ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 9, Issue 2, Feb 2022

Automatic Computer Propped Diagnosis Framework of Liver Cancer Detection using CNN-LSTM

[1] Mr. Imran Shaikh*, [2] Dr. V.K. Kadam

[1] Department of Electronics and Telecommunication Engineering, Govt. Polytechnic, Osmanabad, India
[2] Associate Professor and HOD (Electronics and Telecommunication), P.E.S. College of Engineering, Aurangabad, India
Corresponding Author Email: [1] shaikh.imran7@gmail.com*, [2] vipulsangram@pescoe.ac.in

Abstract*— Liver cancer detection using the computer vision methods and machine learning already received significant attention of researchers for authentic diagnosis and on-time medical attentions. The Computer Aided Diagnosis (CAD) preferred for cancer detection all over the world which is based on image processing service. Earlier CAD tools were designed using conventional machine learning techniue using semi-automatic approach. The modern growth of deep learning for automatic detection and classification leads to significant improvement in accuracy. This paper the automatic CAD framework for liver cancer detection using Convolutional Neural Network (CNN) including Long Short Term Memory (LSTM). The input Computed Tomography (CT) scan images early pre-processed for quality enhancement. After that we applied the lightweight and accuracy field of Interest (ROI) extraction technique using dynamic binary segmentation. From ROI images, we extracted automated CNN-based appearance and hand-craft features. The consolidation of both features formed unique feature set for classification purpose. The LSTM block is then achieve the classification either into normal or diseased CT image. The CNN-LSTM model is designed in this paper to complement the accuracy of liver cancer detection compared to other deep learning solutions. The experimental results of proposed design using CNN-based features and hybrid hand craft features outperformed the recent state-of-art methods.

***Index Terms*— Computer tomography, computer aided diagnosis, convolutional neural network, deep learning, features extraction, segmentation, and liver cancer**

I. INTRODUCTION

Computers have remain successfully applied to various fields of medical sciences such as biochemical analysis, drug development & recognition of diseases from medical images. Successful identification of lung cancer, brain tumor is desirable with the existing CAD. However, little research has been focused on liver being of the difficulties in segmenting liver from other adjacent abdominal organs such as kidney, stomach & gall bladder using abdominal images due to gray level similarities of adjacent organs. The most prevalent medical imaging studies for early detection & diagnosis of liver diseases include Ultra Sonography (US), Computed Tomography (CT) & Magnetic Resonance Imaging (MRI) [1].

Liver infections are treated appropriately, in light of the fact that liver is crucial essential to the contnuation of a patient. Liver is feasibly the biggest organ in the human body situated in the upper right bit of the mid-region. The liver has numerous significant capacities, such as allowance poisons from the blood, utilizing drugs, blood proteins & produce bile which helps processing [2]. Liver can be forever harmed because of various reasons which incorporate infection contaminations, response because of medications or liquor, tumors, innate conditions & issue with the body's invulnerable framework. Liver infections establish a significant clinical issue of overall extents. Roughly half individuals [3] are influenced by liver sicknesses.

1.1 Liver Cancer In human body after skin the biggest organ is liver. The heaviness of the liver of a grown-up is roughly three pounds. Liver is situated at the right side under the right lung & is ensured by rib confine. Two significant sorts of cells populate the liver projections: parenchymal & non-parenchymal cells. Of these 80% of the liver volume is involved by parenchymal cells generally alluded to as hepatocytes. The human liver & its situation in the human body are displayed in Figure 1.1.

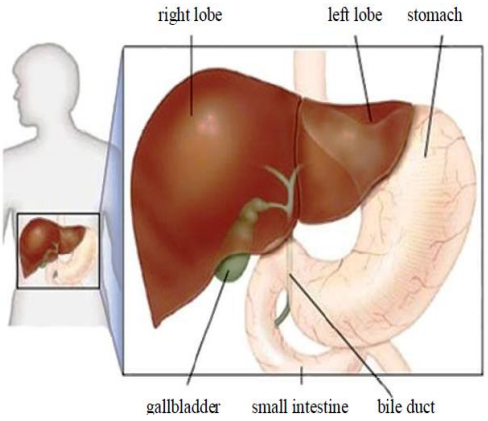

Figure 1.1. Components of human liver

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 9, Issue 2, Feb 2022

Benign tumors: Benign tumors are rarely harmful to life. Unlike malignant if it is once removed it does not generally grow again. It assaults tissues around them & doesn't stretch out to other piece of the body.

Malignant tumors: Malignant is harmful to life. It is very unsafe & grows again even if is detached from the body. It can be fatal for stomach or intestine. Tumor in hepatocytes is called hepatocellular carcinoma (HCC). It is a primary liver cancer. Around 75-90 percent of liver cancer is HCC. There are other primary liver cancers such as cholangiocarcinoma or bile duct cancer, mixed HCC & cholangiocarcinoma tumor of mesenchymal tissue, sarcoma & hepatoblastoma, a rare malignant tumor found in children.

