DETEKSI HILAL BERDASARKAN DATA VIDEO DENGAN TEKNIK *COMPUTER VISION*

SKRIPSI

Diajukan untuk Memenuhi Sebagian dari
Syarat Memperoleh Gelar Sarjana Komputer
Program Studi Ilmu Komputer

oleh:

ALIF RIZZA ZUHUDI

1901434

PROGRAM STUDI ILMU KOMPUTER
FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS PENDIDIKAN INDONESIA

2023

2023

DETEKSI HILAL BERDASARKAN DATA VIDEO DENGAN TEKNIK *COMPUTER VISION*

Oleh

Alif Rizza Zuhudi

1901434

Skripsi yang Diajukan untuk Memenuhi Salah Satu Syarat Memperoleh Gelar Sarjana Komputer di Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

Universitas Pendidikan Indonesia

Agustus 2023

Alif Rizza Zuhudi

1901434

DETEKSI HILAL BERDASARKAN DATA VIDEO DENGAN TEKNIK *COMPUTER VISION*

DISETUJUI DAN DISAHKAN OLEH PEMBIMBING:

Pembimbing I,

Lala Septem Riza, M.T., Ph.D.

NIP. 197809262008121001

Pembimbing II,

Dr. Judhistira Aria Utama,M.Si.

NIP. 197004101997021001

Mengetahui,

Ketua Departemen Pendidikan Ilmu Komputer

Dr. Muhammad Nursalman, M.T.

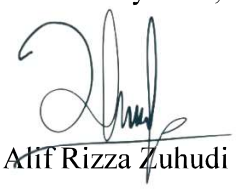
NIP. 197909292006041002

SURAT PERNYATAAN

Dengan ini penulis menyatakan bahwa skripsi dengan judul "DETEKSI HILAL BERDASARKAN DATA VIDEO DENGAN TEKNIK *COMPUTER VISION*" ini beserta seluruh isinya adalah benar-benar karya penulis sendiri. Penulis tidak melakukan penjiplakan atau pengutipan dengan cara-cara yang tidak sesuai dengan etika ilmu yang berlaku dalam masyarakat keilmuan. Atas pernyataan ini, penulis siap menanggung risiko/sanksi apabila di kemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain terhadap keaslian karya penulis ini.

Bandung, Agustus 2023

Yang Membuat Pernyataan,



Alif Rizza Zuhudi

NIM 1901434

DETEKSI HILAL BERDASARKAN DATA VIDEO DENGAN TEKNIK *COMPUTER VISION*

Oleh

Alif Rizza Zuhudi | alif.11296@upi.edu

1901434

ABSTRAK

Lebih dari satu setengah miliar orang di seluruh dunia menggunakan kalender berdasarkan penampakan hilal. Dalam kalender Hijriah, sangat penting untuk mengenali penampakan hilal untuk pertama kalinya setelah konjungsi, terutama untuk tiga bulan penting yaitu Ramadan, Syawal, dan Dzulhijjah. Penelitian ini menggunakan data video yang akan diproses menggunakan algoritma *computer vision* untuk mengidentifikasi kemunculan hilal. Hilal akan ditangkap dengan menggunakan *Gaussian Blur* dan *Adaptive Thresholding*. Teknik *Image Processing*, seperti ekstraksi *frame* dari video, pra-pemrosesan gambar, dan algoritma deteksi menggunakan *Circular Hough Transform* (CHT), semuanya diimplementasikan menggunakan *library* OpenCV. Kami memilih dua puluh pengamatan sebagai sampel yang disediakan oleh Badan Meteorologi, Klimatologi, dan Geofisika (MCGA). Waktu komputasi model yang diusulkan relatif lebih cepat dibandingkan dengan frekuensi *frame* yang ditampilkan per detik pada video. Akurasi program dalam membedakan antara *frame* dengan dan tanpa hilal cukup baik dimana tingkat akurasi model ini bervariasi antara 43,68% hingga 96,51%. Kami menyimpulkan bahwa model yang diusulkan dapat secara akurat dan cepat mendeteksi kapan hilal akan muncul.

