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Auto-WCEBleedGen Version V1 and V2: Challenge, Datasets and Evaluation

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Abstract In this document, we provide an overview of the Auto-WCEBleedGen Version V1 and V2. The challenge V1 was organized virtually by MISAHUB (Medical Imaging and Signal Analysis) in collaboration with the 8th International CVIP 2023 (Conference on Computer Vision and Image Processing) from August 15 - November 11, 2023. The challenge V2 was organized virtually by MISAHUB in collaboration with the 31st IEEE ICIP 2024 (International Conference on Image Processing) from January 20 - March 6, 2024. The document contains information about the need of this challenge, datasets utilized, and winners of challenge V1 and V2. We also release the benchmark-evaluation of classification, detection, and segmentation tasks for the WCEBleedGen dataset (training data).

Keywords Biomedical Challenge · Bleeding · Open-source datasets

1 Introduction

Gastrointestinal (GI) bleeding is a medical condition characterized by bleeding in the GI tract, which circumscribes oesophagus, stomach, small intestine, large intestine (colon), rectum, and anus [1]. Since blood flows into the GI tract, a cascade of risks emerges, ranging from immediate dangers to potential long-term consequences. Excessive blood loss from GI bleeding may lead to a drop in blood pressure, reduced oxygen delivery to organs and tissues, and potentially life-threatening organ dysfunction [2].

According to World Health Organization (WHO), GI bleeding is responsible for approximately 300,000 deaths every year globally [3]. These statistics serve as a catalyst for research, propelling innovative treatment modalities and diagnostic advancements aimed at mitigating the dangers posed by GI bleeding. In last decade, the availability of advanced diagnostic innovations like Wireless Capsule Endoscopy (WCE) has led to better understanding of the GI bleeding in GI tract. The disposable capsule-shaped device travels inside the GI tract via peristalsis and comprises of an optical dome, a battery, an illuminator, an imaging sensor, and a radio-frequency transmitter.

During 8-12 hours of WCE procedure, a video of the GI tract trajectory is recorded on a device attached to the patient's belt which produces about 57,000-100,000 frames; analysed posterior by experienced gastroenterologists [4]. Presently, an experienced gastroenterologist takes approximately 2−3 hours to inspect the captured video of one-patient through a frame-by-frame analysis which is not only time-consuming but also susceptible to human error. In view of the poor ratio of patient-to-doctor across globe, there arises a need for investigation and state-of-the-art development of robust, interpretable and generalized Artificial Intelligence (AI) models that can aid in reducing the burden on gastroenterologists and save their valuable time by computer-aided classification, detection, and segmentation of bleeding and non-bleeding frames in WCE.

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Due to the lack of dedicated WCE datasets for computer-aided classification, detection, and segmentation of bleeding and non-bleeding frames in WCE, different lesions such as angioectasia, ulcers, polyps, etc which may cause bleeding have been included in automated pipelines of bleeding frames [5]. In addition, WCE-based bleeding frames with annotations have been scarcely available in existing datasets of WCE (see Table 1). For a robust, interpretable and generalized AI tasks, a dedicated dataset which only contains bleeding and non-bleeding WCE frames is essential.

Based on the above discussed research problems, Auto-WCEBleedGen challenge V1 was organized virtually, by MISAHUB (Medical Imaging and Signal Analysis) in collaboration with the 8th International CVIP 2023 (Conference on Computer Vision and Image Processing) from August 15 - November 11, 2023. The challenge V1 focused on automatic classification between bleeding and non-bleeding frames and further detection of bleeding region in that frame. A new, first-of-its-kind training dataset called the WCEBleedGen (version V1) and testing datasets called the AutoWCEBleedGen-Test were developed.

The training dataset comprised of 2618 bleeding and non-bleeding WCE frames. They were collected from multiple internet resources, datasets with a vast variety and types of GI bleeding throughout the GI tract (see Table 2). Fig. 1 depicts the dataset preparation method. Fig. 2 depicts the frames available in the training dataset. They were medically validated with the help of experienced gastroenterologists. Processed frames with binary masks and bounding boxes in three formats (txt, XML, and YOLO txt) were released for the training dataset.