1.1.1 Causes

At the time of diagnosis doctor always cannot explain the causes of the cancer but some probable causes are as follows:

- **Liver Infection:** Development of infections with HBV or HCV leads to liver cancer. It is an outcome of infected blood or unprotected sex. These viruses may be passed through infected mother. Liver cancer is not contagious diseases although HBV & HCV are contagious. This infection does not show any symptom but the presence of virus can be revealed by the blood test. The HBV & HCV vaccine can be used to prevent these viruses.
- **Consumption of heavy alcohol:** Excess intake of alcohol leads to liver cancer & it is extremely harmful. In Western & Asian countries people suffers from the alcoholic liver diseases (ALD). Long term ALD leads to liver cirrhosis & then becomes liver cancer. Due to the alcohol consumption the liver injury & chronic viral hepatitis infection may collectively occur. In western or Asian countries alcoholism is responsible approx. 493,300 deaths & 14,544,000 disability adjusted life years (DALYs). Studies indicate that mortality is higher in men compared to women in between ages of 35 to 64 years old. It occurs around 20% hospitalized alcoholic liver patients undergoing liver biopsy.
- **Aflatoxin:** Aflatoxins, are human liver carcinogens formed due to the fungi (*Aspergillus flavus* & *Aspergillus parasiticus).* Aflatoxins are found in many dietary substances such as maize, groundnuts, rice, & cassava in dry weather planting, high moisture during harvesting, insufficient drying & storage of crops in countries of latitudes between 40o N & 40o S(such as Africa, Southern Asia, India, China). Figure 1.2 shows the Aflatoxins cases across the world. These countries are prone to aflatoxin contamination. In a survey it is found that aflatoxin occurring in maize, groundnuts & sorghum in Africa is higher than the European Union territory.
- **Infections due to iron storage:** It has been investigated that excess intake of iron leads to liver cancer (Hepatocellular carcinoma). Hereditary hemochromatosis(HH) infected patients after getting infected by HCC & it leads to fatal outcome viz death. It has been reflected that HCC develops almost 9% of HH infected patients.
- **Cirrhosis:** The cirrhosis is developed when the liver cells are damaged & changed into the wound tissues. There are many other causes of cirrhosis including HBV or HCV infection, intake of heavy alcohol, certain drugs & parasites. Many people in United States suffer from cirrhosis due to heavy alcohol intake & hepatitis B or C infection. Cirrhosis is a deadly disease that may become liver cancer thereafter.
- **Obesity & diabetes:** Some studies show that the diabetes & obesity may also play vital role in liver cancer.

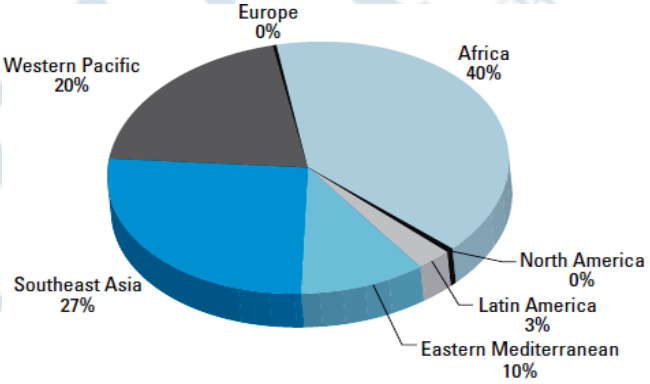

Figure 1.2. HCC cases caused by aflatoxin across the world

1.1.2 Trend in India

During a survey of death rate in liver cancer of 172 countries it was found that the death rate is very low (approx 2.85 in India) to ranking of 156. The liver cancer cases are observed in India between 40 to 70 years however it occurs in two peaks one is at young age between 40 to 55 years & another above 60 year (approximately 99 per 100,000 males). In India total number of cancer cases are about 9,48,858 based on national cancer registry program (NCRP). Apart from skin cancer, total number of liver patients in India is approx 20,000 (2.77% for males & 1.38% for females in 2008. 80% of all HCC incidences caused by the cirrhosis of liver out of that 60% due to the hepatitis B positive carriers). Symptoms of liver cancer are less reflective but dangerous. Normally proper data on epidemiology of HCC is not very clear.

1.1.3 Diagnosis Tools

A. Physical Tests

If there is problem in liver, then doctor investigates whether liver gets enlarged or not by fevering abdomen & verifies color of eyes or nails of being fellowship in nature. Patients who are present with symptoms of liver tumours undergo a thorough medical examination. During the

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 9, Issue 2, Feb 2022

examination, the doctor will carefully evaluate the patient for the following symptoms: (i) Hepatomegaly (enlargement of the liver), (ii) Splenomegaly (enlargement of the spleen), (iii) Ascites (abnormal accumulation of fluid in the abdomen) & (iv) Jaundice.