Kata kunci : *Circular Hough Transform, computer vision, hilal detection, Image Processing*

YOUNG LUNAR CRESCENT DETECTION BASED ON VIDEO DATA WITH COMPUTER VISION TECHNIQUES

Arranged by

Alif Rizza Zuhudi | alif.11296@upi.edu

1901434

ABSTRACT

More than one and a half billion people worldwide use a calendar based on the young lunar crescent apparition. In the Hijri calendar, it is crucial to recognize the appearance of the lunar crescent for the first time after conjunction, especially for the three critical months of Ramadan, Shawwal, and Dzulhijjah. This work uses video data to be processed using computer vision algorithms to identify the young lunar crescent's appearance. The lunar crescent will be captured using Gaussian Blur and Adaptive Thresholding. Image Processing techniques, such as frame extraction from video, pre-Processing Images, and detection algorithms utilizing Circular Hough Transform (CHT), are all implemented using the OpenCV package. We chose ten observations as a sample provided by the Meteorological, Climatological, and Geophysical Agency (MCGA). The computation time of the proposed model is relatively faster than the frequency of the frames displayed per second on the video. The accuracy of the program in distinguishing between frames with and without hilal is quite good where the accuracy level of this model varies between 43.68% to 96.51%. We conclude that the proposed model can accurately and quickly detect when the young lunar crescent will appear.

Keywords: Circular Hough Transform, computer vision, crescent detection, Image Processing

KATA PENGANTAR

Puji dan syukur penulis panjatkan kehadirat Allah swt. karena hanya dengan kehendak, berkat, serta karunia-Nya lah penulis dapat menyelesaikan skripsi yang berjudul "DETEKSI HILAL BERDASARKAN DATA VIDEO DENGAN TEKNIK COMPUTER VISION" ini dapat terselesaikan.

Penyusunan skripsi ini ditujukan untuk memenuhi dan melengkapi salah satu syarat untuk penyusunan skripsi yang merupakan syarat untuk mendapatkan gelar sarjana komputer atas jenjang studi S1 pada Program Studi Ilmu Komputer Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam Universitas Pendidikan Indonesia.

Penulis menyadari bahwa dalam penyusunan skripsi ini masih terdapat banyak kekurangan dan keterbatasan yang perlu disempurnakan. Oleh karena itu, penulis sangat mengharapkan saran maupun kritik yang membangun agar tidak terjadi kesalahan yang sama di kemudian hari dan dapat meningkatkan kualitas ke tahap lebih baik.

Bandung, Agustus 2023

Penyusun

UCAPAN TERIMAKASIH

Alhamdulillahirobbilalamin, puji dan syukur kehadirat Allah SWT Yang telah melimpahkan rahmat dan hidayah-Nya sehingga penulis diberikan kelancaran dalam menyelesaikan penulisan skripsi ini. Dalam proses menyelesaikan penelitian dan penyusunan skripsi ini, peneliti banyak mendapat bimbingan, dorongan, serta bantuan dari berbagai pihak. Oleh karena itu, pada kesempatan ini penulis mengucapkan terimakasih serta penghargaan yang setinggi-tingginya, kepada:

