CST8912 Group Final Project:

Architecture of a Movie Recommendation Engine



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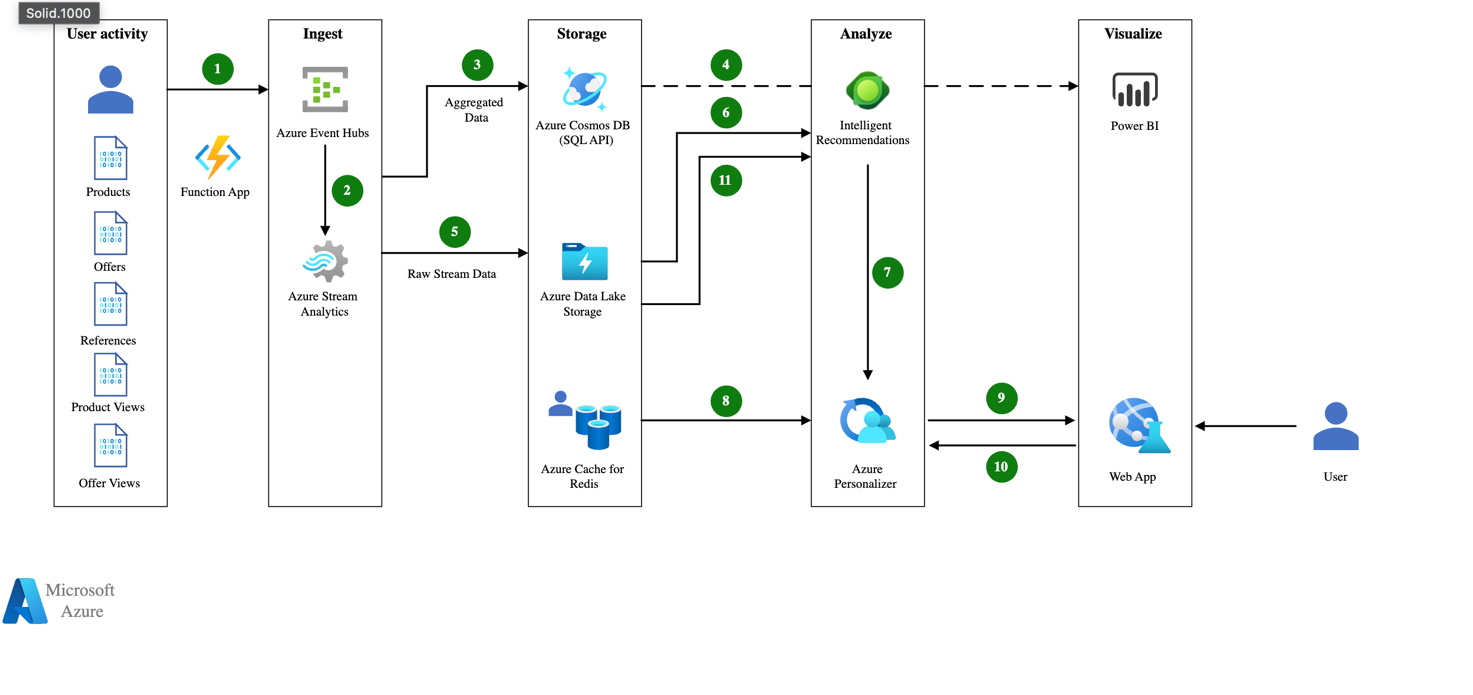
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# Introduction:

In this final project, we discuss and plan the architecture for creating a Movie Recommendation Engine. The goal behind the recommendation engine is to use Azure AI services such as Azure Personalizer and Azure Intelligent recommendations to analyze user activity data such as movie watching or reviews. Afterwards, the AI services can use the aggregated user data to provide recommendations to movies the user might like. This is incredibly useful within movie streaming platforms such as Netflix or Disney+ to create targeted advertising as well as movies to keep users engaged with the platform. Below, this paper will describe the Cloud Service Model approach to the architecture, an explanation of the architecture and how it works, Cost predictions for implementing the architecture, Which Region is best suited and availability, Deployment, Security and Compliance, Challenges to encounter, and lastly, Cloud Governance.

