

Kyle Chan kxc180021
Ryan Banafshay rcb170002

Chatbot Report

For this project, we decided to design and implement an interactive chatbot from scratch. We decided against using any supplementary platforms, such as Google's DialogFlow or Amazon Lex, as we felt those frameworks did a majority of the work leaving us with very little to code on our own. The chatbot is specifically built to communicate with users about topics related to astronomy. The user can ask questions or make direct statements to the prompt and the chatbot will formulate a response based on our knowledge base. The system will keep track of different users by making use of a user model. The user model stores each user's name while also remembering the different topics the user is interested in. This information is then stored into a pickle file. We used a variety of natural language processing techniques in the implementation of this project; such as cutting out stopwords, lemmatizing sentences for precision, analyzing sentiment scores from user responses, etc.

The system initializes by first opening our intents JSON file. This is how most of the responses outside of the knowledge between the bot to the user is determined. Within the file are a collection of 'intents' with different categories such as greetings, goodbye, welcomeback, thanks, and dislikes. The bot will determine which intent is relevant based on a list of user responses. If there is a certain threshold of similarity between the user response and the list of possible patterns within the intent is reached, then the chatbot will then use that intent's list of responses to communicate back to the user. This calculation is done in the classify function. This function uses a model with the x and y values representing the words and the different categories/intents respectively. Those values are then inserted into sklearn and the model will then assign which intents are most relevant in ascending order. The intents JSON also contains a list of context_req and context_set. The category context_req describes what preconditions must be met to access this intent. The prerequisites are represented by previous intents

accessed by the user. The context_set list will set the context once the intent is reached and used.

Once the JSON is loaded, the model is then loaded in. This model is created using sklearn. For our training data, we used a variety of natural language processing techniques to give us better results for our model. We eliminated all stop words except for no, not, can, and are. Every word was then subsequently stemmed and lowercased. Finally we removed all duplicates leaving us with an improved set of data to work with. The user data, which is represented by a continually updating pickle file, is then loaded and initialized allowing for the chatbot to begin the conversation by asking for the user's name. When the user starts communicating with the chatbot, it determines what intent is most relevant and bases a response on that intent. For simple questions that are outside the scope of our knowledge base, the communication between the user and the bot is done exclusively with the intent system. Once the system recognizes the user is starting to ask questions on the topics of astronomy and blackholes, we flag that we must go into our knowledge base to give a response. When this occurs, we save and then lemmatize the particular subject the user is asking for. We then take that lemmatized word and search for that topic in the knowledge base. From there we extract the sentence that is relevant to the question and give it back to the user.