1. Diri saya sendiri hingga mencapai titik ini atas segala usaha dan tenaga yang dicurahkan dan terus melakukan yang terbaik kepada diri sendiri.
2. Kedua orang tua yaitu Koesoebagio dan Oriza Sativa yang selalu memberi dukungan morill dan materiil, motivasi, dan doa serta selalu menjadi penyemangat utama dalam menempuh pendidikan tinggi sehingga penulis dapat menyelesaikan skripsi ini.
3. Bapak Prof. Dr. Lala Septem Riza, M.T. selaku pembimbing I atas segala waktu dan tenaga yang dicurahkan untuk membimbing penulis demi terselesaikannya skripsi ini.
4. Bapak Dr. Judhistira Aria Utama, S.Si., M.Si. selaku pembimbing II atas saran dan masukan yang diberikan kepada penulis selama proses menyelesaikan penelitian dan penulisan skripsi.
5. Bapak Yudi Ahmad Hambali, M.T. selaku dosen pembimbing akademik.
6. Bapak Dr. Muhamad Nursalman, M.T selaku Ketua Program Studi Ilmu Komputer FPMIPA Universitas Pendidikan Indonesia.
7. Ibu Dr. Rani Megasari, M.T. selaku Kepala Program Studi Ilmu Komputer FPMIPA Universitas Pendidikan Indonesia Periode 2018-2023.
8. Bapak dan Ibu Dosen Prodi Pendidikan Ilmu Komputer dan Ilmu Komputer yang telah berbagi ilmu yang bermanfaat kepada penulis dan mahasiswa lainnya.
9. Tim penelitian yaitu teman-teman penelitian Zulfikar, Yudi, Fajar Zuliansyah, Muhammad Fajar, Iqbal, Izzudin, Ira, Melvyn, dan Arfiansyah yang senantiasa

memberikan dukungan, semangat, dan kegiatan positif lainnya selama proses penelitian dan pengerjaan skripsi.

Bandung, Agustus 2023

Alif Rizza Zuhudi

DAFTAR ISI

Daftar Tabel

Daftar Gambar

DAFTAR PUSTAKA

Acharya, T., & Ray, A. K. (2005). *Image processing: Principles and applications*. John Wiley & Sons.

Acharya, U. R., Fernandes, S. L., WeiKoh, J. E., Ciaccio, E. J., Fabell, M. K. M., Tanik, U. J., Rajinikanth, V., & Yeong, C. H. (2019). Automated detection of Alzheimer's disease using brain MRI images–a study with various feature extraction techniques. *Journal of Medical Systems*, *43*, 1–14.

Adem, K. (2018). Exudate detection for diabetic retinopathy with circular Hough transformation and convolutional neural networks. *Expert Systems with Applications*, *114*, 289–295. https://doi.org/10.1016/j.eswa.2018.07.053

Ahmad Junaidi, M. (2021). *ASTROFOTOGRAFI: Adopsi dan Implementasinya dalam Rukyatulhilal di Indonesia*. Q Media.

Ahmad, N., Nawawi, M. S. A. M., Zainuddin, M. Z., Nasir, Z. M., Yunus, R. M., & Mohamed, I. (2020). A new crescent moon visibility criteria using circular regression model: A case study of Teluk Kemang, Malaysia. *Sains Malaysiana*, *49*(4), 859–870.

Ahmed, A. K., & Aziz, A. H. A. (2014). Young moon visibility criterion based on crescent illumination and sky brightness contrast model. *Middle-East Journal of Scientific Research*, *21*(9), 1641–16.

Ahmed, T. (2020). Predicting the Visibility of the First Crescent: Predicting the Visibility of the First Crescent. *KIET Journal of Computing and Information Sciences*, *3*(2), 10–10.

Aizenberg, I., Bregin, T., Butakoff, C., Karnaukhov, V., Merzlyakov, N., & Milukova, O. (2002). Type of blur and blur parameters identification using neural network and its application to image restoration. *Artificial Neural Networks—ICANN 2002: International Conference Madrid, Spain, August 28–30, 2002 Proceedings 12*, 1231–1236.

Alrefay, T., Alsaab, S., Alshehri, F., Alghamdi, A., Hadadi, A., Alotaibi, M., Almutari, K., & Mubarki, Y. (2018). Analysis of observations of earliest visibility of the lunar crescent. *The Observatory*, *138*, 267–291.

