

UCF RET Site: Research Experiences in Computer Vision and Bio-Medical Imaging Lesson/Unit Plan

3027020: Biotechnology 2

Kathy Savage

3027020: Biotechnology 2

July 22, 2018

RET Site: Research Experiences in Computer Vision and Bio-Medical Imaging Lesson/Unit Plan

Course(s): Biotechnology
Grade Level: 10
Suggested Length of Lesson: 13 50-minute class periods

Equipment/Technology Needed (assumes the teacher will have six groups of four students each)

- A minimum of eight classroom computers with Internet access and 3D Slicer installed.

Where this Fits

- Anatomy and physiology
- Unregulated cell growth and cancer
- Epigenetics
- Gene expression
- Technology

Lesson Objective(s)/Learning Goal(s)

Learning Goal

- Students will understand the role of computer vision as an important tool in early stage lung cancer detection, diagnosis, & treatment.

Lesson Objective(s)

- Define computer vision and describe how it benefits society in a variety of fields
- Understand some of the challenges associated with computer vision.
- Identify some of the current and future roles of computer vision in personalized medicine.

Next Generation Sunshine State Standards (Science 912)

- SC.912.I.14.44
- SC.912.N.1.1
- SC.912.N.1.6
- SC.912.N.3.5
-

Standards for Mathematical Practice

- Not applicable.

Evidence of Learning (Assessment Plan)

Informal Assessment

- Monitoring and observation
- Worksheets
- Exit tickets
- Discussion

Formal Assessment

- Case Study Radiology Report
- Group / Individual Presentations
- Post test

Instructional Strategies

- Classroom Discussions
- Use of Content-Specific Vocabulary
- Integration of Multiple Content Areas
- Project-Based Learning
- Activating prior knowledge
- Cooperative Learning
- Discovery/Inquiry-based learning
- Generating and Testing a Hypothesis
- Modeling
- Hands-on learning
- Case Study Analysis
- Think, Pair, Share

Description of Lesson Activity/Experiences

Students are introduced to computer vision and its applications to medical imaging. Students will then play the role of a radiologist and analyze patient data and CT scans for an assigned case study of a lung cancer patient(s). Students will perform a simulated microarray experiment to look for signature gene expression patterns. Finally, students will use data from the CT scan and the microarray to detect, diagnose, and make treatment suggestions for their case study patient and present their case to the class.

DISCLAIMER
This lesson is not meant to be a portrayal of verified clinical information and is not meant to supplant advice from a qualified medical professional. While all efforts have been made to ensure fidelity to the medical profession, some medical information and practices have been modified, summarized, or simplified to meet the needs of the Biotechnology curriculum and expectations for high school instruction.

Day 1: Unit Introduction and Lung Cancer

This unit assumes that the subject of cancer biology, especially with respect to cell signaling, has already been covered. The first day, therefore, transitions the students from this general subject of cancer to lung cancer specifically. Students use classroom computers to answer overview questions on lung cancer in the form of a WebQuest. These overview questions cover everything from symptoms and diagnosis to treatment and prognosis. Once the WebQuest has been completed, the teacher facilitates a discussion using the provided PowerPoint. The PowerPoint discussion will begin to transition students from lung cancer to computer vision specifically with how computer vision in the form of medical imaging can be used for early detection. The teacher should hand out the MD Anderson Lung Cancer Screening Algorithm to incorporate into the discussion about early detection.

Discussion questions listed in the PowerPoint are listed below, but teachers should not feel limited to these questions, but should direct all discussion toward the topic of the importance of early detection.

1. What is the mortality rate of someone diagnosed with lung cancer at each stage?
2. Why is the mortality rate so much higher than breast cancer or prostate cancer?
3. How would early detection improve the survival rate for lung cancer patients?
4. What would early detection look like?
5. How would we determine who qualifies for preventative screening?
6. How would we get the word out (especially in high risk areas)?