B. Blood Test

If there is problem in liver, then doctor investigates whether liver gets enlarged or not by fevering abdomen & verifies color of eyes or nails of being fellowship in nature. AFP has to check at an interval of 3-4 months. However, high level of this symptom indicates the liver cancer.

C. Imaging Techniques

The significance of hepatic imaging & the quantity of imaging modalities accessible have expanded impressively in the course of recent many years. This section provides an introduction to the different imaging techniques applied for liver tumour diagnostics. Additionally US can't by & large separate benevolent from harmful liver sores. It isn't pretty much as touchy as CT or Magnetic Resonance Imaging (MRI) Rather than recognizing constriction of X-beams, as in CT, MRI utilizes the attractive properties of protons in hydrogen particles as signs & doesn't include ionizing radiation.

- ***CT Scan:*** It is a non-invasive diagnostic image method in which it is the sequence of X-ray & computer tomography to produce the horizontal, or axial images of the liver. Hence image processing-based research work facilitates in liver cancer treatment. In computer tomography X-ray beam moves in a circle about the body. By this it gives the different view of same organ. CT scans is done with or without “Contrast” (type of material that taken by mouth &/or injected into an intravenous (IV) line that cause liver organ or tissues under supervision to become clearer).
- ***MRI:*** It is also an imaging tool that generates cross sectional images inside the liver. It uses the radiofrequency waves, strong magnets & a computer. It gives infected tissue image clearly. MRI has important role in diagnosis, staging & treatment planning. It can diagnose the diseases on pinpoint level of cancerous cells in the liver. It is also helpful to disclose metastases. It takes typically 30-60 minutes. MRI is very safe because radiation is not used. The contrast injection can cause some side effects such as feeling sick, skin rash, headache etc.
- ***Ultrasound test:*** This method uses ultrasound sound waves. It works on the sound pattern echoes generated by human organs. This echo produces sonogram of liver & in abdomen. Tumor may generate echoes which are different from the normal tissues.

D. Liver Biopsy

The most widely recognized intricacy of liver biopsy is torment, which happens in over 30% of patients. Genuine inconveniences are destined to happen inside 24 hours of the method & 60% happen inside 2 hours; 1% to 3% of patients require delayed hospitalization. The most widely recognized genuine complexity is dying, which may not be proclaimed by torment. Draining from a liver gash can be hazard, bringing about hypotension & shock. The danger of genuine drain is about 0.3% & increments with age, threat in the liver & the quantity of needle passes utilized for biopsy.

- ***A needle though the skin:*** Under guidance of CT or ultrasound small amount of tissue are removed with help of the thin needle.
- **Laparoscopic surgery**: Doctor cuts a small portion in the abdomen & then inserts a thin tube to remove the tissue from the liver.
- **Open Surgery**: If the area of the infected portion is very small, then doctor prefers open surgery whereby through a large cut, the tissue from liver is eliminated.

1.2.4 Therapy

The therapy of liver cancer depends on a variety of factors including the size, number & distribution of tumours. It also depends on the severity of liver disease, the suitability of the patient for liver transplantation, the functional status of the patient & local expertise. The various therapies for liver cancer are:

(i) Liver resection & transplantation,
(ii) Cryosurgery,
(iii) Radiofrequency ablation,
(iv) Hepatic artery chemoembolization,
(v) Percutaneous ethanol injection,
(vi) Percutaneous radio frequency ablation &,
(vii) Cisplatin gel infusion.

1.3 Research Objectives

- To present the significance of CAD solutions for cancer detection.
- To study the liver cancer detection techniques using the various segmentation & feature extraction methods.
- To study & analysis existing liver lesions features for early detection of cancer
- To propose the novel framework to optimize the liver cancer detection performance.
- To propose the liver cancer severity analysis using the dynamic threshold technique.
- To develop & implement computerized module for detection of liver cancer masses using the machine & deep learning classifiers.
- To model, simulate, & evaluate the proposed techniques with state-of-art methods.

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 9, Issue 2, Feb 2022

II. RESEARCH METHODOLOGY

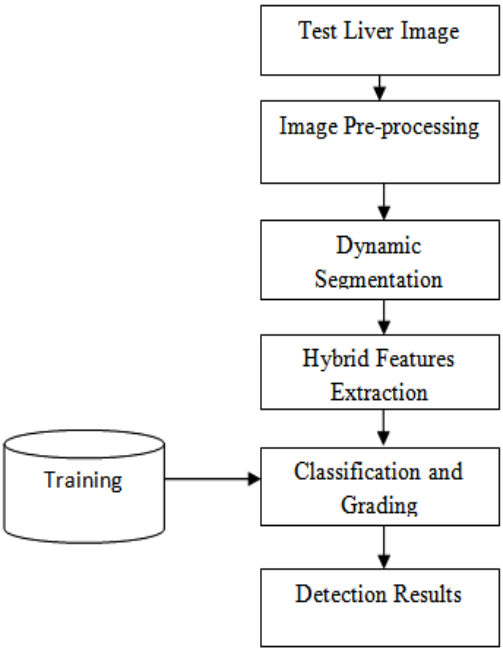

Figure 2.1. Proposed methodology for liver cancer detection & classification

Figure 1.3 shows the proposed research methodology that consists of the below phases such as pre-processing, segmentation, hybrid features extraction, & classification:

Pre-processing: After the CT/MRI image acquisition, image smoothing & normalization are required to improve the detection accuracy. As a basis, a bilateral filter is a non-linear, edge-preserving, & Gaussian noise-reducing filter. The fundamental principle of bilateral filtering is that individual pixel is replaced by a weighted average of its neighbors. In this work, we designed the bilateral filtering technique to perform noise cancellation from the liver image.

Segmentation: The following commitment of this proposition is the utilization of a productive segmentation strategy. Segmentation of the liver from Computed Tomography (CT) volumes assumes a significant part during the decision of treatment methodologies for liver illnesses. Regardless of loads of consideration, liver segmentation stays a difficult undertaking because of the absence of noticeable edges on most limits of the liver combined with high fluctuation of both force examples & anatomical appearances with this load of challenges turning out to be more conspicuous in neurotic livers. We plan the unique segmentation strategy wherein the underlying place of segmentation is progressively chosen which can differ from one image to another dependent on the setting of a specific image. After the segmentation, the Region Of Interest (ROI) is situated for the element extraction.

Features Extraction: Feature extraction is another vital challenge for CAD systems after segmentation. In this work, we introduced multiple feature extraction techniques to include the complete texture features of the segmented liver image such as texture features & automatic Convolutional Neural Network (CNN) features. The fusion of all extracted features used for the classification step.

Classification: We introduce the various classifiers to optimize the classification performance.

III. PROPOSED SYSTEM

This section presents the design of proposed model for automatic liver cancer detection followed by the severity analysis of tumour. Fig. 1 shows the functionality of this model. As showing in fig. 1, the key steps of proposed model includes the ROI extraction, features extraction, classification, and grading. The input CT scan image first acquires into the system, then, pre-processing applied to enhance the quality of image for accurate investigation. The ROI extraction plays the significant role, thus we designed simple and robust mechanism for ROI extraction before applying the feature extraction.

The existing methods perform ROI extraction using deep learning methods; however, it is time consuming process to only segment tumour from input CT image. In this case, it is further required to automatically extract features as well. Hence, rather than applying deep learning for segmentation, we designed computationally efficient approach for ROI extraction without compromising the accuracy. For features extraction, we prefer both hand crafted features and automatic CNN features as using automatic features may not consider the tumour specific features like shape and texture. The hand crafted features and automatic features fused and normalized using min-max technique. For classification purpose, LSTM block designed where the hybrid feature vector is taken as input for classification through the LSTM layers. On the detection of cancer input CT image, its grading performed into either of three stages.

A. Pre-processing: The CT scan devices may not accurate to produce the high quality images for liver diagnosis. Thus for CAD models, the first step is to improve the quality of scanned images by removing the noises, artifacts, low contrast regions. The input CT image C is pre-processed by applying techniques that work adaptively such as intensity values adjustment and median filtering. The first operation focused on adjusting the image intensity values of low contrast CT images

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 9, Issue 2, Feb 2022

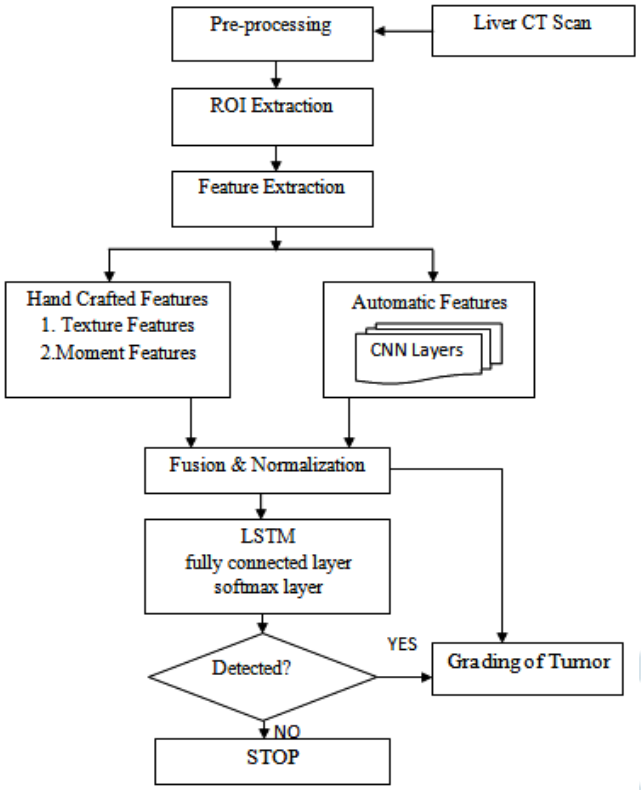

Fig. 3.1 Proposed automatic liver cancer detection and grading analysis

B. ROI Extraction: The extraction of tumor related information from the pre-processed image C^2accurately is important research problem. The conventional techniques suffered from challenges like inaccuracy, over-segmentation, etc. In this paper, we designed the robust but Proper accuray ROI extraction technique using binarization followed by morphological operations. The steps of proposed segmentation are:

