Simple Automated Verification of Field Size Indicator for Quality Assurance of Medical Linear Accelerator

by Eko Hidayanto

Submission date: 13-Jun-2022 09:26AM (UTC+0700)
Submission ID: 1855666264
File name: ndicator_for_Quality_Assurance_of_Medical_Linear_Accelerator.pdf (258.1K)
Word count: 3328
Character count: 16497

International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST22922

Simple Automated Verification of Field Size Indicator for Quality Assurance of Medical Linear Accelerator

Siti Hanan[1], Choirul Anam*[1], Eko Hidayanto[1]

[1]Department of Physics, Faculty of Sciences and Mathematics, Diponegoro University, Jl. Prof. Soedarto SH, Tembalang, Semarang 50275, Central Java, Indonesia

Article Info

Volume 9, Issue 2

Page Number : 55-60

Publication Issue

March-April-2022

Article History

Accepted : 05 March 2022

Published : 15 March 2022

ABSTRACT

Purpose: The purpose of this study is to automate the field size verification to facilitate mechanical check aspect medical linear accelerator (linac) quality assurance in a MATLAB-based algorithm on electronic portal imaging device (EPID) images.

Methods: A total of 5 reference datasets (i.e. field sizes of 5 cm × 5 cm, 10 cm × 10 cm, 15 cm × 15 cm, 20 cm × 20 cm, and 25 cm × 25 cm) and 15 test datasets (i.e. reference field sizes plus 1 mm, 3 mm, and 5 mm increments) acquired by 6 MV Elekta Linac were used in this study. The proposed algorithm implemented a full automatic threshold with a value of 230 as a segmentation technique. The automated results were compared with manual results obtained using a ruler.

Results: The automated results are comparable to manual results (i.e., the difference of both is within 2% or equal to 3 mm). The range of minimum to maximum difference between automated and manual was 0 - 3 mm and the maximum difference found in the 15.3 cm field size setting.

Conclusions: We have successfully developed an automated procedure of field size verification and confirmed that the proposed algorithm provide a fast and accurate results.

Keywords: Collimator, Field Size Indicator, Linear Accelerator, Quality Assurance, Radiotherapy

I. INTRODUCTION

The international growth in the number of cancer and deaths worldwide caused by cancer encourages the stakeholders to take into consideration the most efficacious treatment techniques and modalities [1-3]. Since the potential of radiation was discovered in the late 1890s, scientific and technological developments regarding the use of high-energy ionizing radiation to kill cancer cells rapidly followed this discovery, and it led to radiotherapy [4]. At the time, the progress was focused on the construction of innovative radio-therapeutic modalities [5]. The first medical linear accelerator (linac) was used to treat patients by delivering megavoltage X-rays in early of 1950s [6]. Nowadays, design, components, safety and control features of medical linac have evolved in order to provide stable, reliable, flexible, and cost-effective radiotherapy treatment modality [6-8].

Copyright: © the author(s), publisher and licensee Technoscience Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited

Radiotherapy has been an effective treatment for many cancers. In order to meet the goal of radiotherapy, it is crucial to monitor the performance of all medical linac components. The medical linac must be controlled periodically to assure that performance parameters have not deviated from their baseline value in accordance with the time of the device acceptance. For the purpose of quality assurance (QA) of medical linac, the American Association of Physicists in Medicine (AAPM) issued the report Task Group 40 (TG-40) [9]. In 2009, AAPM released an update of TG-40 in TG-142 [10]. Dosimetry, mechanical, safety, and respiratory gating aspect were included in the QA procedure. However, there are certain aspects of the QA procedure that occasionally followed further exploration as needed to ensure that users can perform QA efficiently and identify the errors [11]. The collimator is included in the linac equipment that needs to be checked periodically.

Field size and its shape are crucial in accurately dose delivery in radiotherapy. A conventional treatment machine shapes the radiation field by a set of dense metal collimator and configures into rectangular fields. A combination of these collimator jaws and secondary customized blocks produces the desired radiation beam [12]. In consequence, most recommendations for QA of medical linac require verification of collimator field size indicator. AAPM suggested that the field size indicators are checked monthly by comparing the indicated field size to the measured value on QA BeamChecker Plus or a graph paper [9, 10].