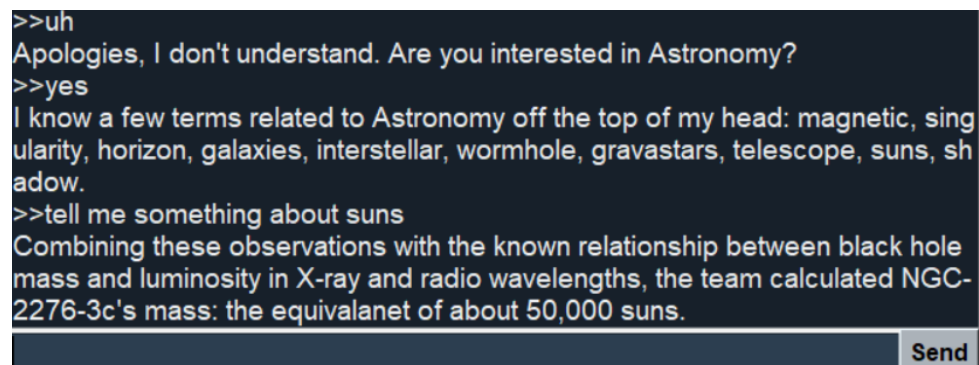
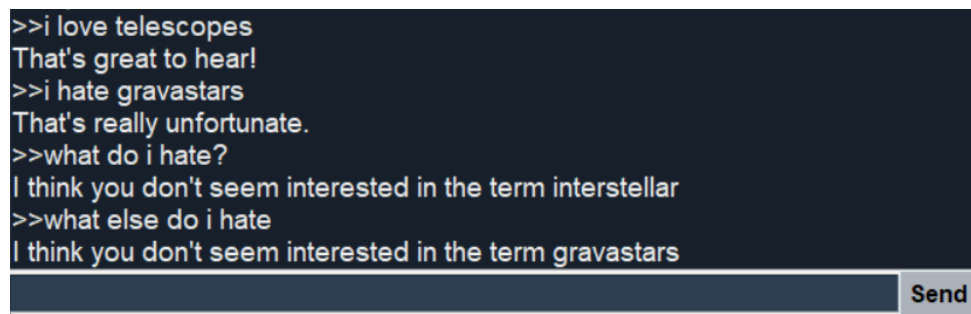
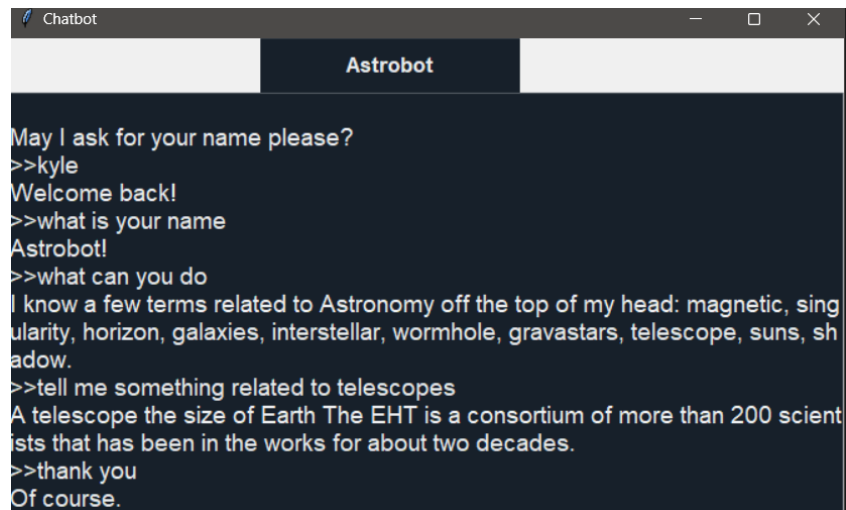
Along the way, we are also recording determining whether what the user is saying is considered a positive, negative, or objective statement. When a user asserts a statement that is positive, we add that to the user model as a topic of interest. When a user asserts a statement that is negative, we remove that from the user model as a topic of interest if it existed there previously. If it is objective, we continue on without making any changes. We determine this by using the natural language processing technique of sentiment analysis. The specific path we went about this with is a process known as VADER (Valence Aware Dictionary and sEntiment Reasoner).

Our knowledge base was developed using a web crawler we had previously created in a prior project. The web crawler extracts contents from different web pages which are relevant to black holes and astronomy. The top 50 words were chosen from those web pages using the NLP technique known as TF-IDF (Term Frequency - Inverse Document Frequency). From this list we handpicked the top 10 words we found the most relevant. These words are magnetic, singularity, horizon, galaxies, interstellar, wormhole, gravastars, telescope, suns, and shadow. These are 10 central topics that our chatbot is oriented around conversing with. The knowledge base is stored in a pickled dictionary, with each of these key topics associated with a list of relevant responses on the subject. See the appendix on the knowledge base for a sample of one of the topics.

