CSCI531 SEMESTER PROJECT

Designing a Secure Electronic Voting System

Pooja Rajan

- Overall Description

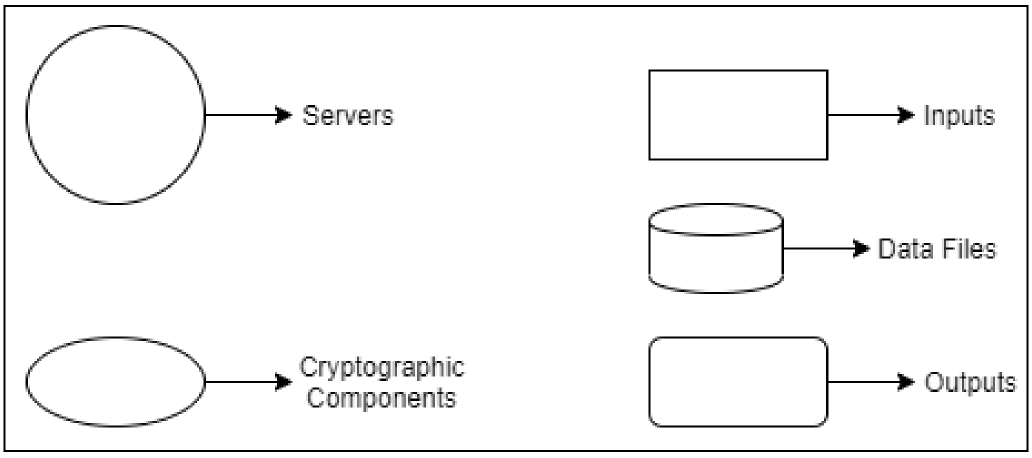
  Secure E-Voting System is a python based project. It handles the security of data during the registration of the voters while polling on election day, and counting and auditing of the votes to ensure an unbiased voting environment. It also ensures that the voter is a registered and unique voter who is eligible to vote and its ballot for voting is personalized and secured.

- Proposed System Architecture

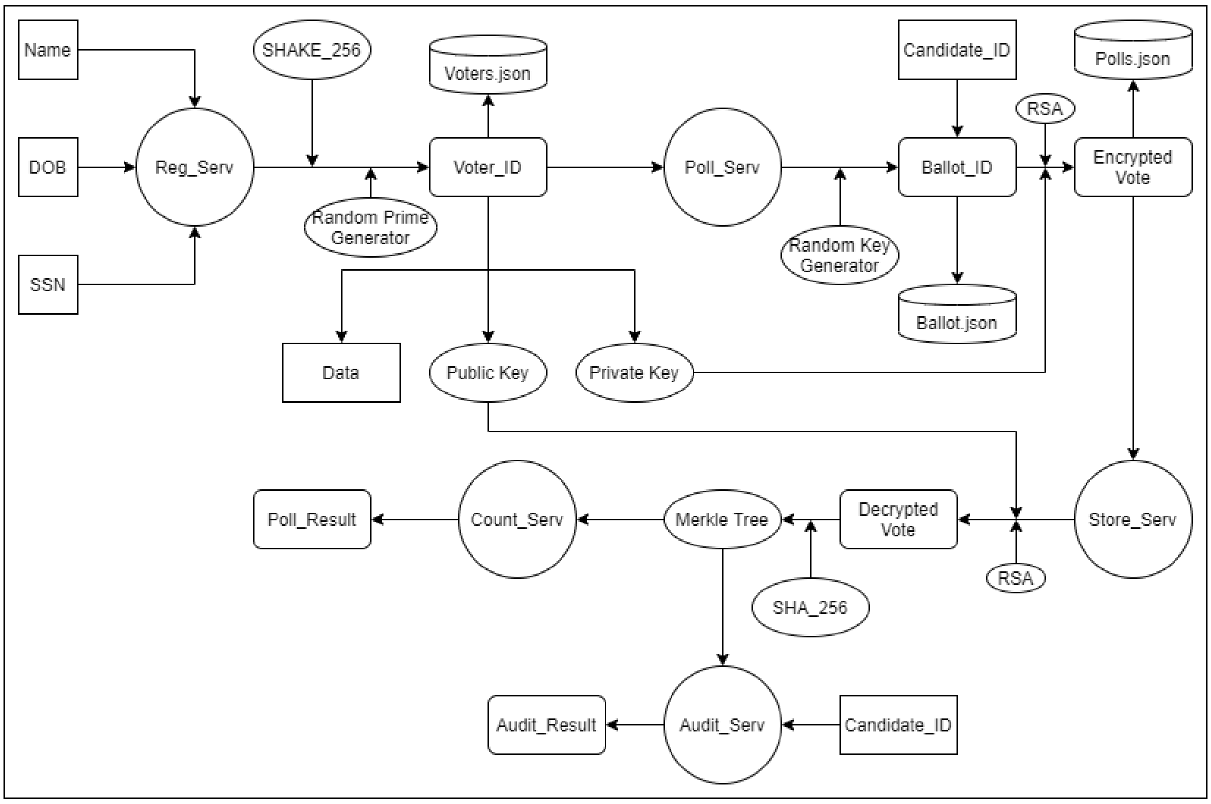
  The proposed architecture consists of five components:-