The test dataset was an independently collected WCE data containing bleeding and non-bleeding frames of more than 30 patients suffering from acute, chronic, and occult GI bleeding referred at the Department of Gastroenterology and HNU, All India Institute of Medical Sciences (AIIMS) New Delhi, India. It was only accessible to challenge participants and shared through Google drive link throughout the challenge V1. It consisted of a total 564 frames. It was divided into dataset 1 and 2 (see Fig. 3 and 4). Test dataset 1 contained 49 frames which were randomly collected from seven different patient's data at AIIMS New Delhi. The frames were then annotated by a group of experienced gastroenterologists at AIIMS New Delhi. The annotations were marked in the frames. The test dataset 2 contained 515 frames which were collected from twenty-three different patient's data. The annotations were not marked in the frames. A list of frame names with respect to patient were released for the challenge participants. Test dataset 1 was developed for non-sequential, random frame analysis. Test dataset 2 was developed for sequential-frame analysis. After the challenge V1, the test dataset was improved and released on November 14, 2023 at zenedo platform. Binary masks of dataset 1 and 2 were developed and the un-marked frames of dataset 1 were added in this version.

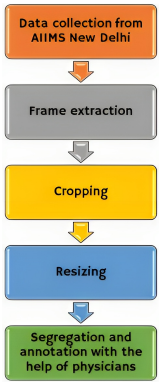

Fig. 1 Dataset preparation method.

Fig. 2 Training dataset (a) Bleeding WCE frames (b) Non-bleeding WCE frames

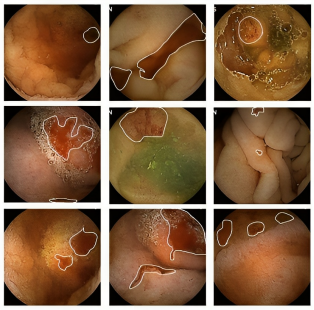

Fig. 3 WCE frames in test dataset 1.

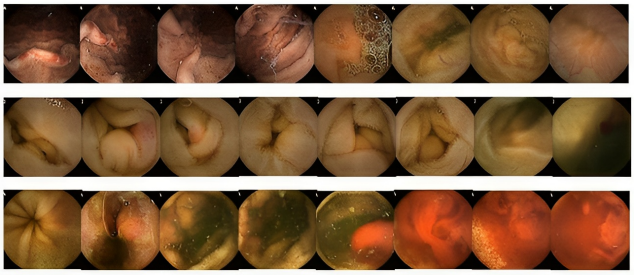

Fig. 4 WCE frames in test dataset 2.

Table 1 Existing, open-source wireless capsule endoscopy dataset details till 2022.

Dataset name	Year	Size	No.of bleeding images	Dimension	Cross-side variability	Data Augmented images	Labels
Set 1 (red lesions) and Set 2 (bleeding and non-bleeding)	2017	506 MB	448	320×320, 512×512	Yes	No	Binary masks (red lesions only)
Gastrolab image gallery (multiple anomalies)	-	3 GB	Variable	Variable	Yes	No	-
Kvasir capsule (multiple anomalies)	2021	89 GB	458	336×336	No	No	Class labels, Bounding boxes
KID (multiple anomalies)	2014	335 MB	5	320×320	No	No	Class labels, binary masks
Farah deeba (only bleeding)	2016	1.04 MB	50	568×430	No	No	Binary masks
EndoSLAM dataset	2020	23.2 GB	-	-	No	No	-
VRCaps (synthetic data development)	2020	-	-	-	-	-	-
WCEBleedGen dataset (bleeding and non-bleeding)	2023	168 MB	1309	224×224	Yes	Yes (release 2)	Class labels, binary masks, and bounding box

Table 2 WCEBleedGen dataset details.

Type of data	Original source	Image S.No.	Total No.	Binary mask availability (previously)
Bleeding	1. Set-2 data	1-152	152	yes
	2. farah deeba data	153-202	50	yes
	3. KID	203-207	5	yes
	4. kvasir capsule (fresh blood)	208-650	443	no, matrix given
	5. kvasir capsule (hematin blood)	651-660	10	no, matrix given
	6. Self collected (YouTube video 1 and 2)	661-952	292	no
	7. Gastrolab	953-1309	357	no
	Total bleeding images and annotations =		1309	
Non-bleeding	1. Set-1 data	1-500	500	no
	2. Set-2 data	501-580	80	no
	3. Self collected (YouTube video)	581-761	181	no
	4. Gastrolab	762-1309	548	no
	Total non-bleeding images and annotations =		1309	

The challenge V1 was a huge success with 378 team registrations across the globe. Following its success, a proposal for the challenge V2 was submitted to the 31st IEEE ICIP 2024 (International Conference on Image Processing). Upon approval, it was organized virtually from January 20 - March 6, 2024. The challenge V2 focused on automatic classification between bleeding and non-bleeding frames and further detection and segmentation of bleeding region in that frame. Updated training dataset called the WCEbleedGen (version V2) and test datasets called the AutoWCEBleedGen-Test (version V2) were released for the challenge V2.