Day 2: Computer Vision: "Better Medicine through Machine Learning")

The teacher will show a TED talks video to the class while the students answer questions on the accompanying worksheet. The video is eighteen minutes so, effectively, half the class period. The speaker is Suchi Saria who has been listed among 2016's 'Artificial Intelligence's Ten to Watch' by the Institute of Electrical and Electronics Engineers and as one of Popular Science's 'Brilliant 10'. The talk allows for an almost seamless shift from early detection of disease to the broader topic of machine learning. Saria introduces a computer program called TREWS (Targeted Real-time Early Warning Score) which is being used for early detection of sepsis. TREWS analyzes huge amounts of data in real-time, comparing a specific patient's data to that of a more general population of sepsis patients to allow for the early warning of sepsis onset. Teacher facilitated discussion

follows the video asking students to hypothesize how machine learning could benefit patients being screened for lung cancer. An exit ticket, which can be used to monitor understanding or as a formative assessment tool, is given to the students about 5 minutes before class ends.

Recommended transition questions for teacher facilitated discussion after the video:

1. What are some ways that computers can help with scientific research? personalized medicine?
2. In what ways do you think we can apply machine learning to early-stage lung cancer detection?

Day 3: **Computer Vision:** ***"How we teach computers to understand pictures")***

This is a repeat of day two, but with a different TED video. This video features Fei Fei Li who has served as Chief Scientist of Artificial Intelligence and Machine Learning for Google Cloud and is the director of the Artificial and Intelligence lab at Stanford. Li describes the difference between 'seeing' and 'understanding' and that when we talk about computer vision and artificial intelligence, what we really mean is the capability of a computer to assign meaning to what it 'sees'. Li explains what our current capabilities and limitations are within the field of computer vision. Relying heavily on the use of detecting cats as objects, Li describes some of the current challenges faced by computer vision scientists. Recommended questions for the teacher facilitated, post video discussion are designed to encourage students to transition from thinking about why early disease detection is important to how a computer might be able to make a detection in the first place. An exit ticket, which can be used to monitor understanding or as a formative assessment tool, is given to the students about 5 minutes before class ends.

Recommended transition questions for teacher facilitated discussion after the video:

1. In what ways do you think we can apply machine learning/computer vision to early-stage lung cancer detection?
2. What would we have to teach a computer to recognize to detect early-stage lung cancer?
3. What would we tell a computer to look for when segmenting out a tumor from an MRI scan?
4. What would we tell a computer to do if we wanted a 3D model of that tumor?

Day 4: Computer Vision: Crowd Counting Demo and Analysis

Crowd counting is an important application of computer vision. Being able to identify or, even better, to predict, the number of people in a crowd is a valuable tool in many fields from security to politics. Researchers at the University of Central Florida (UCF) are world leaders in the development of crowd counting algorithms. UCF has put a crowd counting demo on their website that allows someone to upload images and run one of their algorithms to provide a close approximation of the number of people in a crowd. Students will use this demo to make a hypothesis as to what the computer 'sees' and how it identifies an image as a person to provide a count estimation. For example, students may hypothesize that computers are better at detection a person if they are not wearing a hat than if they are wearing a hat, or that computers are better at counting the number of people in a crowd if the image is in color than if it is in black and white. Students will then gather images from Google to upload to the UCF Crowd Counting demo and test their hypothesis.

Day 5: Computer Vision: Segmentation and Region Growing

Region growing is a pixel-based image segmentation method that employs the use of seed points. In order to help students grasp the concept of region growing, the teacher should begin the lesson by showing the 15 second animations of region growing provided in the PowerPoint. The teacher should ask the students what the computer is doing and how they think it is doing it, as well as asking them how an application that uses a region growing algorithm might be applied to early lung cancer detection. This will transition students back from basic computer vision to its applications for medical imaging. After the discussion, the teacher can show the third video on the PowerPoint "How Region Growing Image Segmentation Works" which briefly explains the RGB color numbering system and how mathematics can be applied by the computer to analyze a pixel and determine whether it should be added to the region of interest. After the video, the teacher should return to the facilitated discussion questions to determine the level of student understanding of region growing.

Once the students can demonstrate a basic understanding of region growing and segmentation, the teacher should pass out the Memorial Healthcare System Video worksheets and allow the students to use the remainder of the class period to watch two videos and answer the accompanying questions. These videos will transition the students from computer vision to lung cancer detection and segmentation.

Day 6: 3D Slicer Tutorial

During this class period, students will all have the same data set. Students can work alone or with a partner, depending on the number of available computers, and go through the tutorial to segment their lung nodule and build a 3D model of the nodule in 3D Slicer. Students should figure out how to measure the approximate diameter and volume of their nodule using the 3D Slicer program.