  - Registration Server - For registration of the voter and key generation to ensure confidentiality of the voter while or after voting.
  - Poll Server - For the creation of a unique ballot for each voter upon confirmation and to cast their votes securely and secretly.
  - Store Server - To authenticate the ballots passed after polling, and storing and managing the votes from all the anonymous(registered) voters.
  - Count Server - To count the votes for each candidate.
  - Audit Server - To conduct an audit to ensure that the votes counted are from unbiased voting methods only.

A diagram has been included to further understand the working of this system.



Index for System Architecture



System Architecture of the System

A comprehensive working of each component, the data flow between them and other functionalities are described below:-

- Registration Server - In this module, a voter, using their SSN number or DL number, registers itself on the Voters List. An SSN or DL number is used to uniquely verify each voter and avoid any duplicity due to a change in location. Upon collecting details from the voter, a unique 10-digit hash is generated for the voter which acts as the voter's unique Voter ID. In case the voter tries to re-register itself, its already existing ID is retrieved and displayed. This voter ID is generated using SHAKE-256. The voter ID, along with other data, is also stored in a file for future tallying and verification. Also, while registering, a voter's year of birth is also used to verify that he/she is eligible to cast a vote. The default minimum age to cast a vote is presumed as 21 years. Along with ID, a public and private key is also generated for secure voting on the election day. The public key is passed on to the Election Committee.
- Poll Server - In this, a voter uses their voter ID for verification process that they are registered voters by tallying up against the voters' file.

When this verification is successful, the voter receives a random unique ballot that has its own ID which is stored in a separate file when a voting has been done using it. Using this ballot ID and the corresponding private key from the previous module, the voter casts a vote which will be encrypted using the private key. This way no one can view or change the vote in the ballot unless they have the voters' public key which is available only with the Election Committee. After the voting is done, both the ballot ID and the encrypted vote is sent to Store Server for authenticating and storing the data.

- Store Server - The data from the Poll Server is read and checked for any duplicity or tampering with the votes by checking it against the ballot file which has a list of all the voters who have voted. Once verified, the encrypted votes are decrypted using the public keys from the Election Committee. The ballot ID serves the purpose of identifying the voter ID to use the corresponding public keys for decryption. The votes are basically candidate IDs, which are then hashed again using SHA-256 hash algorithm and the binary hashes are stored in merkle tree. This merkle tree is then sent to the Election Committee.
- Count Server - The merkle tree is used to count the votes for each candidate. It also checks for any tampering with the votes. Any change in the votes will change the sister nodes and root of the merkle tree and hence will be alerted to the system, that there has been a tampering with the votes.
- Audit Server - This component checks for the consistency of votes received. This way we get to know if any new vote has been added or if any existing votes have been changed. The duplicity of voters is prevented during the registration itself. The uniqueness of the ballot used for voting is also achieved during the ballot generation.

➢ Cryptographic Components Used

The encryption schemes used are:-

- RSA Encryption
- Merkle Tree Hashing

The key management is done using:-

- SHAKE_256 hash algorithm
- SHA-256 hash algorithm
- Private key and Public key using GCD and Modular Inverse
- Random key generator.

Using voter data, SHAKE_256, a SHA3 + Keccak-256 combined hashing algorithm is used for generating a hash. SHAKE_256 is used because it has a somewhat better performance rate as compared to SHA-256. It also allows variable length of the hash key produced. This way the length extension attack can also be avoided. Also, it is easier for any voter to remember and use it easily. It also takes more hash bits, which means it can resist collision attacks for longer periods. SHAKE_256 is also known to be useful for OAEP padding which can be used with RSA Encryption.

