees Fahrenheit.

B. Isotherm

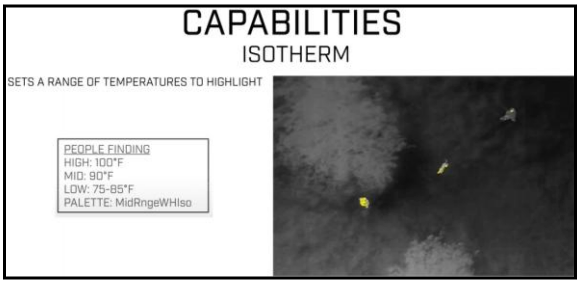

Fig. 2.Capabilities: ISOTHERM

Without modeling the image this would usually fall between 75 and 85 degrees Fahrenheit anything above 85 degrees Fahrenheit. Using isotherm is unlikely to be useful and the suggested color palette would be mid range white hot ISO color palette that would be available [7]. In the Zen muse-XT setting the low temperature below 80 degrees will generally pick up clothing as well so you might want to do some experimentation when using isotherm to see what works best in your area with the humidity and temperature that you're dealing with and the given time of year as shown in Fig. 2.

C. Radiometry

It is the process in converting radiated energy into temperature and advance radiometric cameras that filter puts out will allow you to gather the temperature data from every pixel within the scene and you can use this for post flight analysis using software like Flora tools for instance. This white image does not have this range on the right hand side that shows the temperature scale as shown in Fig. 3.

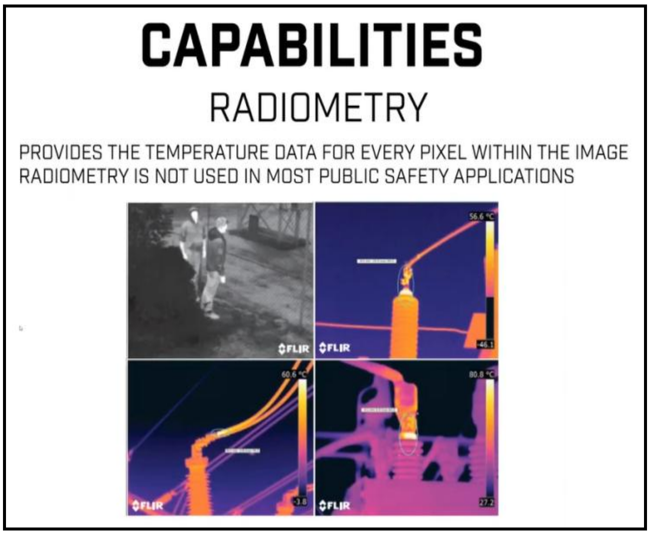

Fig. 3.Capabilities (Radiometry)

D. Covering Ground

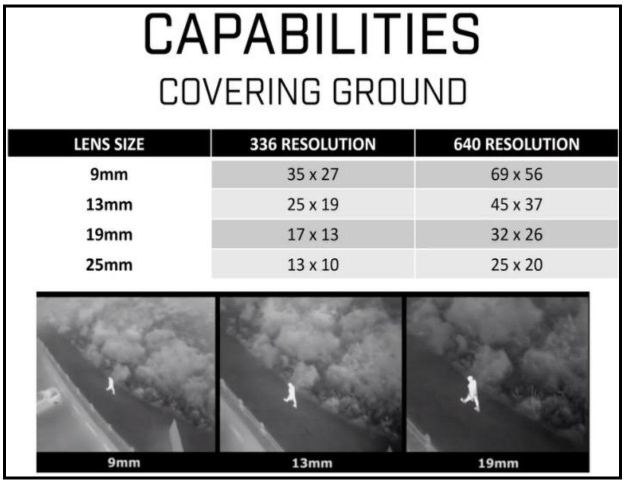

Fig. 4.Capabilities Covering Ground

Each resolution and lens combination they put out a different field of view to capturing the symmetry. The basic concept here is that the wider field of view that you have the more you'll see at a specific given time but you'll also get less detail of the subject that you're looking for. It was in the image [8]. This can make locating a person quicker but also the possibility of missing them greater. The inverse is true with narrow field of view which gives you more specificity more detail but you can present a challenge in locating and staying locked on your target because it's like looking through a soda straw. It's important to consider basically for things the resolution of the camera the lens size and field of view the size of your target that you're trying to identify and the distance between the camera and the target as shown in Fig. 4.