The current field size indicator QA at Ken Saras Hospital, Central Java, Indonesia, is performed using a print-out of electronic portal imaging device (EPID) images to identify the errors manually using a ruler. The manual observation can be less accurate, time-consuming, and not practically performed as a routine test in clinics. Conversely, using commercially available QA software (i.e Siemens Medical Solutions) leads to increase in substantial funds. Previous researchers developed software or methods for the purpose of field size QA programs [13, 14]. Abdallah and Boshara [13] used texture analysis to assess 10 cm × 10 cm field size from a radiographic film image [13]. The computerized assessments were then compared to manual measurements. Njeh et al. [14] reported the simple QA test tool which can be used in conjunction with either EPID or computed radiography (CR) to visually verify linac light and radiation field congruence with respect to the purpose of positioning the patient. Both measurement results were within the tolerance level recommended by the AAPM (i.e. tolerance level of 2 mm) [9, 10]. However, radiographic films provide limited accuracy and cannot be processed digitally. Even more with the drive toward film-less radiation therapy setting, so that the recent field size checks replaced film to EPID [14,15]. To the best of our knowledge, there has no studies on the automation of field size measurements from EPID images. Therefore, the objective of the current study was to develop a simple and efficient algorithm in MATLAB for mechanical check aspects of monthly QA (collimator field size indicator) based on EPID images for various field sizes.

II. METHODS AND MATERIAL

A. Image acquisition procedure

This study was conducted at Ken Saras Hospital, Central Java, Indonesia. A total of 20 EPID images were classified into reference and test datasets. The images of reference dataset (i.e. field sizes of 5 × 5 cm, 10 × 10 cm, 15 × 15 cm, 20 × 20 cm, 25 × 25 cm) were presented in Figure 1. The test datasets were implemented to assess the error in the proposed algorithm. A total of 15 field sizes were taken from reference field sizes plus 1 mm, 2 mm, and 3 mm increments. All EPID image datasets were acquired using 6 MV Elekta Linac, between September – October 2020. The acquisition procedure was performed by positioning source-to-surface distance (SSD) at 100 cm, gantry and collimator were set to 0 degrees. Shadow tray was used to set both reference and test field sizes. Acquisition protocol was set so an image was acquired for the appropriate field size. The image datasets were then saved in TIFF format.

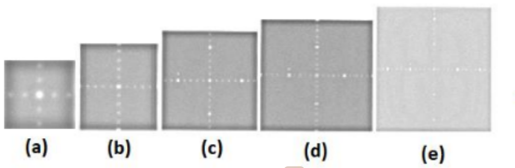

Figure 1. Reference datasets: (a) 5 × 5 cm, (b) 10 × 10 cm, (c) 15 × 15 cm, (d) 20 × 20 cm, and (e) 25 × 25 cm of rectangular field sizes.

B. Proposed algorithm

The automated procedure for verification of field size indicator was developed on MATLAB R2015b. Figure 2 presents the flowchart of the proposed algorithm. There were several steps in the automated verification of the field size. The first step was to input all reference and test images. The next step was image segmentation [16]. We used a threshold with a value of 230 in the segmentation stage due to it was not sensitive to background noise. The image was then converted from grayscale to binary image and so the foreground object can be calculated in terms of its area. The last step was calculation the side boundary of the rectangular field size. The displays user interface of the algorithm is shown in Figure 3.