The public and private key for each voter is used during voting, for encrypting the votes using RSA. The private key of the voter is used to encrypt the vote casted by the voter in his unique ballot. The votes are encrypted so as to avoid any tampering with the votes while sending and storing the votes. The Election Committee can decrypt the votes using the public key of the voter to collect all the votes for each candidate and then count the votes to announce the results later after auditing. RSA is known for sending sensitive data securely over insecure networks too because of its large prime number generation for GCD and Modular Inversions. A random key generator is used for producing the ballot IDs.

After the votes are decrypted, it is hashed again using SHA-256 to create a hashed leaf node for merkle tree, which is then sent for counting and auditing by the Election Committee. SHA-256 is used to generate a unique 32-byte hash of votes, to verify data integrity and any unintentional corruption in the votes stored. Although it has better security against collision attacks, it is still vulnerable to length extension attacks. But it still wins as one of the best secure hashing algorithms. The hashed leaf nodes produce sister hashes which then traverses up till the root in a bottom-up approach. Any change in the votes reflects a change in the hash data and hence the root is also changed. This way we can check for any discrepancies in the votes after the casting of votes also.

- Packages and Modules Used

  The packages used are datetime, hashlib, helpers, json, mymerkle, os, pickle, random, and sys. The modules used are argv[], dumps(), encode(), hexdigest(), MerkleTools(), now(), pow(), randrange(), sha256(), shake_256(), and urandom().

  - datetime - used for getting date and/or time
    - now() - to get the current date.
  - hashlib - used for hashing purposes.
    - hexdigest() - to return data in hexadecimal format.
    - sha256() - for producing hash key of a data using SHA-256.
    - shake_256() - for producing hash key of a data using SHAKE-256.
  - helpers - to perform read and write operations on a JSON file.
    - update_file - to read and write data according to r and w respectively. Also checks for duplicate records.
  - json - for reading and writing of simple data in a JSON file.
    - dumps() - to write data in a .json file.
    - load() - to read data from a .json file.
  - mymerkle - An external file used for formation of a merkle tree and data manipulation in it.
    - MerkleTools() - to implement a merkle tree.
  - os - for using system-generated data and functions.
    - urandom() - to generate cryptographically secure random keys.
  - pickle - for reading and writing of serialized data in any file.
    - dump() - to write serialized data in a file.
    - load() - to read serialized data from a file..
  - random - for random data generation.
    - randrange() - to give a range for the random number to generate between.
  - sys - for taking arguments from the command line

        - argv[] - to assign the argument from the command line to a variable, with the appropriate position number.
    - Miscellaneous -
        - pow() - for modular exponentiation calculations

- Assumptions, Limitations and Future Works
    a) The files in data.zip and mymerkle.zip must be downloaded as it is. The files inside it should not be downloaded separately.
    b) A voter's year of birth is considered here for ease of use. In an actual system, the whole Date of Birth can be used for fairness.
    c) The process of registering and polling is assumed to be known by the voter.
    d) The minimum age of the voter is assumed to be 21years.
    e) It is not necessary to use an actual SSN or DL number. Any dummy 4-5 digit number would work too.
    f) The number of candidates can be more than two.
    g) It is assumed that the Election Committee gets the public keys of all the voters during the registration.
    h) Merkle tree's pickled object should be binary for read/ write purposes.
    i) The server used here provides the vote count in a hashed format where the admin has to then match with the valid candidate ID.
    j) The audit doesn't check for all the valid candidates. Only a chosen candidate at a time is enquired for validity and consistency.
    k) An audit is not performed for uniqueness of the voter or the ballot in the audit server as it is already prevented from happening from the beginning.
    l) We can include timestamps for future works to track further, for any changes made in votes.
    m) We can explore other functionalities of SHAKE_256 like OAEP and use them in future models of this system.

- File Description

  There are 6 python files, namely :-
    - regserv.py - This file is the start of the system. In this, it takes 3 arguments from the command line; the name, the year of birth, and the

SSN number of the voter. Using the year, it checks if the voter is eligible to vote or not. The default age assumed is 21 years. An SSN is used to verify that an individual is uniquely identified. If a voter accidentally tries to re-register, he is assigned his previously generated voter ID along with new public and private keys. Once this verification is complete, a new 10-digit voter ID is generated using the SHAKE_256 on the SSN. Along with this, a hashed data of all the data provided is also created. A unique public and private key is also generated for future purposes of encryption of votes. All these data for each voter is mapped in a JSON file called data/voters.json. Every new voter data appends the existing data in it.