E. Ability to see in complete dark:

We're particularly sensitive to infrared radiation. One of its most unique and useful characteristics that we will show simultaneous capture of visible imagery on the left part of the picture and thermal imagery on the right side of the picture as shown in Fig. 5.

Fig. 5.Clarity of view through thermal camera

So this is a night-time driving condition. There's a reasonable amount of illumination. But if you watch the picture and pay attention you'll notice a pedestrian starting to cross the road and through thermal video, we're able to detect and classify the pedestrian crossing the road with the thermal camera significantly in advance of the visible camera as shown in Fig. 6 and Fig. 7.

Fig. 6.Clarity of view through thermal camera

Fig. 7.Pedestrian crossing the road

F. *Not blinded by the sun*

So we can see at night. We can see in complete darkness, one of the useful properties of thermal cameras. Another interesting and useful characteristic of thermal cameras is since we're looking at heat and not light we're not blinded when we're driving into the sun as shown in Fig. 8.

Fig. 8.Thermal not blinded by the sun

Basically reduce the flare and glare that you see in the visible image here but fundamentally in a thermal image since we're not sensitive to the light coming from the sun we don't experience the same type of flare or glare that you see in visible camera.

G. *Able to view in most type of fogs:*

Another characteristic of long wave infrared thermal cameras is that we're able to see exceptionally well in most types of fog as shown in Fig. 9 and Fig.10.

Fig. 9.Performs well in many types of fog (part1)

Fig. 10. Performs well in many types of fog (part2)

So we're not bothered by the reflective light that's impacting the performance of a physical camera. So you'll be able to see in this scene if you pay attention to the thermal image and particularly along the sidewalk region here you'll notice there are a number of pedestrians that you can easily see in the thermal image that you can't see at all in the visible image. Here's a pedestrian approaching the intersection that you're able to detect very clearly thermally for example that you're not able to see with the visible camera and the person who took this picture actually went bike riding along this path after the data collection and struggled to really see details and feel comfortable in that bike right afterwards. So thermal cameras do a great job in a lot of difficult environmental conditions like fog.

II. RESEARCH DESIGN AND METHODOLOGY

A. *Data source credits : The data used for this study were collected by below sources:*

1. *https://www.x20.org/product/m1-d-micro-ptz-infrared-camera/* [Las Vegas, United States based SPI Corp which gives thermal imaging frameworks to law authorization, border watch and country security]
2. *https://www.flir.com/discover/security/thermal/5-benefits-of-thermal-imaging-cameras/* [Based in Wilsonville, Oregon, United States, FLIR Systems Inc. FLIR is The Global Leader in the Design, Production, and Sales of Thermal Imaging Infrared Cameras]
3. *[dronehub.tk]/datasets-96fc4f9a92e5/* [A multidisciplinary team at University of Klagenfurt and Lakeside Labs performs research on networked autonomous aerial systems.]

B. *Technological design, workflow, tools , alogorithm ehhancements and methodology*

TensorFlow can run on multiple CPU's and GPU's with optional Cuda for general purpose computing on graphics processing unit. And TensorFlow, its flexible architecture allows for easy deployment of computation across a variety of platforms which are the CPU's, GPU's and TPU's and from desktops to clusters and servers to mobile.

TensorFlow Context Diagram:

Now TensorFlow computations are expressed as state full data flow graphs. The name TensorFlow derives from the operations that such neural network performs on multi-dimensional data arrays which are known as the tensor. Now let's see how object detection can be performed in tensor flow. So first of all we provide our input data which is a set of images and using tensor flow, we train our model. Now this model is strained using deep learning and the main object of this model is to extract the features as shown in Fig. 11.