Aly, M. (2005). Survey on multiclass classification methods. *Neural Netw*, *19*(1–9), 2.

Astola, J., & Kuosmanen, P. (2020). *Fundamentals of nonlinear* Digital *filtering*. CRC press.

Atherton, T. J., & Kerbyson, D. J. (1999). Size invariant circle detection. *Image and Vision Computing*, *17*(11), 795–803.

Bajcsy, R. (1988). Active perception. *Proceedings of the IEEE*, *76*(8), 966–1005.

Banhom, M., & Katsaggelos, A. (1997). Digital Image Denoising. *IEEE Signal Process*, *14*, 24–41.

Bennett, J. O. (2008). *The Cosmic Perspective*. Pearson Addison-Wesley.

Berry, R., & Burnell, J. (2000). The handbook of astronomical image processing. *The Handbook of Astronomical Image Processing*.

Bertone, G., Hooper, D., & Silk, J. (2005). Particle dark matter: Evidence, candidates and constraints. *Physics Reports*, *405*(5–6), 279–390.

Borucki, W. J., Koch, D., Basri, G., Batalha, N., Brown, T., Caldwell, D., Caldwell, J., Christensen-Dalsgaard, J., Cochran, W. D., DeVore, E., & others. (2010).

Kepler planet-detection mission: Introduction and first results. *Science*, *327*(5968), 977–980.

Bruin, F. (1977). The first visibility of the lunar crescent. *Vistas in Astronomy*, *21*, 331–358. https://doi.org/10.1016/0083-6656(77)90021-6

Buolamwini, J., & Gebru, T. (2018). Gender shades: Intersectional accuracy disparities in commercial gender classification. *Conference on Fairness, Accountability and Transparency*, 77–91.

Burger, W., & Burge, M. J. (2008). An algorithmic introduction using Java. Digital *Image Processing*.

Burt, P. J., & Adelson, E. H. (1987). The Laplacian pyramid as a compact image code. In *Readings in computer vision* (pp. 671–679). Elsevier.

Caldwell, J. A., & Laney, C. D. (2000). First visibility of the lunar crescent. *African Skies*, *5*, 15.

Canny, J. (1986). A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *6*, 679–698.

Castleman, K. R. (1979). Stereometric Ranging. Digital *Image Processing, Prentice-Hall, Inc., Englewood Cliffs, New Jersey*, 364–369.

Chen, L.-C., Papandreou, G., Kokkinos, I., Murphy, K., & Yuille, A. L. (2017). Deeplab: Semantic image segmentation with deep convolutional nets, atrous convolution, and fully connected crfs. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *40*(4), 834–848.

Cinzano, P., Falchi, F., & Elvidge, C. D. (2001). The first world atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society*, *328*(3), 689–707.

Collaboration, P., Aghanim, N., Akrami, Y., Ashdown, M., Aumont, J., Baccigalupi, C., Ballardini, M., Banday, A., Barreiro, R., Bartolo, N., & others. (2020). *Planck 2018 results. VI. Cosmological parameters*.

Cooley, J. W., & Tukey, J. W. (1965). An algorithm for the machine calculation of complex Fourier series. *Mathematics of Computation*, *19*(90), 297–301.

Danjon, A. (1932). Jeunes et Vieilles Lunes. *L'Astronomie, Vol. 46, Pp. 57-66*, *46*, 57–66.

Daway, H. G., Kareem, H. H., & Hashim, A. R. (2018). Pupil Detection Based on Color Difference and Circular Hough Transfor. *International Journal of Electrical and Computer Engineering (IJECE)*, *8*(5), 3278. https://doi.org/10.11591/ijece.v8i5.pp3278-3284

Debevec, P. E., & Malik, J. (2008). Recovering high dynamic range radiance maps from photographs. In *ACM SIGGRAPH 2008 classes* (pp. 1–10).