- Compute dynamic threshold amount of input pre-processed image C^2
- Apply binary segmentation using computed threshold value of C^2
- Apply morphological structuring element operation using disk size 3 on segmented image
- The structuring element used in morphological closing operation to produce the accurate ROI image C^3
- Return C^3

C. Hand-Crafted Features: Hand-Crafted features widely prefer in domain of pattern recognition systems. There are different types of hand-crafted features in image processing domain. The rich and unique set of features leads to accurate classification and disease analysis. Two types of hand-crafted features are extracted such as texture features using GLCM and moment invariant features. Both features deal with geometry, shape, and texture properties of ROI images. The well-known GLCM technique used to extract 20 features that consist of 16 GLCM features and 4 statistical features. The 4 GLCM properties such as contrast, correlation, energy, and homogeneity computed to get 16 features.

E. Fusion and Normalization*:* After extracting the hand-crafted features (X) and automatic CNN features (Y), we performed the fusion and normalization stage. As the there is significant variations in these hybrid features, features normalization applied for performance improvement. The feature normalization convert all features in range of 0 to 1 using min-max normalization technique.

F. LSTM for Classification: The extracted features of input CT image in V^{norm} vector are then passed to LSTM block for classification. The LSTM block consists of different layers like LSTM layer, Fully Connected Layer and Classification Layer (softmax layer). The LSTM layer layer consists of memory blocks embarrassed by memory cells such as input gate, forget gate, output gate, and peephole connections. The output of LSTM layer is then transfer to fully connected layer where the prediction task performed by mapping the outcome of LSTM layer to the particular output. Fully connected layer takes input as hidden units and output size. The outcome of fully connected layer passed to classification layer where prediction of liver cancer performed.

IV. SIMULATION RESULTS

The simulation results and comparative analysis of proposed model CNN-Fused Normalized-LSTM (CNN-FN-LSTM) using MATLAB tool are presented in this section. The dataset consist of 100 CT scan liver images collected from different sources from Kaggle [28] and Github [29] repositories. 50 images are normal and 50 are liver cancer of different subjects. The performance of proposed model investigated using ANN, SVM, and CNN-FN-LSTM classifiers against the texture features (20 features), moment features (8 features), and normalized-fused features (28 features). The performance compared with proposed automated model CNN-FN-LSTM (we represented as CNN in graphs). In FN block, we varied the texture, moment, and normalized fused texture + moment features for performance investigation. The performance metrics such as accuracy, precision, recall, F1-score, and specificity parameters analyzed.

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 9, Issue 2, Feb 2022

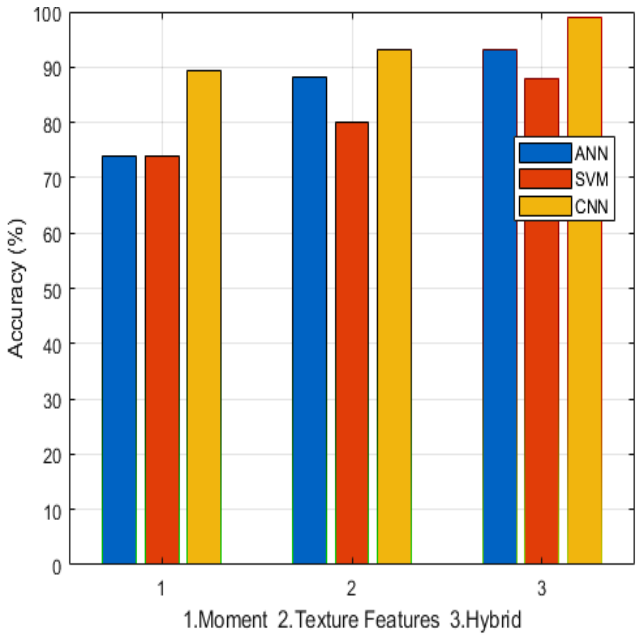

Fig. 2 Accuracy analysis of proposed model

Fig. 2 demonstrates the outcome of accuracy using different classifiers with different set of features. For ANN and SVM, only hand-crafted features were used such as moment, texture, and hybrid. In CNN, the hand-crafted features combined with automatic CNN extracted features. This leads to improvement in accuracy performance compared to both ANN and SVM outcomes significantly. The accuracy of proposed CNN-FN-LSTM using all hand-crafted features is higher compared to all other configurations.