- pollserv.py - The polling process happens in this file. The voter enters the voter ID and the vote for his candidate by mentioning his candidate ID in the beginning in the command line. The voter ID is then used to verify if the voter is registered or not, by tallying it against voters.json file. If he is registered, then a unique ballot and ballot ID is generated for the voter to store the casted vote. The ballot ID along with its corresponding voter ID is stored in data/ballot.json file once the voting has been completed. After this, the vote is encrypted using the voter's private key for which data is loaded from voters.json . It is encrypted using the RSA Encryption Algorithm. The ballot ID and the encrypted vote is mapped in a data/polls.json file.
- storeserv.py - It reads data from all the files used for mapping and storing generated data. It uses the ballot.json to verify the ballot ID against the ballot ID present in polls.json file. It is also used to figure out the corresponding voter ID to any given ballot ID. Using the voter ID, we access the voter's public key to decrypt the encrypted vote. The vote comprises of a candidate ID. The sequence of candidate IDs is shown as a result. The sequence follows the same structure as the votes were stored. This sequence of candidate IDs is then hashed using SHA-256 and used as a leaf node to form a merkle tree. This tree is then dumped using pickle, in a file called Merkle.

- countserv.py - This file reads data from the Merkle file and counts the total votes for each candidate by using a counter for each of them while reading it from the Merkle file. The file initially reads from the pickled 'merkle' file which consists of the MerkleTools object. This object has the whole merkle tree in an immutable, binary form to read and process the leaves. The leaves of the Merkle Tree consists of the individual vote received for the candidate. The merkle tree helps in protecting the vote data from any kind of tampering and preserves the state of the voting sequence.
- auditserv.py - This file is used to verify the state of the merkle tree which is pickled from the 'Merkle' file. In this, a new candidate is taken from the argument in the command line. It is then checked against the Merkle file to check if it is a valid leaf node or sister node. If not, it will have a different root than the actual root. This way we can verify if the votes have ever been tampered at any time. Validating the proof of the target node provided in the argument makes the audit a success. If the node exists as leaf, then the tree is valid. Whereas it gives a false response on reading the tampered tree thereby verifying the voting sequence.
- helper.py - This file is mainly used for all the read and write data to and from a JSON file. It takes the name of the file, the data, and the type it is to be accessed. Then it dumps for writing and loads for reading a data from the .json file. It also checks if any duplicate voter is there and if someone is trying to tamper the votes, by always checking for a duplicity in the write data before appending the file.

➢ Implementation Example

The steps for command line interface of Windows 10 :-

```
>>>py regserv.py alice 1988 23047
You are registered. Your voter ID is: 1af6e92d0d. Do not disclose it to any unknown sources and third-parties.
>>> py regserv.py eva 2005 91475
Underage! You are not eligible to vote.
>>>py pollserv.py 1af6e92d0d 10
```

```
A unique ballot has been created for voter ID: 1af6e92d0d
Your vote has been casted successfully. Thank you!
>>> py pollserv.py ff7tb78y9p 5
Voter not found. Register!
>>>py pollserv.py 1af6e92d0d 10
You have already registered a vote. You cannot vote again.
>>>py storeserv.py
The sequence of votes stored:-
['5', '5', '6', '10', '10', '11', '10']
>>>py countserv.py
The count of votes for each candidate:-
{'ef2d127de37b942baad06145e54b0c619a1f22327b2ebbcfbec78f5564afe39d': 2,
'e7f6c011776e8db7cd330b54174fd76f7d0216b612387a5ffcfb81e6f0919683': 1,
'4a44dc15364204a80fe80e9039455cc1608281820fe2b24f1e5233ade6af1dd5': 3,
'4fc82b26aecb47d2868c4efbe3581732a3e7cbcc6c2efb32062c08170a05eeb8': 1}
The candidate ID has been hidden for security reasons.
>>>py auditserv.py 6
True, candidate ID: 6 exists.
>>>py auditserv.py 16
Candidate ID: 15 doesn't exist.
```

To view the JSON files of stored data from the system:-

```
>>>type voters.json
```

[This will display the list of voter IDs, their hashed data, and the public and private keys for each one of them.]