Des Marais, D. J., Nuth III, J. A., Allamandola, L. J., Boss, A. P., Farmer, J. D., Hoehler, T. M., Jakosky, B. M., Meadows, V. S., Pohorille, A., Runnegar, B., & others. (2008). The NASA astrobiology roadmap. *Astrobiology*, *8*(4), 715–730.

Doggett, L. E., & Schaefer, B. E. (1994). Lunar Crescent Visibility. *Icarus*, *107*(2), 388–403. https://doi.org/10.1006/icar.1994.1031

Duda, R. O., & Hart, P. E. (1972). Use of the Hough transformation to detect lines and curves in pictures. *Communications of the ACM*, *15*(1), 11–15.

Fakhar, M., Moalem, P., & Badri, M. A. (2014). Lunar crescent detection based on image processing algorithms. *Earth, Moon, and Planets*, *114*(1–2), 17–34.

Fatoohi, L. J., Stephenson, F. R., & Al-Dargazelli, S. (1998). The Danjon limit of first visibility of the lunar crescent. *The Observatory, Vol. 118, p. 65-72 (1998)*, *118*, 65–72.

Figueiredo, M., & Nowak, R. (2003). *An EM algorithm for wavelet-based image restoration: IEEE Transactions on Image Processing*. IIPRE4.

Forsyth, D. A., & Ponce, J. (2002). *Computer vision: A modern approach*. prentice hall professional technical reference.

Fotheringham, J. K. (1910). Moon, on the smallest visible phase of the. *Monthly Notices of the Royal Astronomical Society*, *70*, 527.

Fried, D. L. (1978). Probability of getting a lucky short-exposure image through turbulence. *JOSA*, *68*(12), 1651–1658.

Garcia-Garcia, A., Orts-Escolano, S., Oprea, S., Villena-Martinez, V., & Garcia-Rodriguez, J. (2017). A review on deep learning techniques applied to semantic segmentation. *ArXiv Preprint ArXiv:1704.06857*.

Gonzalez, R. C., & Woods, R. E. (2018). Digital *image processing* (Fourth edition, india edition). Pearson India.

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A., & Bengio, Y. (2014). Generative adversarial nets. *Advances in Neural Information Processing Systems*, *27*.

Guessoum, N., & Meziane, K. (2001). Visibility of the thin lunar crescent: The sociology of an astronomical problem (A case study). *Journal of Astronomical History and Heritage (ISSN 1440-2807), Vol. 4, No. 1, p. 1-14 (2001).*, *4*, 1–14.

Haralick, R. M., Sternberg, S. R., & Zhuang, X. (1987). Image analysis using mathematical morphology. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *4*, 532–550.

Hartley, R., & Zisserman, A. (2003). *Multiple view geometry in computer vision*. Cambridge university press.

Hashemi Sejzei, A., & Jamzad, M. (2016). Evaluation of various Digital image processing techniques for detecting critical crescent moon and introducing CMD – A tool for critical crescent moon detection. *Optik*, *127*(3), 1511–1525. https://doi.org/10.1016/j.ijleo.2015.09.158

Hawley, J. F., & Holcomb, K. A. (2005). *Foundations of modern cosmology*. Oxford University Press.

Hoffman, R. E. (2003). Observing the new Moon. *Monthly Notices of the Royal Astronomical Society*, *340*(3), 1039–1051.

Horn, B. (1986). *Robot vision*. MIT press.

Hoskin, M. (1999). *The Cambridge concise history of astronomy*. Cambridge University Press.

Huang, T. (1996). Vandoni, Carlo, E, ed. Computer Vision: Evolution And Promise (PDF). 19th CERN School of Computing. Geneva: CERN. *Doi*, *10*(5170), 978–9290830955.

Hunt, C. (2008). Observing the Moon: The Modern Astronomer's Guide. *Reference Reviews*, *22*(6), 40–41.