# Our Project: Movie Recommendation Engine

## Architecture Reference for Personalized Movie Recommendations:



(Sundararajan, 2024)

# Cloud Service Models

The movie recommendation architecture focuses on a PaaS service model with some additional SaaS and FaaS services. The PaaS solution allows for increased scalability and analyzation of data. The focus of this architecture is to gather and analyze an extensive amount of user data. For the use case of Netflix, the data being collected for a movie recommendation model are as follows:

* **Notification settings**: chosen preferences by the user they wish Netflix to notify.
* **Advertising information**: Interactions on third-party advertisements involving Netflix as well as information preferences on targeted advertising.
* **Profiles**: data on profile settings like playback preferences, parental controls, number of profiles, language settings.
* **Content Interaction**: data on a user’s interaction with content such as viewing history, search history, ratings/reviews, video retention time, movie interactivity (pause, stopping, playing), genre preferences.
* **Device information**: information on devices using Netflix such as IP addresses, devices signed in, and device activity.

(Netflix, *What personal information netflix holds about you and how to request a copy* 2024)

Using Netflix as an example of what data we expect to receive from a Movie recommendation platform helps judge the most optimal cloud service model to apply to the architecture. As for the cloud service provider, Microsoft Azure is chosen to explain the personalized movie architecture. Focusing on the PaaS cloud service model, we can leverage Microsoft Azure services without having to specify the underlying infrastructure and deploy at scale. These are the services that fall under their respective cloud service models include:

## PaaS:

* Azure Event hubs: to ingest and collect data in real-time and load balances to other services.
* Azure Stream Analytics: to analyze the data in real-time.
* Data Lake Storage: to store raw data.
* Azure Cache for Redis: stores states of user data to ensure uptime
* Azure Cosmos DB: stores the edited compiled data such as Account information.
* Azure Web App: deploys the web application and results such as Netflix webpage.
* Azure AI Service (Contains Azure Personalizer): Uses Machine Learning and collected data to output a personalized recommendation of movies

## SaaS:

* Azure intelligent Recommendations: AI that processes the data from Azure data lake develops recommendations and sends it to Azure personalizer.
* PowerBI: visualizes the data into graphs and dashboards to display to the Web App

## FaaS:

* Azure Functions: records user activity made within the Netflix website to physically gather user data to send to Event Hubs.

Keeping mind these services and how they apply to each service model will help us further down to decide which service to deploy first when creating the architecture. (Sundararajan, 2024)

# Cloud Architecture.

## Networking

For networking, we can secure the connection between AI services like Azure Personalizer or Azure Recommendations by using Azure Virtual Networks with private endpoints. this is to ensure security of the important data in transit, restrict access from important data in transit, and restrict access from the important data in training to AI services like Azure Personalizer. In addition to virtual networks, we can use the application gateway to connect the front-end user activity and the AI services. Azure Bastion can also be used as a secure way to connect to the user activity VM services using RDP/SSH as well as encrypting the user's data as they access the front-end websites. (Stephen-Sumner & Microsoft, 2023)

## Storage

Our movie recommendation system can utilize Data Lake Storage, Azure Redis Cache and Azure Cosmos DB to handle large amounts of data and provide fast, personalized recommendations for users of the platform and ensure scalability options. The following are each storage providers described and their use in the system infrastructure:

### Data Lake Storage:

Data Lake Storage will mainly be used to store big volumes of raw unstructured data. In the movie recommendation system. We will be using Hot storage. It will be used to store the following:

* Any user data, such as raw logs of user interactions like clicks, views, watch history, and personal ratings.
* Movie metadata such as information about movies listed like genres, actors involved, directors, release dates, ratings, etc.
* Any Event data such as logs of user activity on the platform, stored to be analyzed for improvements on the recommendations for users.
* External data from other sources being imported such as reviews, social media platform data.