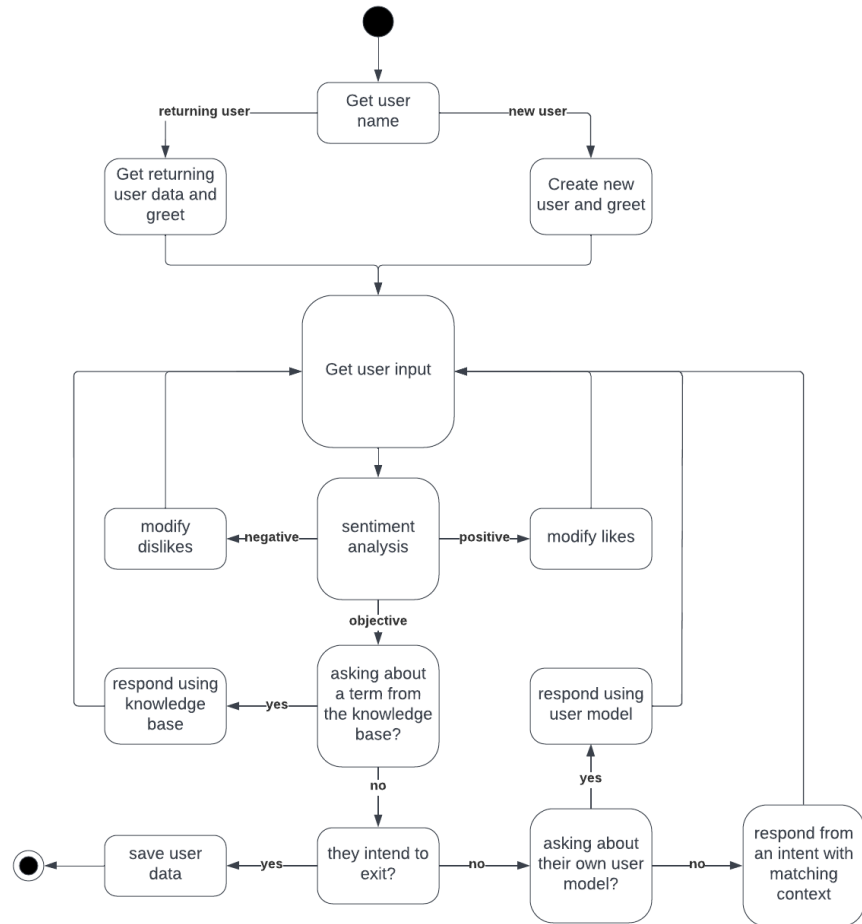
Evaluation

We developed the chatbot from scratch without using any prior framework, which makes the system very simple and prone to error. There are some problems in the system when it comes to asking very detailed questions that go beyond simply asking for an explanation of a certain topic. For example, the bot could have a difficult time differentiating the question “What is a telescope used for” and “How is a telescope built”. The system will see that a question about a telescope is being asked, so it will enter our knowledge base for an answer. It would then answer the first question very accurately but struggle with the second question. This is both that we may not have the answer in our knowledge base as this is not a question about astronomy and the bot is not sophisticated enough to recognize that.

Sample Dialog Interactions



Dialog Logic



Appendix User Model

```
1 import pickle
2
3 class User:
4     def __init__(self, name, likes, dislikes):
5         self.name = name
6         self.likes = likes
7         self.dislikes = dislikes
8
9 user1 = User("john", ['planet', 'galaxy', 'star'], ['blackhole', 'magnetic'])
10 user2 = User("kyle", ['blackhole', 'magnetic'], ['interstellar', 'wormhole'])
11 user3 = User("ryan", ['interstellar', 'wormhole'], ['singularity', 'galaxy'])
12
13 user_list = [user1, user2, user3]
14
15 pickle.dump(user_list, open('user_list.p', 'wb'))
```

Appendix Knowledge Base

Terms: magnetic

[Image credit: Dust and magnetic fields: NASA/SOFA; Star field image: NASA/Hubble Space Telescope] Magnetic forces may explain why the supermassive black hole at the heart of the Milky Way is so much quieter than its counterparts in other galaxies. "New observations, taken by NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) mission, reveal unprecedented information about the strong magnetic field lines at the center of the galaxy." "Understanding how black holes interact with their magnetic fields can help scientists understand the difference between active and quiet black holes." "Related Images: Black Holes of the Universe Whether they exist around refrigerator magnets or black holes, magnetic fields are invisible." "Because dust grains line up perpendicular to magnetic fields, astronomers were able to map the shape and infer the strength of the magnetic field around the black hole." "Combining the new map with mid- and far-infrared images of Sagittarius A* revealed the direction of the magnetic field." "While some of the material from the surrounding ring of gas and dust is falling toward the black hole, the magnetic field also directs material away from the hungry giant, researchers said." "The spiral shape of the magnetic field channels the gas into an orbit around the black hole." HAWK+ principal investigator Darren Dowell, of NASA's Jet Propulsion Laboratory in Pasadena, California, said in a statement. "This is one of the first instances where we can really see how magnetic fields and interstellar matter interact with each other," said study co-author Joao Schmelz, an astrophysicist at NASA Ames Research Center in California. "But the observational data from electromagnetic observations have become so good, so impressive, that I don't think there's any doubt anymore." "To view the neighborhood supermassive black hole and the one churning farther away, the telescopes need to observe the entire range of the electromagnetic spectrum, from the radio up to the gamma rays," Markoff said. "Psaltis said photons, plasma, gas and magnetic fields are all described in a black hole's forecast." "Watch the video Scientists can't directly observe black holes with telescopes that detect X-rays, light, or other forms of electromagnetic radiation."