Day 7: Case Study using 3D Slicer

At the beginning of this period, students should be provided with their case study patient data. Teachers may use the ****** website to identify a set of data where the lung nodules are obvious enough for the student to see and identify and then download the sets of data needed for class so that each group of four students has a different data set than any other group. Allow the students to use the entire class period to segment their lung nodule and complete the appropriate section of their radiologist report.

Day 8: Epigenetics and Gene Expression

Again, students can work alone or with a partner, depending on the number of available computers, Students will walk through a Learn Genetics interactive website that will help them to understand what epigenetics is and what is meant by gene expression. Students should use the website to complete the accompanying worksheet. Once all student groups have completed the assignment, the teacher can use the discussion questions to round off the lesson and get students to think about what they have just learned. About five minutes before the bell rings, the teacher should pass out the exit ticket which asks the student to compare and contrast genetics and epigenetics.

Day 9: Epigenetics and Gene Expression

Students should be provided with excerpts from journal articles on gene profiling for lung cancer patients. They will then use this information to respond to some questions in a think-pair-share activity. The students must use their knowledge to determine whether providing a gene expression profile should be standard practice for stage one lung cancer patients and explain their reasoning. After the think-pair-share activity, students will read a journal article titled "Gene Expression Profiling and Non-Small Cell Lung Cancer: Where are we now?" and answer questions on the accompanying worksheet.

Day 10: Microarrays

Students again use the Learn Genetic website to participate in a virtual microarray lab activity. As students proceed through the lesson, they will be answering questions on the accompanying worksheet. After the activity has been completed, the teacher can use the discussion questions in the PowerPoint to help students organize their thoughts.

Day 11: Case Study using Microarrays

Using an Edvotek microarray simulation lab, students will analyze the gene expression for their case study. They will then combine the gene expression data with the data gathered from using 3D Slicer to discuss and agree on the best treatment option for their patient.

Day 12: Student Presentations

Student groups get the chance to present their case study to the class. The teacher should use the rubric provided in this lesson, but can choose to use it as a formative or summative assessment tool.

Day 13: Guest Speaker and Wrap-up

A guest speaker working in computer vision will be brought into the classroom. Students can ask the questions they have written in some of their exit tickets if there is time and the guest speaker is agreeable. About 10 minutes before the bell rings the teacher should pass out the post-test / survey and have the students complete it so that data from the pretest and post-test can be compared if the teacher chooses to do so.

Recommended Assessment(s) and Steps

Alternative Assessment Options Not Included

- Performance-based assessment of students while engaging in the role-play.
- Project-based assessment produced by students describing their experiences and knowledge from the lesson.

List of Materials/Resources Used

-
-

Important Vocabulary

Term	Definition
Metastasis	Metastasis is a characteristic of late-stage cancer where cells from the primary cancer (original cancer location) have entered the lymphatic system and spread throughout the body.
Spiculation	Spiculation is a tumor characteristic involving points and spikes around an abnormal growth of tissue that suggests malignancy.
Computed tomography (CT)	Computed tomography (CT) is the medical imaging process that uses a rotational x-ray projector to create a three-dimensional image of a region of interest.
Algorithm	An algorithm is a programming feature where an action is performed based a set of predetermined steps.
Computer-aided detection (CAD)	Computer-aided detection (CAD) is a computer vision application that improves detection of a specific image feature through the use of computer algorithms. An example of CAD is using region-growing algorithms to detect lung nodules at sizes smaller than those readily seen with the human eye.
Segmentation	Segmentation is a computer vision application that separates a specific structure from nearby structures in an image. For example, segmentation can be used to isolate a pulmonary nodule from the rest of the lung and chest cavities.
Region growing	Region growing is a computer vision application where portions of an image are segmented by the repetitive comparison of a selection, called a seed, to a pre-defined parameter, or threshold. As each neighboring pixel meets the threshold, it is included in the selection. Pixels that do not meet the threshold are excluded from the selection.
Axial	The axial view is an anatomical plane that divides the body in horizontal slices from head to feet.
Sagittal	The sagittal view is an anatomical plane that divides the body in left and right halves. Sagittal comes from the Latin word, *sagitta*, which means arrow. You can imagine the sagittal plane resulting from an arrow piercing the body.
Coronal	The coronal view is an anatomical plane that divides the body in front and rear halves. Coronal comes from the Latin word, *corona*, which means crown. You can imagine the coronal plane resulting from someone placing a crown on someone's head.