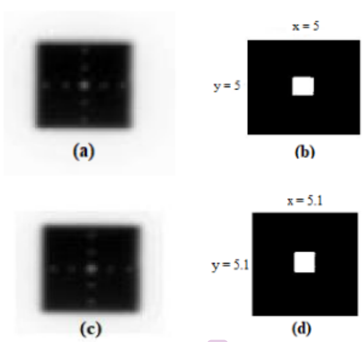

Figure 2. Workflow of the proposed algorithm

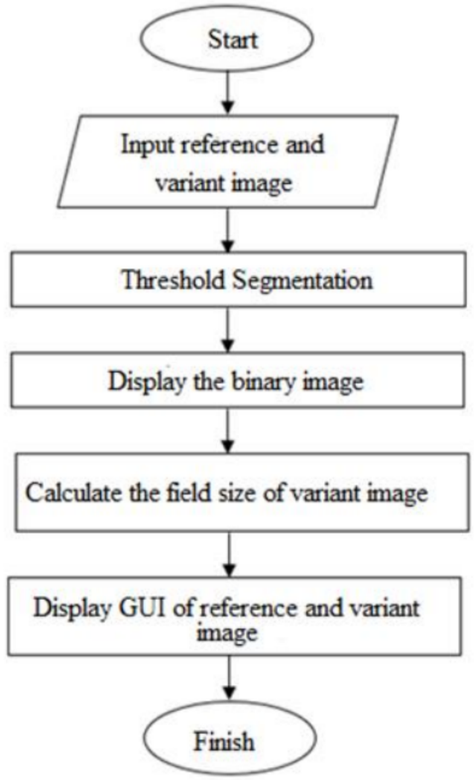

Figure 3. The screen display of the proposed algorithm user interface (a) initial reference image of 5 × 5 cm field size, (b) 5 × 5 cm reference image as a result of thresholding and after filling the all pixels within the field size boundary with a value of 1, (c) initial variant image of 5.1 × 5.1 cm field size, and (d) 5.1 × 5.1 cm variant image after threshold procedure.

C. Manual verification

The final result from the developed algorithm was a rectangular field size dataset in the x- and y-axis. The results of automated measurement were compared to manual datasets which were verified visually by a senior medical physicist of the hospital. Manual measurement of field size was performed by print the EPID image on a sheet of paper. The distances of each side were measured using a ruler. The measurements for each field size were repeated for 3 times, then the averages and standard deviations of the measured field sizes were calculated.

III. RESULTS AND DISCUSSION

The results of manual and automated procedures for both reference and test datasets were tabulated in Table 1. Overall, the difference between manual and automated measurements was less than 2%. In certain field size settings, manual measurement gives greater results than automatic measurement. The maximum difference between automated and manual measurements was 3 mm or still less than 2 %, found in the 15.3 cm field size setting. Therefore, results obtained from this study indicate that all field size setting was still within the tolerance level of 2 mm [9, 10]. The correlation of manual and automated measurements is presented in Figure 4. It is found that both has linear correlation with $R^2 > 0.99$. The R^2 values is close to 1 means that the automatic method has very strong relationship with the manual measurement.

When tested using our laptop supported by Intel® Core™ i5-4210U CPU @ 1.70GHz 2.40 GHz and RAM of 8 GB, our proposed algorithm run less than 4 s, so that it is obviously faster than manual measurement. We realize that the speed of running the program is greatly influenced by the specifications of the device used. Manual measurements can take longer (i.e. longer than 60 s) because it needs to print the EPID images then positioning the print-out image carefully so that the border of the printed image matches to the ruler.

This study aims to develop an automated procedure for field size measurement of medical linac so that an effective and time-saving QA can be performed in the clinical routine. Previously, an automated measurement of field size was proposed and validated on 10 × 10 cm of field size obtained from radiographic film and processed using image texture analysis [13].

Different from Abdallah et al. [13], in the current study, we used EPID as an image acquisition tool. EPID is primary designed for verification of patient setup and to measure the x-ray intensity transmitted through a patient during treatment session [17]. Therefore, due to the EPID image has a sub-millimeter spatial resolution and high contrast resolution, EPID image is an ideal tool for verifying x-ray field size rather than radiographic film [18]. The original image format obtained from EPID is in TIFF format. We used a threshold with the value of 230 as a segmentation technique to separate the main object and background and then assign object fill with a value of one. The segmentation stage in this study was run automatically.