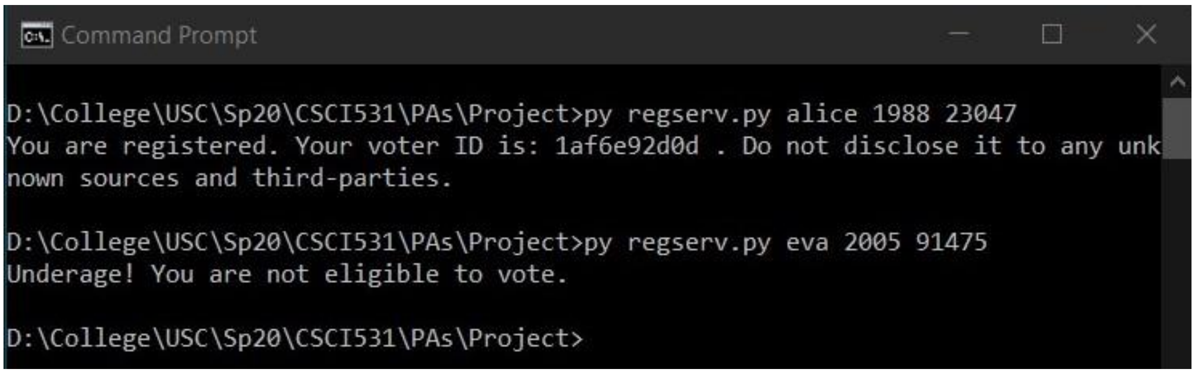
```
>>>type ballot.json
```

[This will display the list of ballots formed for every registered voter who has casted a vote.]

```
>>>type polls.json
```

[This will display the RSA encrypted vote from every ballot used for voting.]

- Screenshots
  - regserv.py <name> <year_of_birth> <ssn>

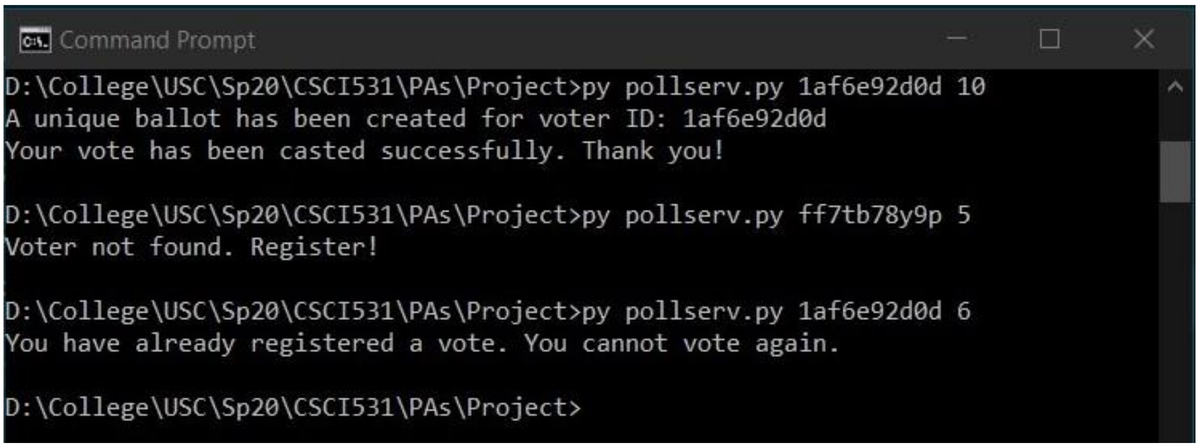


```
D:\College\USC\Sp20\CSCI531\PAs\Project>py regserv.py alice 1988 23047
You are registered. Your voter ID is: 1af6e92d0d . Do not disclose it to any unk
nown sources and third-parties.

D:\College\USC\Sp20\CSCI531\PAs\Project>py regserv.py eva 2005 91475
Underage! You are not eligible to vote.

D:\College\USC\Sp20\CSCI531\PAs\Project>
```

