Computer Vision Concepts with Kernel Crafter for Middle School Students Education

Jonathan porter Squires, University of Georgia
Dr. Ramana Pidaparti, University of Georgia

Ramana Pidaparti, is currently a Professor in the School of ECAM, College of Engineering at UGA. Previously, he was at VCU and IUPUI. Dr. Pidaparti received his Ph.D. degree in Aeronautics & Astronautics from Purdue University, West Lafayette. His research interests are in design, modeling and simulations, STEM education, and bio-inspired designs and systems.

Computer Vision Concepts with Kernel Crafter for Middle School Student Education (Work in Progress)

Jonathan Porter Squires
jps70135@uga.edu
School of Computing
University of Georgia

Ramana Pidaparti
rmparti@uga.edu
College of Engineering
University of Georgia

Introduction

WIP: Engineering education is undergoing a rapid transformation as artificial intelligence (AI) and computer vision (CV) become foundational technologies across science, engineering, and society. Both AI and CV are becoming increasingly important technologies that shape how students interact with the world around them, from smartphones and games to healthcare and transportation. To better prepare K–12 students for future learning and careers in STEM, it is essential to introduce these concepts in developmentally appropriate and engaging ways. To support this goal, we are developing an educational tool that helps students understand how a fundamental component of computer vision works through interactive, hands on learning experiences. Aligned with the CSTA K–12 Computer Science Standards [1] and the Next Generation Science Standards (NGSS) [2], this application is designed to be integrated into classroom instruction as part of a broader, research based curriculum developed by education experts, similar to programs such as ImageSTEAM [3], an ITEST project funded by NSF. By making AI and computer vision concepts accessible and relevant, this tool supports curiosity, computational thinking, and early engineering skills for learners across K–12 grade levels.

In this work in progress, we have designed a prototype of this application and a framework which teachers can use to design courses to teach grades 6-8 concepts related to CV and AI (an example screenshot of the tool is later referenced in Figure 1). In this paper, we describe the motivations for this application, the curriculum which this application may be adapted for, and the current design and anticipated final state of the application. We will also discuss how we plan on moving forwards to test the prototype with middle school teachers and students to validate the usefulness of such an application.

Related Works

There has been a movement towards helping middle school students learn concepts in AI in order to prepare them for future endeavors. Examples of these efforts can be seen in programs that create curriculums and lesson resources such as ImageSteam [3], research of how students learn about AI and what resources they need [4], research on the perceptions of middle school students on AI [5], research on the perceptions of middle school teachers on AI [6], and visual computing professional development for middle school teachers [7].

For decades, teachers have utilized hands-on learning tools to help in education [8]. Programs such as ImageSteam heavily utilize such tools [3]. Focusing on computer vision, we can see tools such as CNN Explainer [9], DoodleIt [10], and Feature Detection Tool [11]. CNN Explainer is an excellent tool to see a high-level picture of how convolutional neural networks (CNNs) function, but it requires a higher depth of knowledge than expected of middle schoolers. DoodleIt and Feature Detection Tool are both fun and interactive tools that can help students learn how computer vision techniques work at a high-level, but they eliminate many elementary and fundamental processes for how computer vision functions.

Other tools have been developed, such as those compiled in [12], but these are not relevant to the target age group and concepts. While each of these tools is useful in their own rights, we see a gap in interactive tools that help middle school students learn how elementary components to some complex artificial intelligence algorithms function. Either the tool is targeted towards a higher level of education or the tool does not adequately explain the concept we are targeting. By creating a tool targeted for middle school grades 6-8 that will help teach computer vision concepts, we aim to fill a gap educational devices that teachers will need in the ongoing mission of AI education.

Motivation

To help students learn about AI, we plan on exposing the concepts of Computer Vision to them. There are many sub-fields in AI such as Large Language Models (LLMs such as ChatGPT), Computer Vision (CV, such as object detection, video anomaly detection, and facial recognition softwares), Reinforcement Learning (such as self-driving car softwares), predictive models (such as stock market prediction programs), and more not listed here.

In this work, we will focus on a fundamental component to CV (more specifically, convolutional neural networks): image processing and convolutions. A key component to a CV model, such as AlexNet, is a convolution layer [13]. Convolutions are also a primary component to image processing techniques such as Sobel edge detection [14]. A convolution is the process of applying a filter over an image to create a new image based on the filter used. In the example of Sobel edge detection, filters are used that exaggerate contrasting pixel intensities in order to identify edges. Since convolutions are an elementary and core component to computer vision, we are targeting this concept which is in need of tools that assist in its education, as discussed in the related works.