Table 1. The results of x-axis and y-axis for various field sizes of automated and manual measurements

Adjusted field size (cm)	Field size (cm)		Difference	
	Automated verification	Manual verification	(mm)	(%)
5.0 × 5.0	5.0 × 5.0	5.0 × 5.0 ± 0.057	0	0
5.1 × 5.1	5.1 × 5.1	5.1 × 5.1 ± 0.057	0	0
5.3 × 5.3	5.3 × 5.3	5.4 × 5.4 ± 0.000	1	1.9
5.5 × 5.5	5.6 × 5.6	5.7 × 5.7 ± 0.028	1	1.8
10.0 × 10.0	10.0 × 10.0	10.0 × 10.0 ± 0.000	0	0
10.1 × 10.1	10.2 × 10.2	10.2 × 10.2 ± 0.057	0	0
10.3 × 10.3	10.3 × 10.3	10.5 × 10.5 ± 0.057	2	1.9
10.5 × 10.5	10.6 × 10.6	10.7 × 10.5 ± 0.000	1	0.9
15.0 × 15.0	15.0 × 15.0	15.0 × 15.0 ± 0.057	0	0
15.1 × 15.1	15.1 × 15.1	15.2 × 15.2 ± 0.000	1	0.7
15.3 × 15.3	15.2 × 15.2	15.5 × 15.5 ± 0.003	3	1.9
15.5 × 15.5	15.5 × 15.5	15.6 × 15.6 ± 0.000	1	0.6
20.0 × 20.0	20.0 × 20.0	20.0 × 20.0 ± 0.057	0	0

20.1 × 20.1	20.2 × 20.2	20.2 × 20.2 ± 0.057	0	0
20.3 × 20.3	20.5 × 20.5	20.5 × 20.5 ± 0.000	0	0
20.5 × 20.5	20.6 × 20.6	20.7 × 20.7 ± 0.057	1	0.5
25.0 × 25.0	25.0 × 25.0	25.0 × 25.0 ± 0.000	0	0
25.1 × 25.1	25.1 × 25.1	25.3 × 25.3 ± 0.000	2	0.8
25.3 × 25.3	25.5 × 25.5	25.5 × 25.5 ± 0.057	0	0
25.6 × 25.6	25.7 × 25.7	25.7 × 25.7 ± 0.057	0	0

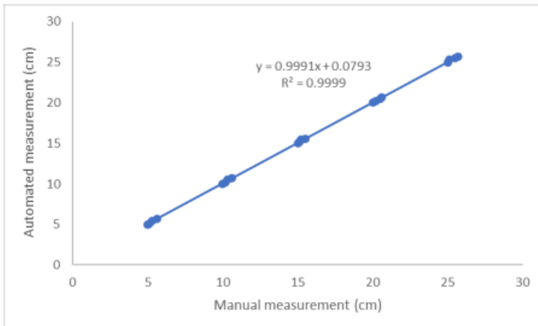

Figure 4. Comparison of manual versus automated measurement

The results of automated measurement were then compared to manual measurement observed by senior medical physicist. We found that the differences between results of automated and manual measurements were within 2%. The automated and manual measurements have a very strong correlation with an R2 > 0.99.

We found our algorithm gives more accurate results than manual observations. In several field size settings, manual measurement provides a higher value than automated measurement. This difference may be affected by user subjectivity during the assessment of the field size boundary with an observation limit of 1 mm. Conversely, our algorithm allows assessment of the edge of field size in an automatically approach with a pixel value was less than 1 mm. Therefore, our proposed algorithm would greatly assist medical physicists in conducting a simpler and more efficient field size verification by pressing a single button.

IV. CONCLUSION

The MATLAB algorithm developed in this study provides a simple way for effective measurement of field size verification. The results revealed that both automated and manual verification still within the tolerance level by AAPM TG-40 and TG-142 (i.e 2 mm). The percentage difference between manual and automated measurements was within 2%. The proposed algorithm was able to obtain accurate results and can be easily performed as a routine test in clinics.

V. ACKNOWLEDGEMENT

This study was funded by the World Class Research University (WCRU), Diponegoro University, Contract number: 118-11/UN7.6.1/PP/2021.

VI. REFERENCES

[1] P. Anand et al., "Cancer is a preventable disease that requires major lifestyle changes." Pharm Res., vol. 25, no. 9, pp. 2097-2116, 2008, doi: 10.1007/s11095-008-9661-9.