  - pollserv.py <voter_id> <candidate_id>



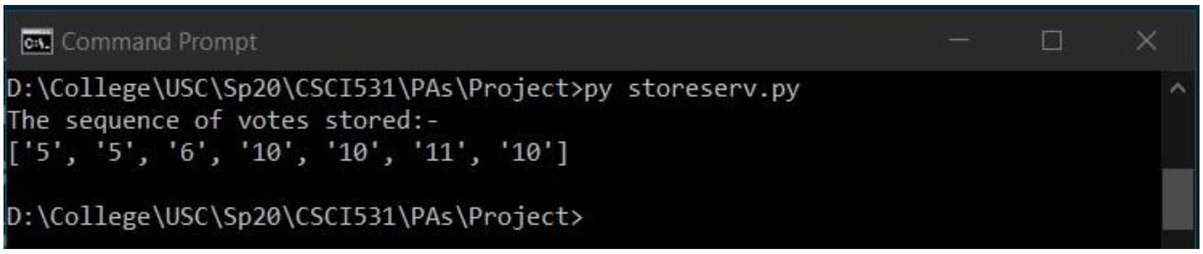
```
D:\College\USC\Sp20\CSCI531\PAs\Project>py pollserv.py 1af6e92d0d 10
A unique ballot has been created for voter ID: 1af6e92d0d
Your vote has been casted successfully. Thank you!

D:\College\USC\Sp20\CSCI531\PAs\Project>py pollserv.py ff7tb78y9p 5
Voter not found. Register!

D:\College\USC\Sp20\CSCI531\PAs\Project>py pollserv.py 1af6e92d0d 6
You have already registered a vote. You cannot vote again.

D:\College\USC\Sp20\CSCI531\PAs\Project>
```

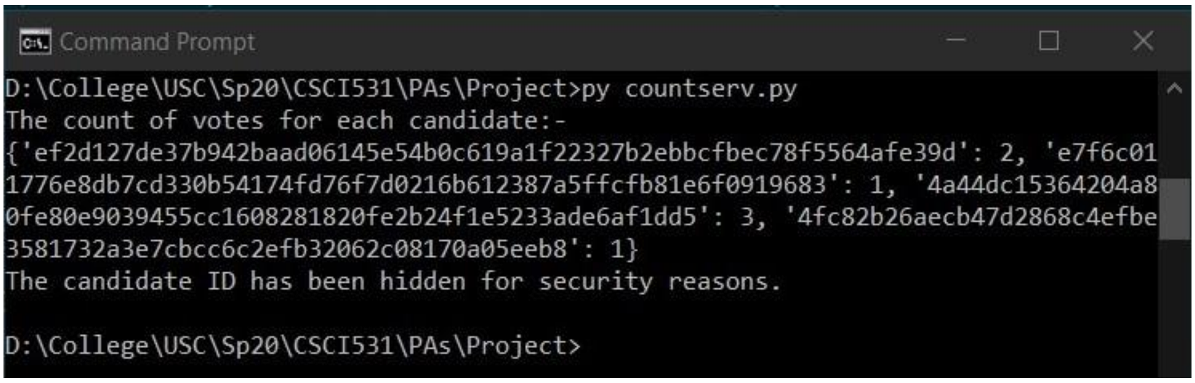
  - storeserv.py



```
D:\College\USC\Sp20\CSCI531\PAs\Project>py storeserv.py
The sequence of votes stored:-
['5', '5', '6', '10', '10', '11', '10']

D:\College\USC\Sp20\CSCI531\PAs\Project>
```