Huval, B., Wang, T., Tandon, S., Kiske, J., Song, W., Pazhayampallil, J., Andriluka, M., Rajpurkar, P., Migimatsu, T., Cheng-Yue, R., & others. (2015). An empirical evaluation of deep learning on highway driving. *ArXiv Preprint ArXiv:1504.01716*.

Ilyas, M. (1983). The Danjon Limit of Lunar Visibility: A Re-Examination. *Journal of the Royal Astronomical Society of Canada*, *77*, 214–219.

Ilyas, M. (1994). Lunar Crescent Visibility and Islamic Calendar; QJR Ast. *Soc*, *35*, 425–461.

Jähne, B. (2005). Digital *image processing* (6th rev. and ext. ed). Springer.

Janesick, J. (2001). Scientific Charge-Coupled Devices, 83 SPIE Press. *Bellingham, Washington*.

Jensen, J. R. (2016). *Introductory* Digital *image processing: A remote sensing perspective*. Pearson Education, Inc.

Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*, *147*, 70–90.

Kass, M., Witkin, A., & Terzopoulos, D. (1988). Snakes: Active contour models. *International Journal of Computer Vision*, *1*(4), 321–331.

Khare, C., & Nagwanshi, K. K. (2011). Implementation and analysis of image restoration techniques. *International Journal of Computer Trends and Technology-May to June*, *2011*.

Koc-San, D., Selim, S., Aslan, N., & San, B. T. (2018). Automatic citrus tree extraction from UAV images and Digital surface models using circular Hough transform. *Computers and Electronics in Agriculture*, *150*, 289–301. https://doi.org/10.1016/j.compag.2018.05.001

Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. *Advances in Neural Information Processing Systems*, *25*.

Lapray, P.-J., Heyrman, B., & Ginhac, D. (2013). A smart camera for High Dynamic Range imaging. *Second Workshop on Architecture of Smart Camera (WASC)*, 1.

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*(7553), 436–444.

Lundervold, A. S., & Lundervold, A. (2019). An overview of deep learning in medical imaging focusing on MRI. *Zeitschrift Für Medizinische Physik*, *29*(2), 102–127.

Maunder, E. W. (1911). On the smallest visible phase of the moon. *Journal of The British Astronomy Association*, *21*, 356–360.

McNally, D. (1983). The length of the lunar crescent. *Quarterly Journal of the Royal Astronomical Society*, *24*, 417.

Moore, P. (1990). *The amateur astronomer*. CUP Archive.

Moshayedi, A. J., Chen, Z., Liao, L., & Li, S. (2022). Sunfa Ata Zuyan machine learning models for moon phase detection: Algorithm, prototype and

performance comparison. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, *20*(1), 129–140.

Muirden, J. (1987). *The amateur astronomer's handbook.*

Murray, J. D., & VanRyper, W. (1996). Encyclopedia of graphics file formats. *Sebastopol: O'Reilly*.

Muztaba, R., Malasan, H. L., & Djamal, M. (2022). Development of an automated Moon observation system using the ALTS-07 Robotic Telescope: 2. Progress report on standard contrast enhancement of Moon crescent image with OpenCV. *Journal of Physics: Conference Series*, *2214*(1), 012004. https://doi.org/10.1088/1742-6596/2214/1/012004

Odeh, M. S. (2004). New criterion for lunar crescent visibility. *Experimental Astronomy*, *18*(1–3), 39–64.

Okokpujie, K., Noma-Osaghae, E., John, S., & Ajulibe, A. (2018). An Improved Iris Segmentation Technique Using Circular Hough Transform. In K. J. Kim, H. Kim, & N. Baek (Eds.), *IT Convergence and Security 2017* (Vol. 450, pp. 203–211). Springer Singapore. https://doi.org/10.1007/978-981-10-6454-8_26

Orton, G., & Yanamandra-Fisher, P. (2005). Saturn's temperature field from high-resolution middle-infrared imaging. *Science*, *307*(5710), 696–698.