### Azure Cache for Redis:

Our movie recommendation system can also utilize Azure Redis Cache, which will provide us in-memory data storage with high performance that can be frequently accessed through caching, which can massively improve performance in our system. We will be using the Basic tier (1GB).

* Storage for specific user sessions to provide faster response times for the user through caching
* Complex recommendation results from the algorithm can also be cached to be quickly available to users upon request
* User profile and preferences data can be stored to be accessed quickly to personalize recommendations
* Frequently visited data or trending data such as the most popular movies at the time can be cached to reduce strain on the database.

### Azure Cosmos DB:

Azure Cosmos DB can be used as the multi-model database choice designed for high-availability and data that prefers low latency to be trafficked. It can be used to store real-time data on users to distribute. We will be using provisioned throughput (400 RU/s).

* Detailed user profiles and preferences data can be stored such as watch history, watch time, and interaction data for future analysis.
* Results from real-time analytics data performed can be stored to create immediate recommendation updates.
* The recommendation engine’s output from the machine learning models used to generate recommendations can be stored.

## Cost

| **Service** | **Cost Component** | **Estimated Cost** |
| --- | --- | --- |
| **Azure Event Hubs** | Throughput unit | $0.028 per unit per hour |
|  | Data processed | Varies based on volume |
| **Azure Stream Analytics** | Streaming unit | $0.011 per unit per hour |
|  | Data processed | Varies based on volume |
| **Azure Cosmos DB** | Provisioned throughput (400 RU/s) | $24 per month |
|  | Storage | $0.25 per GB per month |
| **Azure Data Lake Storage** | Hot storage | $0.0184 per GB per month |
| **Azure Cache for Redis** | Basic tier (1 GB) | $16 per month |
| **Azure Personalizer** | Transactions (50,000) | $1.50 |
| **Power BI** | Pro license | $9.99 per user per month |

## Region/Availability

Netflix operates a global cloud infrastructure powered primarily by Amazon Web Services (AWS). AWS provides Netflix with the scalability, reliability, and geographic reach it needs to deliver a seamless streaming experience to users around the world.

Netflix leverages AWS cloud regions strategically to support its global operations. It designs its systems to operate across multiple Availability Zones within AWS regions and employs a multi-region architecture to enhance resilience.

### Regions of Netflix operation

Netflix operates out of three AWS regions:

* North Virginia (us-east-1)
* Portland, Oregon (us-west-2)
* Dublin, Ireland (eu-west-1)

Each region leverages three distinct Availability Zones (AZs), which are isolated, independent data centers connected by low-latency networks within the AWS infrastructure. (High Scalability, 2017)

“In addition to deploying our services across multiple instances and Availability Zones, we decided to deploy them across multiple AWS Regions as well.” (Netflix Technology Blog, 2013) With multiple AWS cloud regions across geographies, Netflix is able to dynamically shift and scale its global infrastructure capacity across all the countries in which it is present.

### Multi-regional Active-Active solution

By leveraging the multi-regional Active-Active solution, services run simultaneously in multiple AWS regions, with automatic failover capabilities in case one region goes down.

Netflix’s disaster recovery strategy is centered around resilience, redundancy, and automation to minimize downtime and data loss in the face of potential disruptions. “We’re leveraging the principles of Isolation and Redundancy: a failure of any kind in one Region should not affect services running in another, a networking partitioning event should not affect quality of service in either Region.” (Netflix Technology Blog, 2013)  
A diagram of a stable state

Description automatically generated  
A diagram of a diagram

Description automatically generated  
(Netflix Technology Blog, 2013)

If one region goes offline due to a disaster (e.g., natural disaster, hardware failure), other regions can take over the workload seamlessly. For example: If the Dublin region fails, traffic is redirected to North Virginia or Oregon without affecting user experiences.