  - countserv.py



```
D:\College\USC\Sp20\CSCI531\PAs\Project>py countserv.py
The count of votes for each candidate:-
{'ef2d127de37b942baad06145e54b0c619a1f22327b2ebbcfbec78f5564afe39d': 2, 'e7f6c01
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0fe80e9039455cc1608281820fe2b24f1e5233ade6af1dd5': 3, '4fc82b26aecb47d2868c4efbe
3581732a3e7cbcc6c2efb32062c08170a05eeb8': 1}
The candidate ID has been hidden for security reasons.

D:\College\USC\Sp20\CSCI531\PAs\Project>
```
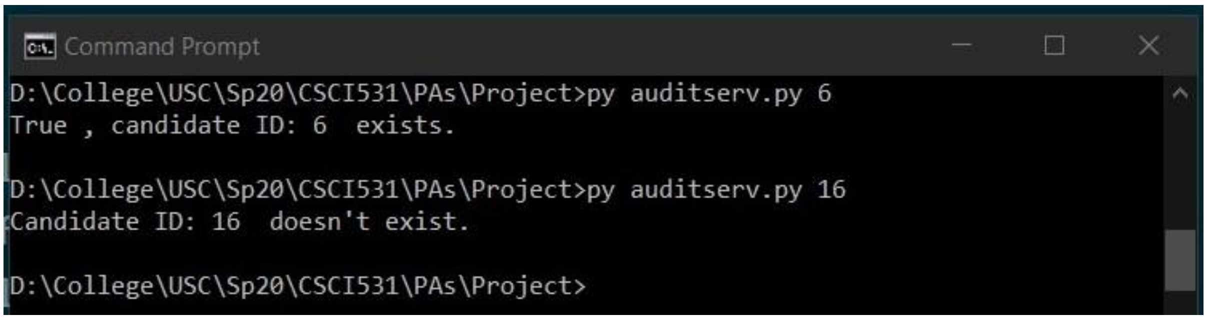
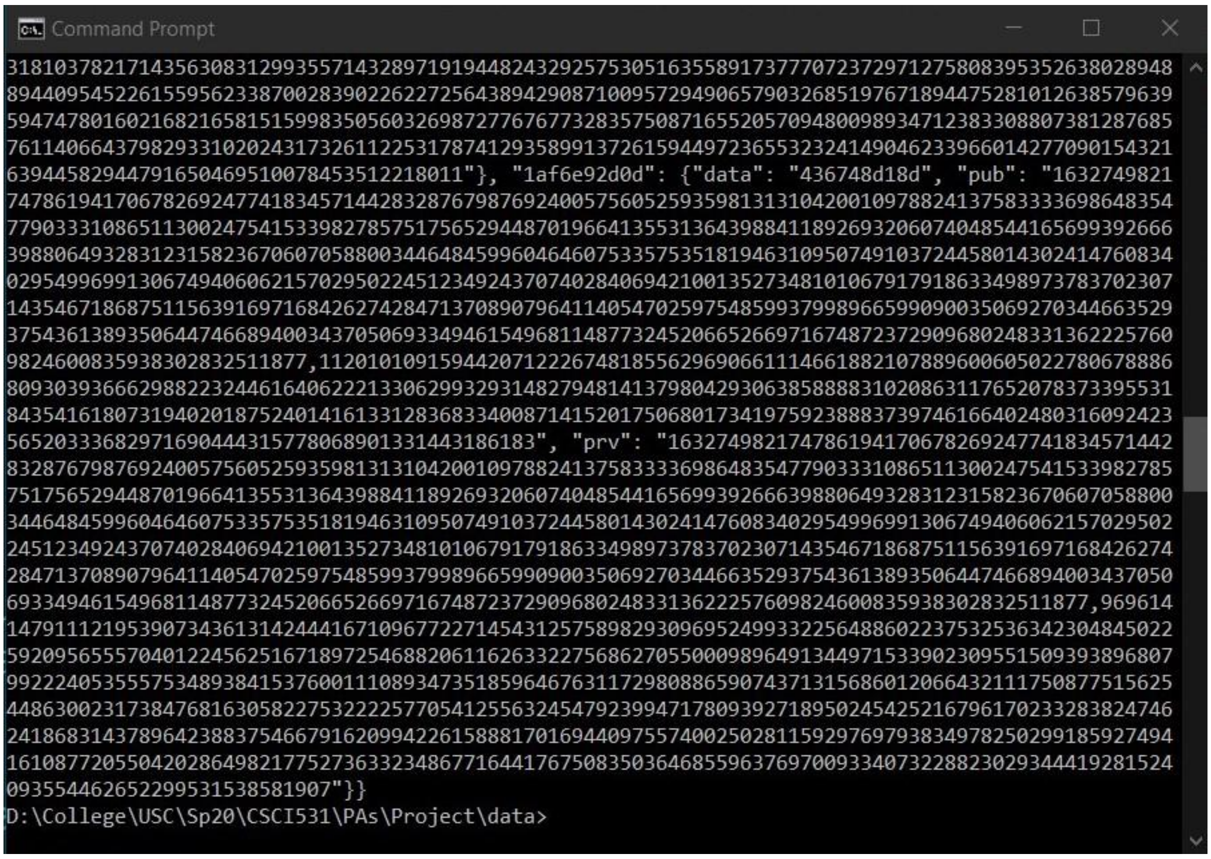

- auditserv.py <candidate_id>



```
D:\College\USC\Sp20\CSCI531\PAs\Project>py auditserv.py 6
True , candidate ID: 6  exists.

D:\College\USC\Sp20\CSCI531\PAs\Project>py auditserv.py 16
Candidate ID: 16  doesn't exist.

D:\College\USC\Sp20\CSCI531\PAs\Project>
```