[2] T. G. Simon and A. T. Chan, "Lifestyle and Environmental Approaches for the Primary Prevention of Hepatocellular Carcinoma." Clin Liver Disvol., vol. 24, no. 4, pp. 549-576, 2020, doi: 10.1016/j.cld.2020.06.002.

[3] R. L. Siegel, K. D. Miller, H. E. Fuchs, and A. Jemal, "Cancer Statistics, 2021," CA Cancer J

Clin., vol. 71, no. 1, pp. 7-33, 2021, doi: 10.3322/caac.21654

[4] P. P. Connell and S. Hellman, "Advances in radiotherapy and implications for the next century: a historical perspective," Cancer Res., vol. 69, no. 2, pp. 383-392, 2009, doi: 10.1158/0008-5472.CAN-07-6871.

[5] S. Gianfaldoni, R. Gianfaldoni, U. Wollina, J. Lotti, G. Tchernev, and T. Lotti, "An Overview on Radiotherapy: From Its History to Its Current Applications in Dermatology," Open Access Maced J Med Sci., vol. 5, no. 4, pp. 521–525, 2017, doi: 10.3889/oamjms.2017.122

[6] D. I. Thwaites and J. B. Tuohy, "Back to the future: the history and development of the clinical linear accelerator," Phys Med Biol., vol. 51, no. 13, pp. R343-R362, 2006, doi: 10.1088/0031-9155/51/13/R20.

[7] S. Yani, I. Budiansah, S. Pratama, M. F. Rhani, C. Anam, and F. Haryanto, "Evaluation of the dosimetric characteristics of 10 MV flattened and unflattened photon beams in a heterogeneous phantom," Int J Radiat Res., vol. 19, no. 4, pp. 835-841, 2021, doi: 10.52547/ijrr.19.4.9.

[8] C. Anam, D. S. Soejoko, F. Haryanto, S. Yani, and G. Dougherty, "Electron contamination for 6 MV photon beams from an Elekta linac: Monte Carlo simulation," Journal of Physics and Its Applications, vol. 2, no. 2, pp. 97-101, 2020, doi: 10.14710/jpa.v2i2.7771.

[9] G. J. Kutcher et al., "Comprehensive QA for radiation oncology: report of AAPM Radiation Therapy Committee Task Group 40," Med Phys., vol. 21, no. 4, pp. 581-618, 1994, doi: 10.1118/1.597316.

[10] E. E. Klein et al., "Task Group 142 report: Quality assurance of medical accelerators," Med. Phys., vol. 36, no. 9, pp. 4197-4212, 2009, doi: 10.1118/1.3190392.

[11] L. Court et al., "Illustrated instructions for mechanical quality assurance of a medical linear accelerator," J Appl Clin Med Phys., vol. 19, no. 3, pp. 355-359, 2018, doi: 10.1002/acm2.12265.

[12] A. Boyer et al., "AAPM Report No. 72: Basic Application of Multileaf Collimators," 2001, doi: 10.37206/71.

[13] Y. M. Y. Abdallah and M. A. Boshara, "Assessment of Field Size on Radiotherapy Machines Using Texture Analysis," Sudan Medical Monitor, vol. 9, no. 1, pp. 5-10, 2014, doi: 10.4103/1858-5000.144642.

[14] C. F. Njeh, B. Caroprese. and P. Desai, "A simple quality assurance test tool for the visual verification of light and radiation field congruent using electronic portal images device and computed radiography," Radiat Oncol., vol. 7, no. 49, pp. 1-14, 2012, doi: 10.1186/1748-717X-7-49.

[15] D. Létourneau, H. Keller, N. Becker, M. N. Amin, B. Norrlinger, and D. A. Jaffray, "Quality control methods for linear accelerator radiation and mechanical axes alignment," Med Phys. Vol. 45, no. 6, pp. 2388-2398, 2018, doi: 10.1002/mp.12910.

[16] A. Naufal, C. Anam, C. E. Widodo, and G. Dougherty, "Automated Calculation of Height and Area of Human Body for Estimating Body Weight Using a Matlab-based Kinect Camera," Smart Science, vol. 10, no. 1, pp. 68-75, 2022, doi: 10.1080/23080477.2021.1983940.