Adjuvant	The term adjuvant describes subsequent treatments used to improve the effectiveness of an initial treatment. An example of an adjuvant treatment is the administration of chemotherapy following the surgical removal of cancer.
Chemotherapy	Chemotherapy is a cancer treatment option that uses oral or intravenous drugs to target rapidly dividing cells, whether cancerous or not. Because of the systemic nature of the treatment, unintended side effects often occur.
Radiation therapy	Radiation therapy is a cancer treatment option that uses electromagnetic and radioactive radiation to kill cells. When targeted effectively, the treatment can minimize damage to healthy cells and primarily target cancerous cells.

Troubleshooting Tips

UNDO/REDO: People familiar with the common "Undo" shortcut, CTRL+Z for Windows or CMD+Z for Mac, will be frustrated by 3D Slicer. Be sure to click the "Undo" button on Editor rather than using keyboard shortcuts.

Undo/Redo: 

SAVING CT IMAGE DATASET: When saving your image dataset, make sure you indicate a source location with your own folder name. Otherwise, it might save to an unrecognizable directory that you are unable to locate.

SEGMENTING DIFFICULTIES: If problems arise during segmentation, such as the region growing algorithm incorporates more or less tissue than desired, you can use the **PaintEffect** tool to erase (use **Background #0** color) or add (use the color of your model) to your selection.

FASTGROWCUT INSTALLATION: An extension tool called **FastGrowCut** must be installed prior to segmentation lung nodules. The FastGrowCut Tutorial by Hillary Lia of Queen's University walks through how to install it.

Other Helpful Information

MODIFICATIONS

- Utilize and provide anatomical models from an anatomy class to supplement lung introduction.
- Provide pre-segmented lung nodule images on 3D Slicer to facilitate diagnosis.
- Provide printed CT scans in case of computer difficulties.
- Provide pre-labeled CT images to facilitate quick characterization and diagnosis.

EXTENSIONS

- 3D printed models of lung cancer nodules and lung segments
- Field trip to visit radiologist at a local hospital
- Bring in a radiologist as a guest speaker

SUPPLEMENTAL RESOURCES

Attachments

- Pretest / Post-test
- WebQuest (student version and teacher key)
- PowerPoint with discussion questions and informational slides
- MD Anderson Lung Cancer Screening Algorithm
- Transcript of all five videos used for this set of lessons
- “Better Medicine through Machine Learning” worksheet and teacher key
- “How we teacher computers to see” worksheet and teacher key
- Five exit ticket worksheets
- Crowd Counting Activity Worksheet
- Memorial Healthcare System’s lung cancer staging and segmentation student worksheet and teacher answer key
- 3D Slicer Tutorial PowerPoint
- Set of eight case study radiology reports
- Set of student presentation cards (one card per group)
- Student presentation rubric
- Epigenetics and Gene Expression student worksheet and teacher answer key to accompany the Learn Genetics website
- Microarray student worksheet and teacher answer key to accompany the Learn Genetics website virtual lab activity
- Think-pair-share journal excerpt cards on gene expression and profiling for lung cancer patients
- Journal article “Gene Expression Profiling and Non-Small Cell Lung Cancer: Where are we now?”, accompanying student worksheet and teacher answer key
- Edvotek microarray simulation modified procedure

References

Adler, C. (retrieved on July 30, 2018). *Seven Strategies to Teach Students Text Comprehension*. Retrieved from Reading Rockets: http://www.readingrockets.org/article/seven-strategies-teach-students-text-comprehension

Ashford, K. (2015, September 1). *To Test Cancer Sooner, we need the Government to invest in the NHS*. Retrieved from Cancer Research UK Science Blog: https://scienceblog.cancerresearchuk.org/2015/09/01/to-test-cancer-sooner-we-need-the-government-to-invest-in-the-nhs/

Association, A. L. (2018). *Lung Cancer Fact Sheet*. Retrieved from Lung Cancer.