- voters.json



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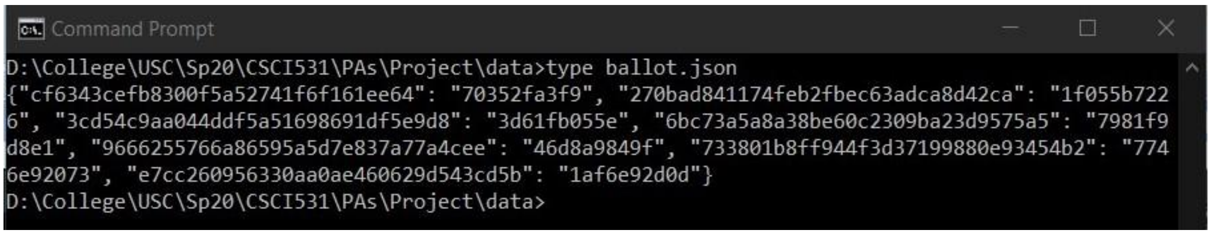
```

- ballot.json



```
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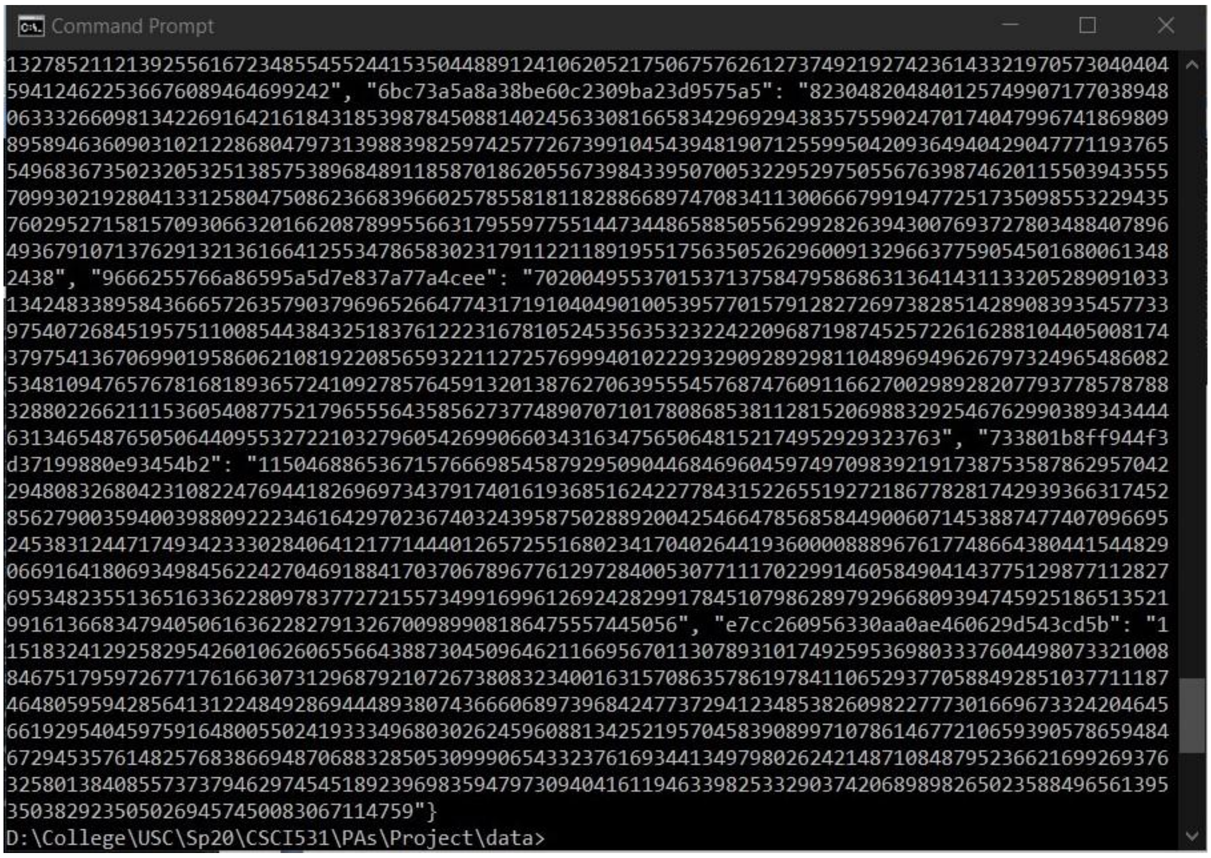
- polls.json



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