The training dataset comprised of the same frames (2618 in no.) as were present in the version V1. However, the multiple bleeding frames were re-annotated. Their new XML and YOLO-TXT were also added in this version (V2). For the test dataset, an improved version of the AutoWCEBleedGen-Test (version V1) was developed. This version contained medically annotated bounding boxes in three different formats (txt, XML and YOLO txt).

Statistical summary of total views and downloads of the training dataset on Zenodo as on February 23, 2024:

- Release Date - January 18, 2023 (Version V1) , November 19, 2023 (Version V2)
- Total views - 2077
- Total Downloads - 1216

Statistical summary of total views and downloads of the testing dataset on Zenodo as on February 23, 2024:

- Release Date - November 14, 2023 (Version V1), February 11, 2024 (Version V2)
- Total views - 293
- Total Downloads - 114

2 Auto-WCEBleedGen Challenge Version V1

The challenge page is available here. The target audience, important dates, registration and rules have been mentioned on the challenge page.

2.1 Prizes

- Exciting cash prizes were sponsored by Intec Infonet and iHUB DivyaSampark
- Free registration to top-5 teams in CVIP 2023 and goodies by CVIP 2023, IIT Jammu and DST-SERB
- Winter internship opportunity at MISAHUB
- Paper writing collaboration
- E-certificate to each participant

2.2 Winners

A total of 378 team registrations were received for the challenge, originating from both within and outside India. Among these, 8 teams demonstrated remarkable outcomes, as listed in Table 3. The felicitation event pictures, winner presentations, and statistics were released here.

3 Auto-WCEBleedGen Challenge Version V2

The challenge page is available here. All details are available on the challenge page. The target audience, important dates, registration and rules have been mentioned on the challenge page.

3.1 Prizes

- Presentation by the winning team (1st runner-up only) in ICIP 2024.
- E-presentation-video and e-certificates to top three winning teams.
- Paper writing collaboration.
- E-certificate to each participant.

Table 3 Team positions and affiliations in challenge V1.

S.No.	Position	Team name	Affiliation
1	First Position	Failed Wizards	Indian Institute of Technology, Tirupati
2	Second Position	DeepNet	Jawaharlal Nehru University, New Delhi
3	Third Position	KU Researchers	Khalifa University & Halcon Systems LLC (UAE)
4	Consolation	The Coders	Jawaharlal Nehru University, New Delhi
5	Consolation	PRIA	IIT Indore, VIT Chennai, and Thapar Institute of Engineering and Technology
6	Consolation	SSSIHLDMACS	Sri Sathya Sai Institute of Higher Learning
7	Consolation	Colorlab	Norwegian University of Science and Technology (Norway)
8	Consolation	NGBU	Tata Elxsi

Table 4 Team positions and affiliations in challenge V2.

S.No.	Position	Team name	Affiliation
1	First Position	ColonNet	Indian Institute of Information Technology, Ranchi
2	Second Position	ACVLab	Institute of Data Science, National Cheng Kung University, Taiwan
3	Third Position	Failed Wizards	Indian Institute of Technology, Tirupati

3.2 Winners

A total of 75 team registrations were received for the challenge, originating from both within and outside India. Among these, 3 teams demonstrated remarkable outcomes, as listed in Table 4.

4 Benchmark-evaluation of WCEBleedGen (training dataset)

The MISAHUB research team conducted an evaluation of the training dataset using vanilla AI models. The dataset was randomly divided into a 70-20-10 ratio for training, validation, and testing purposes. Ten AI models underwent training for 250 epochs and were subsequently assessed on the 10% test subset of the dataset for classification task. Similarly, three AI models each were trained and evaluated for detection and segmentation tasks. No augmentation nor hyper-parameter tuning was performed in any of the AI tasks. All the codes were implemented using Python with TensorFlow in the back end on four port 40 GB DGX A100 NVIDIA workstation with a pre-installed Ubuntu Linux-based system. Table 5, 6, 7, 8, 9, and 10 details the achieved results for each of the AI task. The AI model weights and the codes will be released in due time. These results will help researchers to compare their achieved evaluation metrics with the bench-marked values and further improve on them.