Otsu, N. (1979). A threshold selection method from gray-level histograms. *IEEE Transactions on Systems, Man, and Cybernetics*, *9*(1), 62–66.

Pal, N. R., & Pal, S. K. (1993). A review on image segmentation techniques. *Pattern Recognition*, *26*(9), 1277–1294.

Peebles, P. J. E. (1993). *Principles of physical cosmology* (Vol. 27). Princeton university press.

Percy, J. R. (2007). *Understanding variable stars*. Cambridge University Press.

Pitas, I. (2000). Digital *image processing algorithms and applications*. Wiley.

Pizer, S. M., Amburn, E. P., Austin, J. D., Cromartie, R., Geselowitz, A., Greer, T., ter Haar Romeny, B., Zimmerman, J. B., & Zuiderveld, K. (1987). Adaptive histogram equalization and its variations. *Computer Vision, Graphics, and Image Processing*, *39*(3), 355–368.

Polliack, M. (2003). Major Trends in Karaite Biblical Exegesis in the Tenth and Eleventh Centuries. In *Karaite Judaism* (pp. 363–413). Brill.

Ratledge, D. (2006). Digital *Astrophotography: The State of the Art*.

Riess, A. G., Filippenko, A. V., Challis, P., Clocchiatti, A., Diercks, A., Garnavich, P. M., Gilliland, R. L., Hogan, C. J., Jha, S., Kirshner, R. P., & others. (1998). Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The Astronomical Journal*, *116*(3), 1009.

Roelofs, G. (1999). *PNG: the definitive guide*. O'Reilly & Associates, Inc.

Rosenfeld, A., & Kak, A. (1982). Digital picture processing, Acad. *Press, San Diego*.

Roy, P., Dutta, S., Dey, N., Dey, G., Chakraborty, S., & Ray, R. (2014). Adaptive *thresholding*: A comparative study. *2014 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)*, 1182–1186.

Russ, J., & Neal, F. (2016). Chapter 10 Feature Measurements and Chapter 11 Characterizing Shape. *The Image Processing Handbook, 7th Ed.; CRC Press: Boca Raton, FL, USA*.

Sayood, K. (2017). *Introduction to data compression*. Morgan Kaufmann.

Schaefer, B. E. (1988). Visibility of the lunar crescent. *Quarterly Journal of The Royal Astronomical Society*, *29*, 511–523.

Schaefer, B. E. (1991). Length of the lunar crescent. *Royal Astronomical Society, Quarterly Journal (ISSN 0035-8738), Vol. 32, Sept. 1991, p. 265-277.*, *32*, 265–277.

Schaefer, B. E. (1996). Lunar crescent visibility. *Quarterly Journal of the Royal Astronomical Society, Vol. 37, p. 759*, *37*, 759.

Schwarzschild, M. (2015). *Structure and evolution of stars* (Vol. 2379). Princeton University Press.

Sehgal, M. S. B., Gondal, I., & Dooley, L. S. (2005). Collateral missing value imputation: A new robust missing value estimation algorithm for microarray data. *Bioinformatics*, *21*(10), 2417–2423.

Serra, J. (1982). Image analysis and mathematical morphol-ogy. *(No Title)*.

Sezgin, M., & Sankur, B. lent. (2004). Survey over image *thresholding* techniques and quantitative performance evaluation. *Journal of Electronic Imaging*, *13*(1), 146–168.

Shen, W., Wang, X., Wang, Y., Bai, X., & Zhang, Z. (2015). Deepcontour: A deep convolutional feature learned by positive-sharing loss for contour detection.

Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 3982–3991.

Singhal, P., Verma, A., & Garg, A. (2017). A study in finding effectiveness of Gaussian blur filter over bilateral filter in natural scenes for graph based image segmentation. *2017 4th International Conference on Advanced Computing and Communication Systems (ICACCS)*, 1–6.