Relevant Learning Standards

Middle school students should be familiar with addition, subtraction, multiplication, and division according to Common Core State Standards which NGSS frequently refers to in their standards [15]. Also according to Common Core, middle school grades 6-8 will be learning about ratios, larger equations, and functions. CSTA standards relevant to our work are from the topic “Algorithms and Programming” which state “Use flowcharts and/or pseudocode to address

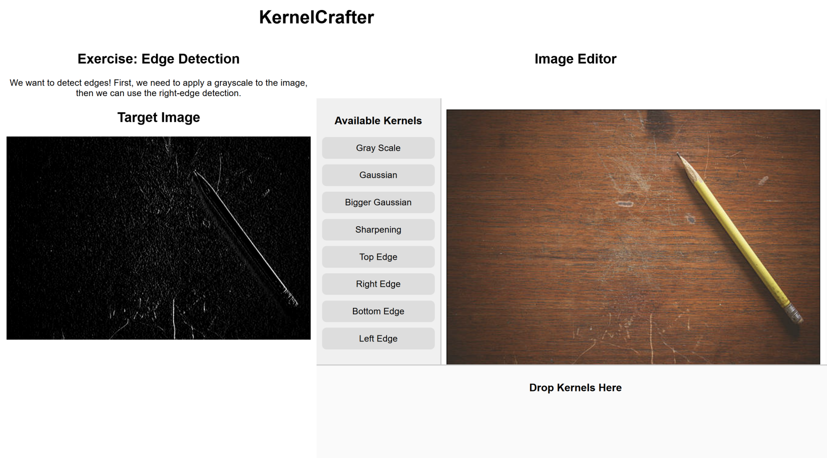

Figure 1: An example problem of KernelCrafter where the user must apply a "Grayscale" and "Right Edge" filter to the image on the right side in order to make it match with the given image on the left side.

complex problems as algorithms" [1]. While NGSS do not have standards directly related to our work, the standards in MS-PS4 for wave functions are similar in nature to the goals of this project, where kernels are similar to waves in the sense that patterns can be identified and certain results can be expected from mathematical relationships [2].

Application and Its Use

Our tool would be used as a module in a curriculum designed to teach image processing and fundamental components of computer vision. To provide motivation for our learning tool, we use basic image processing concepts that students may already be familiar with. For example, infrared images are usually shown in red hues. Typically, the vision of animals is shown in these different kinds of hues and processed images, which will give students a foundation to think of how image processing might be useful [16].

Using our application, students can interactively apply different convolutions to understand how and when images look different based on the convolution processes applied. Applying the motivation, we will use image processing techniques dependent upon convolutions to show students how animal vision depictions are created. To adhere to the learning standards mentioned, we create a sequence of operations as a list of steps (similar to a flow chart) to convey to the students the processes applied to the image. Students will drag kernels into the "Active Kernels" bar of the application to add a kernel to the sequence of convolutions. An example of the application prototype can be seen in Figure 1 (visuals will be improved after prototype).

The application, which we name "Kernel Crafter", will have a series of exercises that students will be able to follow along with in order to sequentially learn about how convolutions work. Early exercises will teach how a simple application of one kernel will affect an image and later exercises will challenge students to think of how many kernels will need to be pieced together in order to achieve a final image. By allowing students to interactively learn how different kernels change images when applied and exposing students to patterns of numbers responsible for these transformation, we hope to allow students to become familiar with the fundamental component of computer vision known as convolutions.

Teacher Perspective and Feedback

We have conducted a preliminary investigation and received positive feedback from a middle school teacher as to how we might motivate students to interact with the app and what concerns there may be for learning and comprehension. While interviewing a single middle school teacher is obviously not comprehensive, we have taken this feedback into account and will continue to seek out further feedback from different teachers and students.

We will also explore further feedback in regard to the suggested curriculum framework and implementation. We are planning to explore the implementation of this tool during a Summer workshop as part of a NSF-ITEST project. During this workshop, we will conduct discussions with teachers and students using this framework to understand the feasibility of the tool for middle school curriculums. By surveying both students and teachers before and after, we will determine if this tool provides a tangible benefit to either teachers or students who are part of classes that learn about artificial intelligence and computer vision. We will survey items such as familiarity with AI and CV, experiences with the tool, frustrations or satisfactions with the content, and how much students were able to learn about convolutions through the use of this tool. We will also make this tool available online to expose this tool to feedback from more educators who may be interested in teaching computer vision, allowing broader easy access to seek further feedback and help those who find it useful.

Conclusion

We have developed a prototype and will continue to develop this tool reflecting AI and CV to be adapted into middle school curriculums, with respect to existing GA learning standards and suggestions from middle school teachers. Through this application, we hope to assist teachers in teaching middle school students fundamental concepts of CV. We plan on completing the first iteration of this application and receiving feedback from students by organizing teachers to conduct an experiment later this year in June or July. We look forward to receiving additional feedback and exploring how our app can help students and teachers in the world of AI.

Acknowledgment

The authors thank the national science foundation for supporting this research through grant NSF#1949493 and grant NSF #1949384.

References

[1] Computer Science Teachers Association, “CSTA K-12 Computer Science Standards, Revised 2017,” accessed Jan. 10, 2026. Available: https://csteachers.org/k12standards/interactive/.