V. CONCLUSION AND FUTURE WORK

The automated CAD model for liver cancer detection and its grading designed in this paper using optimized computer vision techniques and deep learning methods. The detailed design of proposed CNN-FN-LSTM model presented and evaluated. The model consists of pre-processing, ROI extraction, hand-crafted features extraction, automatic CNN features extraction, and LSTM-based classification phases. The design of each phase discussed during this paper. The experimental results shows that CNN-FN-LSTM is improved the performance with respect to parameters such as precision, recall, specificity, accuracy, and F1-score compared to conventional methods. For future work, we suggest to investigate the proposed model with different datasets of other cancers like brain tumour, lung diseases, etc.

VI. ACKNOWLEDGMENT

I would like to express my sincere gratitude towards my guide **Dr. V. K. Kadam** Department of Electronics and Telecommunication for the help, guidance and encouragement, provided during the work. This work would have not been possible without his valuable time, patience and motivation. I thank him for making my study thoroughly pleasant and enriching.

REFERENCES

[1] Nader H. Abdel-massieh, Mohiy M. Hadhoud, Khalid M. Amin, "A Novel Fully Automatic Technique for Liver Tumor Segmentation from CT Scans with knowledge-based constraints", 2010 10th International Conference on Intelligent Systems Design & Applications

[2] Zhang, Xing & Tian, Jie & Deng, Kexin & Wu, Yongfang & Li, Xiuli. (2010). Automatic Liver Segmentation Using a Statistical Shape Model With Optimal Surface Detection. IEEE transactions on bio-medical engineering. 57. 2622-6. 10.1109/TBME.2010.2056369.

[3] Hsu, WT, Yeh, JR, Chang, YC, et al. A computer aided for image processing of computed tomography in hepatocellular carcinoma. In: 2011 IEEE international conference on bioinformatics & biomedicine workshops, BIBMW 2011, Atlanta, GA, 12–15 November 2011, pp.942–944. New York: IEEE.

[4] C. Liu, Y. Huang, J. A. Ozolek, M. G. Hanna, R. Singh & G. K. Rohde, "SetSVM: An Approach to Set Classification in Nuclei-Based Cancer Detection," in IEEE Journal of Biomedical & Health Informatics, vol. 23, no. 1, pp. 351-361, Jan. 2019, doi: 10.1109/JBHI.2018.2803793.

[5] A. F. Abdulgani & M. Al Ahmad, "Label-Free Normal & Cancer Cells Classification Combining Prony's Method & Optical Techniques," in IEEE Access, vol. 8, pp. 32882-32890, 2020, doi: 10.1109/ACCESS.2020.2973468.

[6] Ba Alawi A.E., Saeed A.Y.A., Radman B.M.N., Alzekri B.T. (2021) A Comparative Study on Liver Tumor Detection Using CT Images. In: Saeed F., Mohammed F., Al-Nahari A. (eds) Innovative Systems for Intelligent Health Informatics. IRICT 2020. Lecture Notes on Data Engineering & Communications Technologies, vol 72. Springer, Cham. https://doi.org/10.1007/978-3-030-70713-2_14.

[7] V.Kannan, V.Jagan Naveen 2020. Detection of Liver Cancer Using Image Segmentation . *International Journal of Advanced Science & Technology*. 29, 3 (Apr. 2020), 7067 - 7078.

[8] Todoroki Y., Han XH., Iwamoto Y., Lin L., Hu H., Chen YW. (2018) Detection of Liver Tumour Candidates from CT Images Using Deep Convolutional Neural Networks. In: Chen YW., Tanaka S., Howlett R., Jain L. (eds) Innovation in Medicine & Healthcare 2017. KES-InMed 2018 2017. Smart Innovation, Systems & Technologies, vol 71. Springer, Cham. https://doi.org/10.1007/978-3-319-59397-5_15.

[9] Wang, J., Xu, Z., Pang, ZF. *et al.* Tumour detection for whole slide image of liver based on patch-based convolutional neural network. *Multimed Tools Appl* (2020). https://doi.org/10.1007/s11042-020-09282-x.

[10] E. Trivizakis *et al.*, "Extending 2-D Convolutional Neural Networks to 3-D for Advancing Deep Learning Cancer Classification With Application to MRI Liver Tumour Differentiation," in *IEEE Journal of Biomedical & Health Informatics*, vol. 23, no. 3, pp. 923-930, May 2019, doi: 10.1109/JBHI.2018.2886276.

[11] Eugene Vorontsov, Milena Cerny, Philippe Regnier, Lisa Di Jorio, Christopher J. Pal, Real Lapointe, et al., "Deep Learning for Automated Segmentation of Liver Lesions at CT in Patients with Colorectal Cancer Liver Metastases", *Radiology: Artificial Intelligence*, vol. 1, no. 2, Mar 2019.

[12] Nadja Gruber, Stephan Antholzer, Werner Jaschke, Christian Kremser & Markus Haltmeier, "A Joint Deep Learning Approach for Automated Liver & Tumour Segmentation", Computer Vision & Pattern Recognition, 2019.