[17] J. W. Wong, "Electronic Portal Imaging Devices (EPID)," In: L. W. Brady, T. E. Yaeger, (eds) Encyclopedia of Radiation Oncology. Springer, Berlin, Heidelberg, 2013, doi: 10.1007/978-3-540-85516-3_33.

[18] B. Sun et al., "Daily QA of linear accelerators using only EPID and OBI," Med Phys., vol. 42, no. 10, pp. 5584-5594, 2015, doi: 10.1118/1.4929550.

Cite this Article

Siti Hanan, Choirul Anam, Eko Hidayanto, "Simple Automated Verification of Field Size Indicator for Quality Assurance of Medical Linear Accelerator", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 9 Issue 2, pp. 55-60, March-April 2022. Available at doi : https://doi.org/10.32628/IJSRST22922

Journal URL : https://ijsrst.com/IJSRST22922

Simple Automated Verification of Field Size Indicator for Quality Assurance of Medical Linear Accelerator

ORIGINALITY REPORT

11%	6%	8%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	J. L. Pritchard, J. J. Velthuis, L. Beck, C. De Sio, R. P. Hugtenburg. "High-Resolution MLC Leaf Position Measurements With a Large Area MAPS", IEEE Transactions on Radiation and Plasma Medical Sciences, 2021 Publication	1%
2	www.science.gov Internet Source	1%
3	impressions.manipal.edu Internet Source	1%
4	Baozhou Sun, S. Murty Goddu, Sridhar Yaddanapudi, Camille Noel, Hua Li, Bin Cai, James Kavanaugh, Sasa Mutic. "Daily QA of linear accelerators using only EPID and OBI", Medical Physics, 2015 Publication	1%
5	David I Thwaites. "Back to the future: the history and development of the clinical linear accelerator", Physics in Medicine and Biology, 07/07/2006	1%

Publication

6	Naoto Kubota, Naoto Fujiwara, Yujin Hoshida. "Liver cancer risk-predictive molecular biomarkers specific to clinico-epidemiological contexts", Elsevier BV, 2022 Publication	1%
7	Heath, Amy. "Quality Assurance", Radiation Therapy Study Guide, 2016. Publication	1%
8	Submitted to The ISF Academy Student Paper	1%
9	COMPEL: The International Journal for Computation and Mathematics in Electrical and Electronic Engineering, Volume 33, Issue 1-2 (2014-03-28) Publication	<1%
10	Sridhar Yaddanapudi, Bin Cai, Taylor Harry, Steven Dolly et al. "Rapid acceptance testing of modern linac using on-board MV and kV imaging systems", Medical Physics, 2017 Publication	<1%
11	Colleen K. Spees, Emily B. Hill, Elizabeth M. Grainger, Jackie L. Buell et al. "Feasibility, Preliminary Efficacy, and Lessons Learned from a Garden-Based Lifestyle Intervention for Cancer Survivors", Cancer Control, 2016 Publication	<1%

12	Fuli Zhang, Jinbao Zhang, Mingmin Zheng. "Introduction of Linac quality management experience", The Chinese-German Journal of Clinical Oncology, 2009 Publication	<1 %
13	Submitted to Trinity College Dublin Student Paper	<1 %
14	ejournal.unesa.ac.id Internet Source	<1 %
15	www.osha.gov Internet Source	<1 %
16	www.scribd.com Internet Source	<1 %
17	worldwidescience.org Internet Source	<1 %
18	www.ijcea.org Internet Source	<1 %
19	Awusi Kavuma. "A novel method for patient exit and entrance dose prediction based on water equivalent path length measured with an amorphous silicon electronic portal imaging device", Physics in Medicine and Biology, 01/21/2010 Publication	<1 %
20	Wendel Dean Renner, Kevin Norton, Timothy Holmes. "A method for deconvolution of	<1 %

integrated electronic portal images to obtain incident fluence for dose reconstruction", Journal of Applied Clinical Medical Physics, 2005
Publication

21	ro.uow.edu.au Internet Source	<1 %
22	wjgnet.com Internet Source	<1 %

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		