[2] Next Generation Science Standards, “MS.Engineering Design,” accessed Jan. 10, 2026. Available: https://www.nextgenscience.org/topic-arrangement/msengineering-design.

[3] S. Jayasuriya, K. Swisher, J. Rego, S. Chandran, J. Mativo, T. Kurz, C. Collins, D. Robinson, and R. Pidaparti, “ImageSTEAM: Teacher professional development for integrating visual computing into middle school lessons,” in *Proc. 14th Symposium on Educational Advances in Artificial Intelligence (EAAI-24)*, 2024.

[4] E. Greenwald, M. Leitner, and N. Wang, “Learning artificial intelligence: Insights into how youth encounter and build understanding of AI concepts,” in Proc. AAAI Conf. Artif. Intell., vol. 35, no. 17, pp. 15526–15533, May 2021.

[5] M. Tartuk, “Metaphorical perceptions of middle school students regarding the concept of artificial intelligence,” Int. J. Educ. Lit. Stud., vol. 11, no. 2, pp. 108–116, 2023.

[6] K. Swisher, T. Kurz, S. Jayasuriya, J. Covert, J. Mativo, R. Pidaparti, and D. Robinson, “Middle school teachers’ perceptions of computer vision,” in Proc. Soc. Inf. Technol. Teach. Educ. Int. Conf., E. Langran, Ed., New Orleans, LA, USA: Assoc. Adv. Comput. Educ. (AACE), pp. 1824–1829, 2023.

[7] T. L. Kurz, S. Jayasuriya, K. Swisher, J. Covert, J. Mativo, R. Pidaparti, and D. T. Robinson, “Visual computing professional development and Title I middle school teachers’ STEM computational thinking,” in Proc. Soc. Inf. Technol. Teach. Educ. Int. Conf. (SITE), pp. 40–45, 2025.

[8] D. Klahr, L. M. Triona, and C. Williams, “Hands on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children,” J. Res. Sci. Teach., vol. 44, no. 1, pp. 183–203, 2007.

[9] Z. J. Wang, R. Turko, O. Shaikh, H. Park, N. Das, F. Hohman, M. Kahng, and D. H. Chau, “CNN Explainer: Learning convolutional neural networks with interactive visualization,” in *IEEE Transactions on Visualization and Computer Graphics*, vol. 27, no. 2, pp. 1396–1406, Feb. 2021, doi: https://doi.org/10.1109/TVCG.2020.3030418.

[10] V. Mahipal, S. Ghosh, I. T. Sanusi, R. Ma, J. E. Gonzales, and F. G. Martin, “DoodleIt: A novel tool and approach for teaching how CNNs perform image recognition,” in *Proc. 25th Australasian Computing Education Conference (ACE ’23)*, Melbourne, VIC, Australia, Jan./Feb. 2023, pp. 31–38, doi: https://doi.org/10.1145/3576123.3576127.

[11] D. DiPaola, P. Malachowsky, N. B. Black, S. Alghowinem, X. Du, C. Breazeal. ”An Introduction to Rule-Based Feature and Object Perception for Middle School Students,” The Thirty Seventh AAAI Conference on Artificial Intelligence (AAAI-23), vol. 37, no. 13, July 2024, doi: https://doi.org/10.1609/aaai.v37i13.26900.

[12] U. Rajashekar, A. C. Bovik, D. Sage, M. Unser, L. J. Karam, R. I. L. Lagendijk, “Image processing education,” in *Handbook of Image and Video Processing Education*, 2nd ed. Academic Press, 2010, pp. 73-95. 2005. [Online]. Available: https://www.cns.nyu.edu/∼umesh/publications/2005/urHbook2005IPEdu.pdf.

[13] M. Z. Alom, T. M. Taha, C. Yakopcic, S. Westberg, P. Sidike, M. S. Nasrin, B. C. Van Essen, A. A. S. Awwal, and V. K. Asari, “The history began from AlexNet: A comprehensive survey on deep learning approaches,” arXiv:1803.01164, Mar. 3, 2018. [Online]. Available: https://arxiv.org/abs/1803.01164.

[14] G. W. Gao, X. Zhang, L. Yang and H. Liu, “An improved Sobel edge detection,” in Proc. 2010 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT), Chengdu, China, 2010, pp. 67–71, doi: https://doi.org/10.1109/ICCSIT.2010.5563693.

[15] Common Core State Standards Initiative, “Common Core State Standards for Mathematics,” Sep. 2023. [Online]. Available: https://corestandards.org/wp-content/uploads/2023/09/Math_Standards1.pdf. [Accessed: Jan. 10, 2026].

[16] Google Arts & Culture, “How Animals See the World,” accessed Dec. 12, 2026. Available: https://artsandculture.google.com/story/how-animals-see-the-world/qgWhAEJda6STRg?hl=en.