Terms: singularity

"Is a singularity really a spot of infinite density and zero volume?" "Thorne: That's one way to describe it, but the singularity, like the black hole itself, we believe is quite rich in its structure." "[8 Shocking Things We Learned From Stephen Hawking's Book] As you near the singularity, we expect that it stretches and squeezes you in a chaotic way that ultimately kills you and destroys the matter of which you're made." "And when you get right to the singularity itself, the laws of physics as we know them break down and the laws of quantum gravity take hold." "Since we don't understand those laws very well yet, we can't say what the nature of the very core of the singularity is." "Within the event horizon, one would find the black hole's singularity, where previous research suggests all of the object's mass has collapsed to an infinitely dense extent." "This means the fabric of space and time around the singularity has also curved to an infinite degree, so the laws of physics as we currently know them break down." "The event horizon protects us from the unknown physics near a singularity," Loeb said. "The singularity at the center of a black hole is the ultimate no man's land: a place where matter is compressed down to an infinitely tiny point, and all conceptions of time and space completely break down." "Something has to replace the singularity, but we're not exactly sure what." "Gravastars Another attempt to eradicate the singularity is one that doesn't rely on untested theories of quantum gravity is known as the gravastar." "The difference between a black hole and a gravastar is that, instead of a singularity, the gravastar is filled with dark energy." "The spin of a rotating black hole stretches the singularity into a ring." "And according to the math of Einstein's theory of general relativity (which is the only math we've got), once you pass through the ring singularity, you enter a wormhole and pop out through a white hole (the polar opposite of a black hole, where nothing can enter and matter rushes out at the speed of light) into an entirely new and exciting patch of the universe." "The singularity, stretched into a ring, is rotating at such a fantastic pace that it has incredible centrifugal force." "Outside this region, radiation is falling inward toward the singularity, compelled by the extreme gravitational pull." "But radiation is pushed by the antigravity near the ring singularity, and the turning point is the inner horizon." "Assuming this core has more than roughly three times the mass of the sun, gravity would overwhelm to such a degree that it would fall in on itself into a single point, or singularity, understood to be the black hole's infinitely dense core." "According to Massey, tidal forces would reduce your body into strands of atoms (or 'spaghettification'), as it is also known, and the object would eventually end up crushed at the singularity." "In this study, singularity does not exist, and so it doesn't form an impenetrable barrier that ends up crushing whatever it encounters." "There would be no singularity, and while the apparent field would move inward due to gravity, it would never reach the center and be consolidated within a dense mass."

Terms: horizon

"They get deposited onto the surface, what we call the horizon, of the merged black holes, so you now have four of these vortexes on the horizon." "You would need such a strong gravitational field that you need to be close to what is called the Schwarzschild radius of the object is essentially the event horizon of a black hole," he wrote in The Guardian. "The event horizon is the point beyond which nothing, not even light, can escape a black hole's clutches." "The shadow's edge is the event horizon, a black hole's point of no return." "So photographing a black hole's event horizon complicated." "This infographic shows a simulation of the outflow (bright red) from a black hole and the accretion disk around it, with simulated images of the three potential shapes of the event horizon's shadow." "It's like making a new camera with a new kind of film, a new kind of lens, combining it with other cameras, all at once, and if that could happen, if we could actually get in and see right up close to the horizon." "As the surface of the star nears an imaginary surface called the 'event horizon,' time on the star slows relative to the time kept by observers far away." "When the surface reaches the event horizon, time stands still, and the star can collapse no more — it is a frozen collapsing object." "The event horizon is the ultimate prison wall," BHI founding director Avi Loeb, the chair of Harvard's astronomy department, told Space.com. "So, the EHT images the event horizon, mapping out the black hole's dark silhouette." "From our perspective, Sagittarius A*'s event horizon is so small that it's the equivalent of seeing an orange on the moon or being able to read the newspaper in Los Angeles while you're sitting in New York City," Doelman said during the SXSW event last month. "The shadow's size is the event horizon, and the shadow's shape is the event horizon." "That's because astronomers can calculate the expected size and shape of an event horizon using general relativity, Psaltis explained." "Namely, the event horizon is nearly circular and is the 'right' size for a black hole of that immense mass." "In addition, the shape of an event horizon can reveal whether a black hole is rotating, said Fiona Harrison of the California Institute of Technology, the principal investigator of