Soille, P. & others. (1999). *Morphological image analysis: Principles and applications* (Vol. 2). Springer.

Sonka, M., Hlavac, V., & Boyle, R. (2014). *Image processing, analysis, and machine vision*. Cengage Learning.

Springel, V., White, S. D., Jenkins, A., Frenk, C. S., Yoshida, N., Gao, L., Navarro, J., Thacker, R., Croton, D., Helly, J., & others. (2005). Simulations of the formation, evolution and clustering of galaxies and quasars. *Nature*, *435*(7042), 629–636.

Sultan, A. (2005). The length of the new crescent Moon. *The Observatory, Vol. 125, p. 227-231 (2005)*, *125*, 227–231.

Sultan, A. H. (2007). First visibility of the lunar crescent: Beyond Danjon's limit. *The Observatory, Vol. 127, No. 1, p. 53-59*, *127*, 53–59.

Szeliski, R. (2011). *Computer vision: Algorithms and applications*. Springer.

Szeliski, R. (2022). *Computer vision: Algorithms and applications*. Springer Nature.

Ünver, H., Kökver, Y., Duman, E., & Erdem, O. (2019). Statistical Edge Detection and Circular Hough Transform for Optic Disk Localization. *Applied Sciences*, *9*(2), 350. https://doi.org/10.3390/app9020350

Utama, J., Simatupang, F., & others. (2019). The new hilaal visibility criterion for tropical region. *Journal of Physics: Conference Series*, *1280*(2), 022073.

Utama, J., & Siregar, S. (2013). Usulan Kriteria Visibilitas Hilal di Indonesia Dengan Model Kastner. *Jurnal Pendidikan Fisika Indonesia*, *9*(2).

Weinberg, S. (2008). *Cosmology*. OUP Oxford.

Yallop, B. (1997). A method for predicting the first sighting of the new Crescent Moon. *RGO NAO Technical Note*, *69*.

Yilmaz, A., Javed, O., & Shah, M. (2006). Object tracking: A survey. *Acm Computing Surveys (CSUR)*, *38*(4), 13-es.

Yuen, H., Princen, J., Illingworth, J., & Kittler, J. (1990). Comparative study of Hough transform methods for circle finding. *Image and Vision Computing*, *8*(1), 71–77.

Yussof, W. N. J. H. W., Man, M., Umar, R., Zulkeflee, A. N., Awalludin, E. A., & Ahmad, N. (2022). Enhancing Moon Crescent Visibility Using Contrast-Limited Adaptive Histogram Equalization and Bilateral Filtering Techniques. *Journal of Telecommunications and Information Technology*, *1*.

Zaman, Q. (2015). Memahami makna hilal menurut tafsir Al-Qur'an dan sains. *Universum: Jurnal Keislaman Dan Kebudayaan*, *9*(01), 103–115.

Zhang, S., Benenson, R., & Schiele, B. (2017). Citypersons: A diverse dataset for pedestrian detection. *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 3213–3221.

Zhang, X., & Gao, Y. (2009). Face recognition across pose: A review. *Pattern Recognition*, *42*(11), 2876–2896.

Zhang, Z. (2000). A flexible new technique for camera calibration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *22*(11), 1330–1334.

Ziou, D., Tabbone, S., & others. (1998). Edge detection techniques-an overview. *Pattern Recognition and Image Analysis C/C of Raspoznavaniye Obrazov I Analiz Izobrazhenii*, *8*, 537–559.

Zuiderveld, K. (1994). Contrast limited adaptive histogram equalization. *Graphics Gems*, 474–485.

Zulkeflee, A. N., Yussof, W. N. J. H. W., Umar, R., Ahmad, N., Mohamad, F. S., Man, M., & Awalludin, E. A. (2022). Detection of a new crescent moon using the Maximally Stable Extremal Regions (MSER) technique. *Astronomy and Computing*, *41*, 100651. https://doi.org/10.1016/j.ascom.2022.100651