[13] Amita Dasa U, Rajendra Achary, S.Panda Soumya & Sukanta Sabut, "Deep learning based liver cancer detection using watershed transform & Gaussian mixture model techniques", *Cognitive Systems Research Elsevier*, vol. 54, pp. 165-175, May 2019.

[14] Umit Budak, Yanhui Guo, Erkan Tanyildizi & Abdulkadir Sengur, "Cascaded deep convolutional encoder-decoder neural networks for efficient liver tumor segmentation", *Medical Hypotheses*, vol. 134, pp. 109431, January 2020.

[15] C. Sun, A. Xu, D. Liu, Z. Xiong, F. Zhao & W. Ding, "Deep Learning-Based Classification of Liver Cancer Histopathology Images Using Only Global Labels," in IEEE Journal of Biomedical & Health Informatics, vol. 24, no. 6, pp. 1643-1651, June 2020, doi: 10.1109/JBHI.2019.2949837.

[16] E. Trivizakis et al., "Extending 2-D Convolutional Neural Networks to 3-D for Advancing Deep Learning Cancer Classification With Application to MRI Liver Tumor Differentiation," in IEEE Journal of Biomedical & Health Informatics, vol. 23, no. 3, pp. 923-930, May 2019, doi: 10.1109/JBHI.2018.2886276.

[17] X. Dong, Y. Zhou, L. Wang, J. Peng, Y. Lou & Y. Fan, "Liver Cancer Detection Using Hybridized Fully Convolutional Neural Network Based on Deep Learning Framework," in IEEE Access, vol. 8, pp. 129889-129898, 2020, doi: 10.1109/ACCESS.2020.3006362.

[18] L. Balagourouchetty, J. K. Pragatheeswaran, B. Pottakkat & G. Ramkumar, "GoogLeNet-Based Ensemble FCNet Classifier for Focal Liver Lesion Diagnosis," in IEEE Journal of Biomedical & Health Informatics, vol. 24, no. 6, pp. 1686-1694, June 2020, doi: 10.1109/JBHI.2019.2942774.

[19] Zhen, S., Cheng, M., Tao, Y., Wang, Y., Juengpanich, S., Jiang, Z., … Cai, X. (2020). Deep Learning for Accurate Diagnosis of Liver Tumor Based on Magnetic Resonance Imaging & Clinical Data. Frontiers in Oncology, 10. doi:10.3389/fonc.2020.00680.

[20] Azer S. A. (2019). Deep learning with convolutional neural networks for identification of liver masses & hepatocellular carcinoma: A systematic review. World journal of gastrointestinal oncology, 11(12), 1218–1230. https://doi.org/10.4251/wjgo.v11.i12.1218.

[21] Chen, M., Zhang, B., Topatana, W. *et al.* Classification & mutation prediction based on histopathology H&E images in liver cancer using deep learning. *npj Precis. Onc.* **4,** 14 (2020). https://doi.org/10.1038/s41698-020-0120-3.

[22] PATSADU, O. ., TANGCHITWILAIKUN, P. ., & LOWSUWANKUL, S. . (2021). Liver Cancer Patient Classification on a Multiple-Stage using Hybrid Classification Methods. *Walailak Journal of Science & Technology (WJST)*, *18*(10), Article 9169 (14 pages). https://doi.org/10.48048/wjst.2021.9169.

[23] Ayalew, Y.A., Fante, K.A. & Mohammed, M. Modified U-Net for liver cancer segmentation from computed tomography images with a new class balancing method. *BMC biomed eng* **3,** 4 (2021).

[24] Yang, B., Zhang, B., Xu, Y. *et al.* Prospective study of early detection for primary liver cancer. *J Cancer Res ClinOncol***123,** 357–360 (1997). https://doi.org/10.1007/BF01438313.

[25] Yoshida, H., Yoshida, H., Shiina, S. *et al.* Early liver cancer: concepts, diagnosis, and management. *Int J ClinOncol***10,** 384–390 (2005). https://doi.org/10.1007/s10147-005-0537-2.

[26] Donato, F., Gelatti, U., Chiesa, R. *et al.* A case–control study on family history of liver cancer as a risk factor for hepatocellular carcinoma in North Italy. *Cancer Causes Control***10,** 417–421 (1999). https://doi.org/10.1023/A:1008989103809.

[27] Llovet, J.M. Treatment of hepatocellular carcinoma. *Curr Treat Options Gastro***7,** 431–441 (2004). https://doi.org/10.1007/s11938-004-0002-8.

[28] Badura P., Pietka E. (2012) 3D Fuzzy Liver Tumour Segmentation. In: Piętka E., Kawa J. (eds) Information Technologies in Biomedicine. Lecture Notes in Computer Science, vol 7339. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-31196-3_5.