Acknowledgements

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Declarations

- Conflict of Interest/Competing Interest: The authors declare no personal, academic, or financial conflicts of interest associated with this document.
- Consent and ethics approval: All the videos and extracted image frames were anonymised in the test data and all the information related to the patient was removed. The data, its preparation, and study was done according to Helsinki declarations and was approved by the Department of Gastroenterology and HNU, AIIMS Delhi ethics committee (Ref. No.: IEC-666/05.08.2022). A waiver of consent was granted.
- Availability of data and material:
  - Link to WCEBleedGen Training dataset Version V1
  - Link to WCEBleedGen Training dataset Version V2
  - Link to AutoWCEBleedGen-Test dataset Version V1
  - Link to AutoWCEBleedGen-Test dataset Version V2
- Code availability: It will be released on the Github profile of MISAHUB in due time.

Table 5 Performance metrics for the classification of bleeding and non-bleeding frames in the training and validation data of the WCEBleedGen data with 70-20-10 split.

Type of data	Evaluation Metrics	ResNet101V2	InceptionV3	DenseNet169	ConvNeXT	Xception	VGG19	NasNetMobile	MobileNet	Inception ResNetV2	EfficientNetB7
For training data	Accuracy (average of 250 epochs)	0.99	0.97	0.99	0.95	0.99	0.99	0.99	0.99	0.99	0.53
	Accuracy (last epoch)	1	0.99	1	0.96	1	1	1	1	1	0.53
	Loss (average of 250 epochs)	0.014	0.089	0.009	0.18	0.004	0.008	0.006	0.004	0.005	5.02
	Loss (last epoch)	3.25e-10	0.009	4.85e-08	0.15	3.16e-08	2.70e-06	1.45e-07	6.77e-09	8.73e-08	5.47
For validation data	Accuracy (average of 250 epochs)	0.47	0.50	0.50	0.58	0.55	0.78	0.48	0.52	0.52	0.51
	Accuracy (last epoch)	0.47	0.50	0.50	0.57	0.56	0.78	0.48	0.52	0.52	0.53
	Loss (average of 250 epochs)	636.05	84.39	44.81	10.37	112.91	30.07	36.50	6.46	223.93	7.40
	Loss (last epoch)	637.06	130.15	46	16.71	107.6	43.98	46.72	6.93	209.77	9.28

Table 6 Performance metrics for the classification of bleeding and non-bleeding frames in the test set of the WCEBleedGen dataset (10% subset in 70-20-10 split).

Evaluation Metrics	ConvNeXt	VGG19	EfficientNetB7	MobileNetV2	DenseNet169	Inception ResNetV2	InceptionV3	NasNetMobile	Xception	ResNet101V2
Precision (macro average)	0.37	0.63	0.63	0.25	0.25	0.37	0.63	0.28	0.57	0.52
Precision (weighted average)	0.37	0.63	0.63	0.25	0.25	0.37	0.63	0.28	0.57	0.52
Recall (macro average)	0.38	0.60	0.63	0.50	0.50	0.39	0.52	0.40	0.53	0.52
Recall (weighted average)	0.38	0.60	0.63	0.50	0.50	0.39	0.52	0.40	0.51	0.52
F1-score (macro average)	0.36	0.58	0.63	0.33	0.33	0.36	0.38	0.31	0.43	0.51
F1-score (weighted average)	0.36	0.58	0.63	0.33	0.33	0.36	0.38	0.31	0.42	0.51

Table 7 Performance metrics for the detection of bleeding region in the training and validation data of the WCEBleedGen dataset with 70-20-10 split.