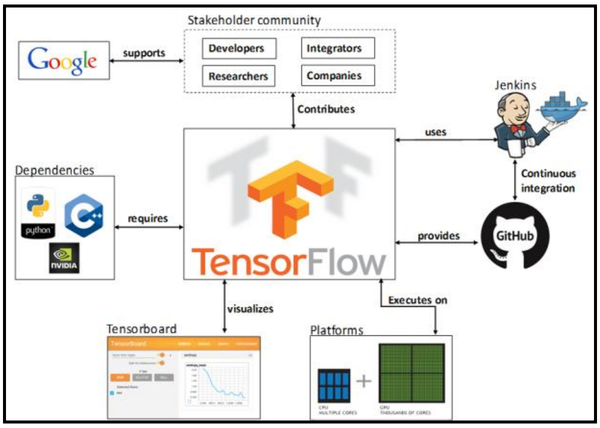

Fig. 11. TensorFlow Context Diagram:

TensorFlow Technical Architecture:

Now these are visual features which are based on edge detection. The higher features, the facial recognition and many more. Now when these features are extracted and then the model is created, to test this model we provide a test data which is again a set of images. In our case and using this model we get our final output in which we have the objects detected in an image as shown in Fig. 12.

Fig. 12. TensorFlow technical architecture

Now the images are converted into a numpy array in the TensorFlow object detection so that the competition can be made easy. We also use the TF record which is the TensorFlow record which contains the record of the image along with the tags such as you can see here, we have the person tag we have the dog tag and the horse tag. Now these tags are just labels which are provided in the input data.

III. SYSTEM DEVELOPMENT AND RESULTS

Please find the solution design as shown in Fig. 13. So for that just go to github and type TensorFlow which is the official github repository of TensorFlow and inside that we have the model section. Just go to these models you can either clone the TensorFlow model or download it as per your wish.

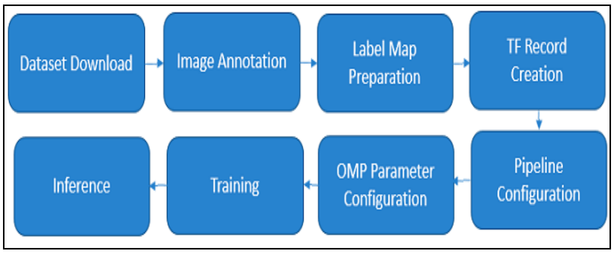

Fig. 13. Solution Design

https://github.com/TensorFlow /models

Now the TensorFlow object detection model uses protobuf. To configure model and the training parameters. Before the going to the next steps, the protobuf libraries should be processed first. Now to download protobuf, all you need to do is go to Google\ protobuf in github.

https://github.com/protocolbuffers/protobuf/releases

You can see this TensorFlow object detection API gives an accurate machine learning model description of how the objects are detected and how you have the steps for the setup.

https://github.com/TensorFlow /models/blob/master/research/object_detection/g3doc/installation.md

And based on that our model will be created. Now next what we are going to do is we are going to select which model to download. So for example here we are using the faster rcnn inception v2 coco 2018 as shown in Fig. 14

Model preparation

```
# What model to download.
MODEL_NAME = 'faster_rcnn_inception_v2_coco_2018_01_28'
MODEL_FILE = MODEL_NAME + '.tar.gz'
DOWNLOAD_BASE = 'http://download.tensorflow.org/models/object_detection/'

# Path to frozen detection graph. This is the actual model that is used for
PATH_TO_FROZEN_GRAPH = MODEL_NAME + '/frozen_inference_graph.pb'

# List of the strings that is used to add correct label for each box.
PATH_TO_LABELS = os.path.join('data', 'mscoco_label_map.pbtxt')
```

Fig. 14. Model preparation

Detection

```
# For the sake of simplicity we will use only 2 images:
# image1.jpg
# image2.jpg
# If you want to test the code with your images, just add path to the images
PATH_TO_TEST_IMAGES_DIR = 'test_images'
TEST_IMAGE_PATHS = [ os.path.join(PATH_TO_TEST_IMAGES_DIR, 'image{}.jpg'.for

# Size, in inches, of the output images.
IMAGE_SIZE = (16, 8)
```