Bolarko, E. (2012, February 13). *Region Growing Method*. Retrieved from YouTube: https://www.youtube.com/watch?v=IjK774GwRGk

Cancer, Y. a. (2017, November 20). *Staging of Lung Cancer*. Retrieved from YouTube: https://www.youtube.com/watch?v=6moQ47RsgYg

Cicero, L. (2016, 10 29). *Computer Vision Leader Fei-Fei Li on why AI Needs Diversity* . Retrieved from Spectrum IEEE: https://spectrum.ieee.org/tech-talk/at-work/tech-careers/computer-vision-leader-feifei-li-on-why-ai-needs-diversity

Epomedicine. (2016, August 15). *TNM and Staging of Lung Cancer Simplified*. Retrieved from Epomedicine: http://epomedicine.com/medical-students/tnm-staging-lung-cancer-simplified/

Francisco, U. S. (2012, January 26). *New Lung Cancer Test Predicts Survival*. Retrieved from YouTube: https://www.youtube.com/watch?v=nZ_6MlTRVEE&t=12s

Haroon Idrees, K. S. (2015). Detecting Humans in Dense Crowds Using Locally-Consistent Scale Prior and Global Occlusion Reasoning. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 1986-1998.

Heid, M. (2016, July 14). *Top 10 Deadliest Types of Cancer*. Retrieved from Prevention: https://www.prevention.com/health/g20429978/top-10-deadliest-types-of-cancer/

K. Lewis, Z. K. (2015, 10 15). *UCF Researchers Perform World's First Automated Mass-Crowd Count*. Retrieved from UCF Today: https://today.ucf.edu/ucf-researchers-perform-worlds-first-automated-mass-crowd-count/

Kim, M. (2015, April 11). *The science of...crowd size estimation*. Retrieved from Philly Voice: https://www.phillyvoice.com/science-crowd-size-estimation/

Klempner SJ, Ou SH, Costa DB, VanderLaan PA, Sanford EM, Schrock A, Gay L, Ali SM, Miller VA. *Clin Lung Cancer. 2015 Sep*

Korting, T. (2014, July 31). *How Region Growing Image Segmentation Works*. Retrieved from YouTube: https://www.youtube.com/watch?v=VaR21S8ewCQ&t=118s

Miller, J. (2006, August). *Evaluating Pulmonary Nodules*. Retrieved from Radiology Roungs Massachusetts General Hospital : https://www.massgeneral.org/imaging/news/radrounds/august_2006/

Nasser, N. J. (n.d.). *Staging of Lung Cancer*. Retrieved from The Best Oncologist(TM): http://www.thebestoncologist.com/Cancer_Diseases/Lung_Cancer/Staging_of_Lung_Cancer.html

Orlando, F. 3. (2014, July 24). *UCF Researchers use AI to spot lung cancer*. Retrieved from FOX 35 Orlando: http://www.fox35orlando.com/local-news/348861120-video

Selena Gonzalez, B. S. (2017, May 22). *How do mortality rates in the U.S. compare to other countries?* . Retrieved from Health System Tracker: https://www.healthsystemtracker.org/chart-collection/mortality-rates-u-s-compare-countries/#item-start

State Cancer Profiles: Interactive Maps. (2018, July 25). Retrieved from National Cancer Institute: https://statecancerprofiles.cancer.gov/map/map.noimage.php

van Rikxoort, Eva & Ginneken, Bram. (2013). *Automated segmentation of pulmonary structures in thoracic computed tomography scans: A review*. Physics in medicine and biology. 58. R187-R220. 10.1088/0031-9155/58/17/R187.\\

Acknowledgements

Authors

Dr. Ulas Bagci, Assistant Professor, CRCV, University of Central Florida
Dr. Niels Lobo, Associate Professor, EECS, University of Central Florida
Dr. Mubarak Shah, Trustee Chair Professor, CRCV, University of Central Florida
Rodney Lalonde, Ph. D. student, CRCV, University of Central Florida
Dr. Josue Urbina, science teacher at Crooms AOIT

Supporting Program

SHAH RET Program, College of Engineering and Computer Science, University of Central Florida.
This content was developed under National Science Foundation grant #1542439.

Contact information

Kathy Savage can be reached via email at kathy_savage@scps.k12.fl.us.