recently in an "Interstellar" science video produced by Wired magazine .', "Facts, theories and definition ó Einstein's theory of general relativity ó The hunt for wormholes: How scientists look for space-time tunnels Let's go for a spin Planck stars and gravastars may have awesome names, but the reality of their existence is in doubt.", "And according to the math of Einstein's theory of general relativity (which is the only math we've got), once you pass through the ring singularity, you enter a wormhole and pop out through a white hole (the polar opposite of a black hole, where nothing can enter and matter rushes out at the speed of light) into an entirely new and exciting patch of the universe.", '(Image credit: All About Space magazine) Jump to: Are black holes wormholes?', 'What about wormholes?', '(Image credit: Karl Tate, SPACE.com contributor) (opens in new tab) Over the years scientists have looked into the possibility that black holes could be wormholes to other galaxies.', '"Reading Kip Thorne's popular book about wormholes is what first got me excited about physics as a child," Massey said.', "But it doesn't seem likely that wormholes exist.", 'Indeed, Thorne, who lent his expert advice to the production team for the Hollywood movie Interstellar, wrote: "We see no objects in our universe that could become wormholes as they age." in his book "The Science of Interstellar" (W.W. Norton and Company, 2014)..', "Artist's concept of a wormhole.", 'If wormholes exist, they might lead to another universe.', "But, there's no evidence that wormholes are real or that a black hole would act like one."]

Term: gravastars

['But outside that surface, gravastars look and act like normal black holes.', 'However, recent observations of merging black holes with gravitational wave detectors have potentially ruled out the existence of gravastars, because merging gravastars will give a different signal than merging black holes, and outfits like LIGO (the Laser Interferometer Gravitational-Wave Observatory) and Virgo are getting more and more examples by the day.', "While gravastars aren't exactly a no-go in our universe, they are definitely on thin ice.", "Facts, theories and definition ó Einstein's theory of general relativity ó The hunt for wormholes: How scientists look for space-time tunnels Let's go for a spin Planck stars and gravastars may have awesome names, but the reality of their existence is in doubt."]

Term: telescope

['Chilingarian and his colleagues are now using one of the Magellan telescopes in Chile to improve their estimates of black-hole masses, and they hope to inspect 13 promising intermediate-mass black-hole candidates with the Chandra X-ray Observatory.', 'Chilingarian also noted that, if the eROSITA X-ray space telescope launches as planned in 2019, "the number of confirmed intermediate-mass black holes will grow by an order of magnitude.", 'The telescope collaboration is set to make a big announcement of results this week , and members also described their research approach at a talk in March.', "To observe the supermassive black hole at the center of the Milky Way galaxy, or to view another of the project's targets ó the supermassive black hole at the core of the supergiant elliptical galaxy Messier 87 ó the EHT team had to turn Earth into a virtual telescope platform.", "That's because the power of a telescope to resolve images is limited to the size of its dish, and by using an array of instruments across the world, the team is effectively breaking up the dish and scattering the pieces globally to make one big space eye.", "(Image credit: Daniel Michalik/South Pole Telescope) The radio telescope observatories involved in EHT's 2017 observations were ALMA (Atacama Large Millimeter/submillimeter Array in Chile; APEX (Atacama Pathfinder Experiment) in Chile; IRAM 30m (Institut de Radioastronomie Millimétrique) in Spain; LMT (Large Millimeter Telescope) in Mexico; SMT (Submillimeter Telescope) in Arizona; JMT (James Clerk Maxwell Telescope) in Hawaii; SMA (Submillimeter Array) in Hawaii; and SPT (South Pole Telescope) in Antarctica.", "To view the neighborhood supermassive black hole and the one churning farther away, the telescopes need to observe "the entire range of the electromagnetic spectrum, from the radio up to the gamma rays," Markoff said.', "Watch the video Scientists can't directly observe black holes with telescopes that detect x-rays, light, or other forms of electromagnetic radiation.", "Soon after its launch in December 2004, NASA's Swift telescope observed the powerful, fleeting flashes of light known as gamma ray bursts.", '(opens in new tab) (opens in new tab) (opens in new tab) (opens in new tab) (opens in new tab) The Event Horizon Telescope, a planet-scale array of eight ground-based radio telescopes forged through international collaboration, captured this image of the supermassive black hole in the center of the galaxy M87 and its shadow.', 'A telescope the size of Earth The EHT is a consortium of more than 200 scientists that has been in the works for about two decades.', 'No single telescope on Earth can make that observation, so Doeleman and the rest of the EHT team had to get creative.', 'The researchers have linked up radio telescopes in Arizona, Spain, Mexico, Antarctica and other places around the world, forming a virtual instrument the size of Earth.']

Term: suns

The above photos are samples of parts of our knowledge base. Each term value has a list of sentences that are associated with it. These sentences were gathered using a web crawler that scraped information on relevant sites associated with black holes. The terms themselves were determined using TF-IDF (Term Frequency - Inverse Document Frequency) to see what terms were most relevant within the text that we had gathered.