Fig. 15. Detection code starts here

So as you can see we have the test image folder here as shown in Fig. 15 and inside that you can input all the images whichever you want to test upon this model. So for example after taking the range from 1 to 8 is taking all the images named image 1 to 7. So let's load this as shown in Fig. 16.

```
for image_path in TEST_IMAGE_PATHS:
  image = Image.open(image_path)
  # the array based representation of the image will be used later in order
  # result image with boxes and labels on it.
  image_np = load_image_into_numpy_array(image)
  # Expand dimensions since the model expects images to have shape: [1, None
  image_np_expanded = np.expand_dims(image_np, axis=0)
  # Actual detection.
  output_dict = run_inference_for_single_image(image_np_expanded, detection_
  # Visualization of the results of a detection.
  vis_util.visualize_boxes_and_labels_on_image_array(
      image_np,
      output_dict['detection_boxes'],
      output_dict['detection_classes'],
      output_dict['detection_scores'],
      category_index,
      instance_masks=output_dict.get('detection_masks'),
      use_normalized_coordinates=True,
      line_thickness=4)
  plt.figure(figsize=IMAGE_SIZE)
  plt.imshow(image_np)
```

Fig. 16. Detection code (For Loop)

So as you can see we're using the Load image into a numpy array. We are using the np.expand and finally we are using the Matplotlib to show us the results that is Labeled Processed Images.

A. *Output Result (Applying deep learning on thermal imagine) are as shown below.*

Fig. 17. Deep Thermal Imaging output-I where two persons are detected

Fig. 18. Deep Thermal Imaging output-II v/s visible imagery comparision where one person is detected fully hidden in vegitation(visible imagery).

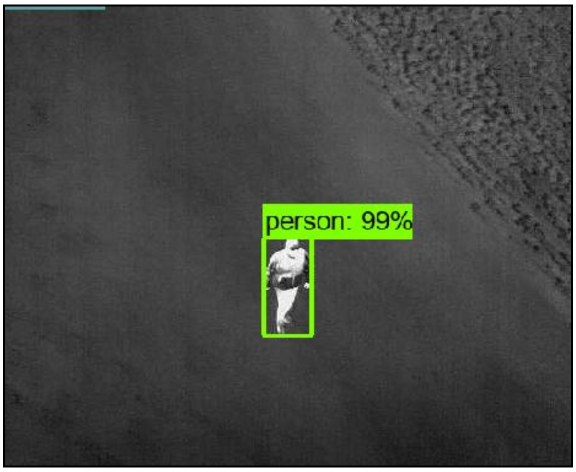

Fig. 19. : Deep Thermal Imaging output-III where one person is detected through a long range thermal camera.

As you can see it identified persons as 87%, 89%, 88%, 99% sequentially as shown in Fig. 17, Fig. 18 and Fig. 19. It has provided a box; the label and the score which is the detection scored how much it is similar to all the images which have been imported in the coco data set. You can see it has not detected the car in fig. 17 as we have filtered out car object in our detection model.

B. *Output Result (Superior detection in clutter)*

We mentioned before that the emissions from people the black body radiation peaks at 9.5 microns. So we do a particularly good job of picking out people in a scene especially a scene which has very complex and contains a lot of clutter.

Fig. 20. Superior people detection in clutter [Visible imagery v/s Thermal imaging]

Figure 20 is basically a drive down State Street of Santa Barbara on a Friday night that happened to have a community wide bike ride. So you'll notice the road is just completely cluttered with people. And by taking those deep learning networks that were developed originally for visible cameras doing a little training with thermal annotated images, we've been able to achieve pretty good results as you see here of picking out the individuals and the cars in the midst of this very cluttered urban scene.