[29] Pan, Q., Zhang, L., Xia, L., Wang, H., and Li, H., "Liver tumour segmentation based on level set", in Tenth International Conference on Digital Image Processing (ICDIP 2018), 2018, vol. 10806. doi:10.1117/12.2502810.

[30] M. Rela, N. R. Suryakari and P. R. Reddy, "Liver Tumour Segmentation and Classification: A Systematic Review," *2020 IEEE-HYDCON*, Hyderabad, India, 2020, pp. 1-6, doi: 10.1109/HYDCON48903.2020.9242757.

[31] AkifDogantekin, FatihOzyurt, EnginAvci and Mustafa Koc, "A novel approach for liver image classification: PH-C-ELM", *Measurement*, vol. 137, pp. 332-338, April 2019.

[32] Ahmed M. Anter and Aboul Ella Hassenian, "Computational intelligence optimization approach based on particle swarm optimizer and neutrosophic set for abdominal CT liver tumour segmentation", *Journal of Computational Science Elsevier*, vol. 25, pp. 376-387, March 2018.

[33] Ahmed M. Anter and Aboul Ella Hassenian, "CT liver tumour segmentation hybrid approach using neutrosophic sets fast fuzzy c-means and adaptive watershed algorithm", *Artificial Intelligence in Medicine Elsevier*, vol. 97, pp. 105-117, June 2019.

[34] Chin-Chen Chang, Hong-Hao Chen, Yeun-Chung Chang, Ming-Yang Yang, hung-Ming Lo, Wei-Chun Ko, et al., "Computer-aided diagnosis of liver tumours on computed tomography images", *Computer Methods and Programs in Biomedicine Elsevier*, vol. 145, pp. 45-51, July 2017.

[35] Zhihua Liu, Long Chen, Lei Tong et.al. "Deep Learning Based Brain Tumour Segmentation: A Survey," Electrical Engineering and Systems Science, Image and Video Processing, 21 Jul 2020.

[36] Todoroki Y., Han XH., Iwamoto Y., Lin L., Hu H., Chen YW. (2018) Detection of Liver Tumour Candidates from CT Images Using Deep Convolutional Neural Networks. In: Chen YW., Tanaka S., Howlett R., Jain L. (eds) Innovation in Medicine and Healthcare 2017. KES-InMed 2018 2017. Smart Innovation, Systems and Technologies, vol 71. Springer, Cham. https://doi.org/10.1007/978-3-319-59397-5_15.

[37] Wang, J., Xu, Z., Pang, ZF. *et al.*Tumour detection for whole slide image of liver based on patch-based convolutional neural network. *Multimed Tools Appl* (2020) https://doi.org/10.1007/s11042-020-09282-x.

[38] E. Trivizakis*et al.*, "Extending 2-D Convolutional Neural Networks to 3-D for Advancing Deep Learning Cancer Classification With Application to MRI Liver Tumour Differentiation," in *IEEE Journal of Biomedical and Health*

Informatics, vol. 23, no. 3, pp. 923-930, May 2019, doi: 10.1109/JBHI.2018.2886276.

[39] Eugene Vorontsov, Milena Cerny, Philippe Regnier, Lisa Di Jorio, Christopher J. Pal, Real Lapointe, et al., "Deep Learning for Automated Segmentation of Liver Lesions at CT in Patients with Colorectal Cancer Liver Metastases", *Radiology: Artificial Intelligence*, vol. 1, no. 2, Mar 2019.

[40] Nadja Gruber, Stephan Antholzer, Werner Jaschke, Christian Kremser and Markus Haltmeier, "A Joint Deep Learning Approach for Automated Liver and Tumour Segmentation", Computer Vision and Pattern Recognition, 2019.

[41] AmitaDasa U, RajendraAchary, S.PandaSoumya and SukantaSabut, "Deep learning based liver cancer detection using watershed transform and Gaussian mixture model techniques", *Cognitive Systems Research Elsevier*, vol. 54, pp. 165-175, May 2019.

[42] UmitBudak, YanhuiGuo, ErkanTanyildizi and AbdulkadirSengur, "Cascaded deep convolutional encoder-decoder neural networks for efficient liver tumor segmentation", *Medical Hypotheses*, vol. 134, pp. 109431, January 2020.

[43] Dong, X., Zhou, Y., Wang, L., Peng, J., Lou, Y., & Fan, Y. (2020). Liver Cancer Detection using Hybridized Fully Convolutional Neural Network based on Deep learning framework. IEEE Access, 1–1. doi:10.1109/access.2020.3006362.

[44] Mahajan, H.B., Badarla, A. &Junnarkar, A.A. (2020). CL-IoT: cross-layer Internet of Things protocol for intelligent manufacturing of smart farming. J Ambient Intell Human Comput. https://doi.org/10.1007/s12652-020-02502-0.

[45] Mahajan, H.B., &Badarla, A. (2018). Application of Internet of Things for Smart Precision Farming: Solutions and Challenges. International Journal of Advanced Science and Technology, Vol. Dec. 2018, PP. 37-45.