Type of Data	Evaluation Metrics	YOLOv5nu	YOLOv8n	YOLOv8x
For Training Data	Box Loss (Avg of 250 epochs)	1.19	1.15	1.26
	Classification Loss (Avg of 250 epochs)	1.27	1.22	1.45
	Distribution Focal Loss (Avg of 250 epochs)	1.46	1.44	1.58
	Box Loss (Last epoch)	0.84	0.80	0.81
	Classification Loss (Last epoch)	0.67	0.66	0.72
	Distribution Focal Loss (Last epoch)	1.22	1.19	1.26
For Validation Data	Box Loss (Avg of 250 epochs)	1.77	1.79	1.73
	Classification Loss (Avg of 250 epochs)	1.70	1.68	1.78
	Distribution Focal Loss (Avg of 250 epochs)	1.99	2.03	3.73
	Box Loss (Last epoch)	1.80	1.84	1.67
	Classification Loss (Last epoch)	1.40	1.44	1.48
	Distribution Focal Loss (Last epoch)	2.05	2.18	2.04
	Precision (Avg of 250 epochs)	0.61	0.62	0.54
	Recall (Avg of 250 epochs)	0.54	0.55	0.49
	Mean Average Precision@50 (Avg of 250 epochs)	0.56	0.57	0.49
	Mean Average Precision@95 (Avg of 250 epochs)	0.28	0.28	0.25
	Precision (Last epoch)	0.69	0.67	0.65
	Recall (Last epoch)	0.62	0.62	0.59
	Mean Average Precision@50 (Last epoch)	0.64	0.65	0.61
	Mean Average Precision@95 (Last epoch)	0.33	0.33	0.33

Table 8 Performance metrics for the detection of bleeding region in the test set of the WCEBleedGen dataset (10% subset, 70-20-10 split).

Evaluation Metrics	YOLOv5nu	YOLOv8n	YOLOv8x
Precision	0.68	0.69	0.65
Recall	0.64	0.56	0.59
Mean Average Precision@50	0.63	0.63	0.59
Mean Average Precision@95	0.35	0.36	0.30

Table 9 Performance metrics for the segmentation of bleeding region in the training and validation data of the WCEBleedGen dataset (70-20-10 split).

Type of Data	Evaluation Metrics	Linknet	Segnet	Unet
For Training Data	Accuracy (Avg of 250 epochs)	0.99	0.98	0.98
	Dice Coefficient (Avg of 250 epochs)	0.93	0.46	0.83
	Intersection over Union (Avg of 250 epochs)	0.89	0.31	0.73
	Loss (Avg of 250 epochs)	0.01	0.27	0.05
	Precision (Avg of 250 epochs)	0.96	0.91	0.92
	Recall (Avg of 250 epochs)	0.99	0.97	0.92
	Accuracy (Last epoch)	0.99	0.99	0.99
	Dice Coefficient (Last epoch)	0.98	0.64	0.95
	Intersection over Union (Last epoch)	0.97	0.47	0.90
	Loss (Last epoch)	0.004	0.11	0.01
	Precision (Last epoch)	0.99	0.98	0.96
	Recall (Last epoch)	0.99	0.98	0.96
For Validation Data	Accuracy (Avg of 250 epochs)	0.97	0.97	0.96
	Dice Coefficient (Avg of 250 epochs)	0.87	0.46	0.77
	Intersection over Union (Avg of 250 epochs)	0.80	0.31	0.65
	Loss (Avg of 250 epochs)	0.06	0.28	0.10
	Precision (Avg of 250 epochs)	0.89	0.88	0.87
	Recall (Avg of 250 epochs)	0.90	0.91	0.82
	Accuracy (Last epoch)	0.98	0.99	0.97
	Dice Coefficient (Last epoch)	0.95	0.65	0.88
	Intersection over Union (Last epoch)	0.90	0.48	0.80
	Loss (Last epoch)	0.04	0.11	0.07
	Precision (Last epoch)	0.93	0.95	0.93
	Recall (Last epoch)	0.97	0.98	0.86

Table 10 Performance metrics for the segmentation of bleeding region in the test set of the WCEBleedGen dataset (10% subset, 70-20-10 split).

Evaluation Metrics	Linknet	SegNet	Unet
Accuracy	0.98	0.99	0.97
Recall	0.97	0.98	0.87
Precision	0.92	0.95	0.93
Intersection over Union	0.90	0.50	0.79
Dice Coefficient	0.94	0.65	0.88

– Both the challenges are a part of the on-going DST-SERB's research project no. CRG/2022/001755. Related work by MISAHUB research team include [4], [6], [7], [8], [9], and [10]. Link for MISAHUB website, Google Scholar
– This document may be used for citation purposes of the challenge, released datasets, and its related information.

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