Retrieval Number: I8135078919/19©BEIESP
DOI:10.35940/ijitee.I8135.078919

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& Sciences Publication

C. Output Result (Range Testing)

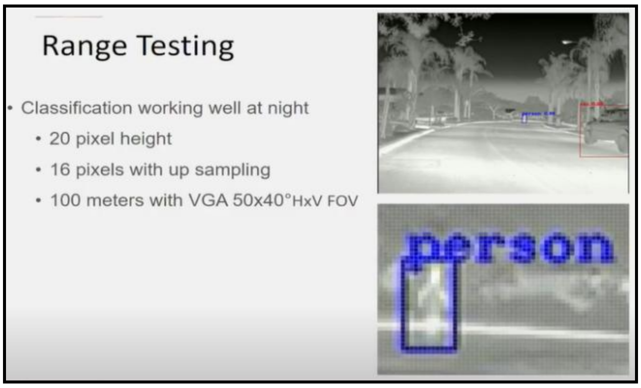

Fig. 21. Thermal camera long range testing

And we've seen using this lightly trained single shot detection network. We've been able to detect a person up to only 20 pixels in height and if we apply up sampling to the thermal image before we apply the deep learning that work we're able to detect a person at 16 pixels. So this corresponds to about 100 meter detection of a person with a VGA thermal camera at a 50 degree horizontal 40 degree vertical field of view as shown in Fig. 21 and Fig. 22.

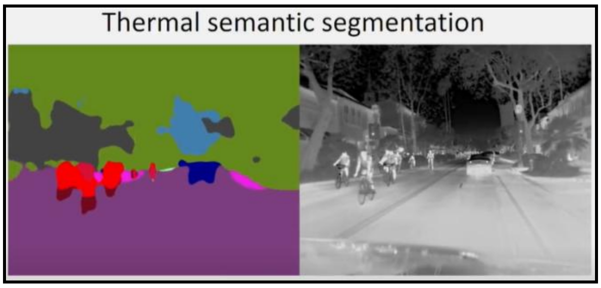

Fig. 22. Thermal Semantic Segmentation

The findings(output results) of this study clearly shows that through deep learning on thermal imaging could play a better role in human search and rescue mission. This works well with adverse conditions like complete darkness, blinded with front sun rays, different types of fog, vegetation and long range.

IV. CONCLUSION

We saw some of the interesting characteristics of thermal cameras that see heat not light. Rebels see in total darkness. We're not blinded by the sun. The work is going to really help to detect people in search and rescue operations even in the night time in different adverse environmental conditions. We have shown some of the work given the spatial similarity between visible and thermal image data. Deep learning networks that were originally developed for visible cameras can be easily extended to thermal cameras and thermal imagine. This concept can be replicated in various applications such as image retrieval security surveillance, face recognition, search and rescue operations, Security, Industrial Quality Checks, Self Driving Cars, Advanced Driver Assistance System (ADAS), Inspection and maintenance.

Future work extension and incoming challenges: We are extending the work to use the dual capture system to capture these videos/pics. So the dual capture system has a flir of formally Point Grey visible camera. It uses a Sony IMX250 CMOS sensor that's a five megapixel sensor but we've been pixels so it has an effective 1.3 or so Megapixels resolution. So we've paired that up with a VGA flir thermal camera and we've enclosed it in a waterproof enclosure and the magnetic mount and then using USB vision interface where we hook this up to a computer and we're able to collect those times synchronized videos that we showed earlier as shown in Fig. 23.

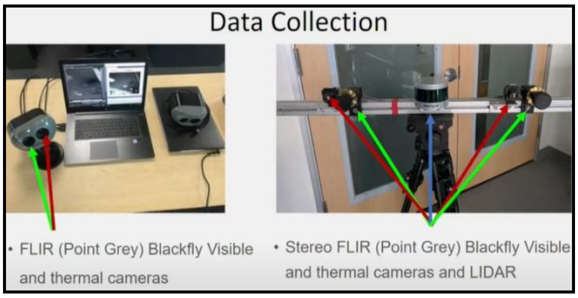

Fig. 23. Data Collection and Future Challenges

Another thing that we've done to expand our data collection capabilities is we've been doing some experiments and will show some of the preliminary results on stereo thermal imagery. Basically extracting depth information from stereo thermal cameras. We have encoded the depth information that's seen from the thermal camera with objects that are closest to the camera in the car/drone being labeled red and the objects that are further away being labeled various shades of blue from a lighter blue to a darker blue for the furthest objects as shown in Fig. 24.

