Instructor: Andy Mina
Grade Level and Subject: 12th Grade - Introduction to Computer Vision
Topic: Introduction to Convolutions
Lesson: 05_gaussian

NYS Computer Science and Digital Fluency Learning Standards	9-12.CT.2 - Collect and evaluate data from multiple sources for use in a computational artifact. 9-12.CT.3 - Refine and visualize complex data sets to tell different stories with the same data set. 9-12.CT.6 - Demonstrate how at least two classic algorithms work, and analyze the trade-offs related to two or more algorithms for completing the same task.
Content Objective	Students will be able to: ● Understand how to construct a square Gaussian kernel of odd size mathematically ● Understand why Gaussian blur is better than Block blur for image editing ● Identify how the sigma parameter changes the size of the Gaussian blur
Scaffolding Needed	Students should be able to: ● Identify and work with the Block blur kernel comfortable
Key Vocabulary	**Gaussian distribution**: a 1D or 2D mathematical function that gives a smooth fall-off of y-values from the peak **Gaussian kernel**: a square kernel constructed using weights from a 2D Gaussian distribution **noise:** random variation of brightness or color in images produced by sensors and cameras
Assessments	Roll for Confidence (Formative) Students will be asked to "roll for confidence" and respond by showing the instructor a number from 1 to 5 on one of their hands. Their confidence is representative of how comfortable they feel in continuing to explore and compare other sorting algorithms on their own. Scores represent the following: 1. **Not confident.** Needs a re-explanation or summary of the lesson with emphasis on key points. 2. **Pretty shaky.** Needs a brief recap and some teacher-guided practice to solidify concepts and understanding. 3. **Okay.** Needs some peer-guided practice and some more time to let things sink in. Ideal rating after

	the lesson. 4. **Pretty confident.** Needs some peer-guided practice for more challenging algorithms, but is self-sufficient for what's covered in class. Ideal rating before a unit test. 5. **Extremely confident.** Needs little to no guidance and can tackle problems of exceptional difficulty with relative ease. Indicative of an under-challenged student. These checks shouldn't take any longer than one minute.
Materials	05_gaussian

Lesson Component	**Description or Execution of Lesson Component (w/ scripting when appropriate)**
Essential Question	What is a Gaussian distribution and how do we apply it to images?
Do Now	**S1, 2m** Walk around the room and chime in where appropriate.
Presentation of Content	**S2-7, 8m** Give a brief introduction to Gauss, but spend some more time on where Gaussian distributions appear. "Gauss is one of those mathematicians that no matter what field you go into, you'll hear his name. All roads lead to Gauss and/or Euler. The simplest formula for a Gaussian distribution is **S4** but we want to make this work for any input x so we get a formula like **S5** instead. I know this looks spooky at first, but YouTuber 3Blue1Brown will break it down for us." After the video, roll for confidence in understanding the parts of Gaussian distribution: ● There's some x input that is the power of e ● We center this x input with some more normalization ● There's a normalization factor at the very front

	S8-9, 4m Review with students why the Gaussian distribution is important in convolution and image editing. Read and emphasize the question at the bottom. So far, we've looked at one-dimensional Gaussians but images are two-dimensional. **S10-11, 6m** Explain to students that there's also a formula for a 2D Gaussian that 3Blue1Brown will also help explain. In a few slides, we'll see how we can translate a 2D Gaussian to a kernel. The height at a certain (x, y) point corresponds to the weight of the pixel at (col, row) in a kernel. "For our class, we'll only be talking about square 2D Gaussian. The x-length and the y-length will always be the same. This means the formula looks pretty similar to the 1D Gaussian. The 2D Gaussian formula is broken into three parts: 1. the squared distance of (x, y) from the center (think Pythagorean Theorem) 2. A normalization factor for this squared distance. We raise e to the power of this normalized distance 3. A normalization factor at the very front to make sure that the sum of all values equals 1." Stop for questions as needed and take this slowly. **S12-14, 6m** "Using the formula on the last slide, and what you'll be doing for homework, we can translate a 2D Gaussian to be a kernel where the output for a certain (col, row) corresponds to that pixel's weight in the convolution. In kernel image form, you can see how the sigma parameter affects how wide our Gaussian will spread. Also note that as we start from the center and go to the borders, the weights gradually decrease, seen by the white -> gray -> black transformation." Note to students that a bigger sigma = more blur, and smaller sigma = less blur. More often than not, a good sigma is the size of the kernel / 5. Roll for confidence in:

	- How a 2D Gaussian applies to image editing with convolution - How the sigma values influences the blur **S15-16, 6m** Go through these slides with students and demonstrate why a 2D Gaussian is important in convolution. "A 2D Gaussian is great for blurring as we saw in the last slides. It's better than the Block blur since it doesn't leave behind the block ridges from where we *didn't* take the average. With a Gaussian, the cutoff is smooth so the blur is smooth. This smoothing is great for getting rid of noise, bits of distracting information. In images, noise manifests as sudden, random variation in brightness or color. The image loses some quality but the smoothness makes it a lot easier to detect edges in images, which is what we'll be doing tomorrow." **S17, 6m** Introduce the homework to students and go over any initial questions or confusion they may. If there's time left over in the period, students should start the homework while they have access to the instructor. They can also work in pairs, but each person must submit their own code.
Homework	n/a