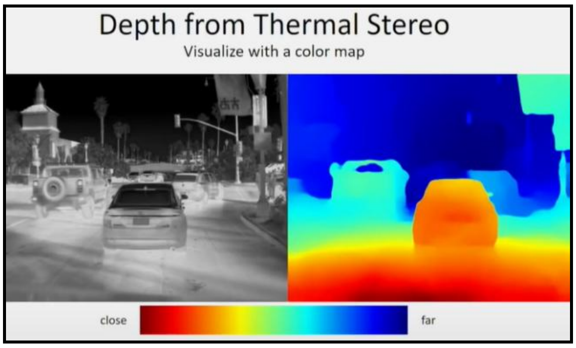

Fig. 24. Depth from Thermal Stereo

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AUTHORS PROFILE

First Author: Mohammad Nasim has extensive live experience of 20+ years for many large scale system projects in developing and architecting software solutions using various latest COTS and open source technologies and products. I am working here on a clients facing role and working as a senior architect in Pubic authority of electricity and water, Muscat, Oman. I do have working and architect knowledge on data center (Custom/Cloud), platforms (SASS, IAAS, PASS) , Technology (COTS, Open Source), storage (Mobile ,Server) , database (Cloud, Oracle, Microsoft SQL, PostgreSQL) , web services (REST, Micro-services) , security(Internet) and application performance and testing. I have completed my Master's Degree of Technology in Computer Science (M.Tech.-CSE) from Shri Venkateshwara University, Gajraula, U.P., India. Now I am persuing my Philosophy in Doctorate in Computer Science (Ph.D.-CSE) from Lingaya's University, Faridabad, Haryana, India. I have participated in IInd International Conference of System Modelling and Advancement in Research Trends (SMART) organized by Teerthanker Mahaveer University, Moradabad, U.P., INDIA and Academic Journals Online in Nov 13 and presented a paper titled "Mobile GIS on ArcGIS technologies for Android". I have participated in International Conference of Advance Research and Innovation organized by International Journal of Advance Research and Innovation, Delhi, INDIA and Delhi Technological University, Delhi, INDIA in Feb 14 and presented a paper titled "Cross Platform Mobile GIS System for Data Collection based on GPS and emerging GIS Technologies". I am member of IEEE since Mar 2016 – Present.

Second Author: Dr. G.V. Ramaraju's recent engagement has been as Pro Vice-Chancellor, Lingaya's Vidyapeeth, Faridabad, India since August 2014 concentrating on Innovation and R&D. His earlier positions include Senior Director and Group Coordinator of R&D in IT, Department of Electronics & Information Technology, Ministry of Communications &IT, Government of India and Managing Director & CEO, Media Lab Asia (now Digital India Corporation) till June 2014. As Group Coordinator of R&D in IT at DEITY, he was programme coordinator of Centre for Development of Advanced Computing, India and the many R&D projects of the Ministry of Electronics and IT including Bioinformatics, Perception Engineering, Free and Open Source Software, Green computing, Ubiquitous Computing, High Performance Computing, Promotion of Technology Innovation and Entrepreneurship Development, promotion of protection of intellectual property of MSME sector, nano-electronics and nanotechnology, development of R&D framework etc till 2014.

He played a very pivotal role for formulating and enabling the initiation of the programme "IT Research Academy" for capacity and capability building of R&D in ICTE across the country in India. He has taken big steps for promotion of R&D in Nanoelectronics in the country in a major way in setting up many Centers of Excellence on nano-electronics and nanotechnology across the country at many Indian Institutes of Technology and Universities. He had been passionately engaged in the ICT for Development sector and led the development and deployment projects of Media Lab Asia especially in the areas of ICT for livelihoods generation and enhancement, ICT for agriculture, primary health care, education, empowerment of the disabled in multi stakeholder environment involving academic and R&D institutions, Government, NGOs and Industry.

He earned his PhD in Physics from Indian Institute of Technology New Delhi, India in 1982 and Masters Degree in Physics with electronics specialization from Andhra University, Visakhapatnam, India in 1976 with distinction. He has been at first position all through his scholarly profession. He was recipient of many scholarships awards including the Fellowship under Indo-US exchange of Scholars, National Merit Scholarship, CSIR Fellowship, IIT Delhi Fellowship etc. His interests include ICT for Development sector, IOT, nano-electronics, high performance computing, innovation and R&D promotion, entrepreneurship development etc. He has published around 40 papers in reviewed journals and conferences in the areas of Information Technology, ICT for development, nano-technology, plasma science etc.