## Deployment Model

The best suited deployment model for a movie recommendation architecture would be a public cloud model for its resource scalability, cost effectiveness and that the data for the architecture should be publicly classified data and not associated with personally identifiable information. Using Microsoft Azure as the basis for public cloud below is a general summary public services deployment: ( loomlike & maxkazmsft, 2018)

### Azure Event hubs:

Azure Event hubs is a service to collect data in real-time and send the data to Azure Stream Analytics for processing. To deploy Azure Event Hub, you must:

1. Create the Event hub within Azure with a name, resource group subscription and region
2. Pick the most cost-friendly service tier (Basic)
3. Set Throughput Units to 5 (the more people you are expecting to access your website to watch movies the higher you need to scale the throughput Units. For now, I put to 1 for cost-effectiveness and testing 1 throughput unit handles 1000 events and can scale with auto-inflate) and create.
4. Within shared access policies and RootManageSharedAccessKey
5. Add the primary key and Connection string-primary key to the configuration file used in Azure Functions service step below.
6. In overview add an event hub
7. Configure the Event Hub name like “**personalizedHubOffer**”
8. Configure Partition Count to account for peak load. For test, 2 or 3 is fine.
9. Configure message retention for 1 day. For movie recommendations you do not need to keep activities/messages for too long.
10. Confirm and create the Hub
11. Create consumer groups with the newly created event hub for click activity. (Spelluru & Microsoft, 2024)

### Azure Stream Analytics:

Azure stream analytics will analyze the data from Azure Event Hub and process it to send to Azure Cosmos DB. below is how to deploy Stram Analytics.

1. Click the create the Stream Analytics Job and enter a job name
2. Choose your subscription, resource group and region
3. Add stream input and connect to the event hub
4. Configure event hub and enter click activity.
5. Select existing event and the event hub name you created earlier like “**personalizedHubOffer**”.
6. Select a Hub Policy name and group events.
7. Create a javascript UDF to record video retention or views
8. Adjust streaming units
9. Repeat this process for the creation of other stream jobs each job should analyze an aspect of an event such as click counts, and video retention.
10. Start the service (Ajetasin & Microsoft, 2023)

### Azure App Service:

The Azure app service plan serves as the front end for customers using the movie recommendations and is what users will find where they receive their personal recommendations here is how a web app is deployed:

1. Create an App Service Plan
2. Select a unique name, subscription, resource group and region.
3. Pick an operating system (ensure they match the OS of the other services)
4. Pick the cost-effective option for pricing tier, Azure offers F1 for free.
5. Review and create. (loomlike & maxkazmsft, 2018)

### Azure Personalizer:

This service is a machine learning model that will output personalized movie recommendations to set up deployment you must first:

1. Create an Azure Personalizer resource
2. Configure the workspaces name, resource group, the created storage account, and web service plan (using cost-effective options)
3. Get the Personalizer Connection key
4. Use .NET to configure the Personalizer key
5. Run Personalizer. (Jcodella & Microsoft, 2024)

### Azure intelligent Recommendations:

1. Have a Data Lake storage and container.
2. Go to Intelligent Recommendations and create.
3. Specify access on viewing recommendation results and queries with Microsoft Entra ID
4. Go to Data Lake container and configure IAM controls and add role assignment
5. Set role to reader and select Managed identity as authentication under Intelligent Recommendation
6. Repeat step 4 and 5 but add storage blob contributor to allow Intelligent Recommendations write access.
7. Add a modeling resource for the model to supply recommendations. Use the Data Lake connection string to connect to Azure Recommendations.
8. Create an Endpoint on Azure Recommendations
9. View Recommendations (Lavanyapg & Microsoft, 2024)

### PowerBI:

PowerBI will help you visualize movie recommendations, and customers personalized offers.

1. Install PowerBI, Preferably PowerBI
2. Add the CosmosDB database credentials using the database Primary Key
3. Create and Select Queries for the CosmosDB such as user movie view number
4. Add the CosmosDB URI and Primary Key to the query
5. Close and apply changes ( loomlike & maxkazmsft, 2018)

### Azure Functions:

Azure functions provide a list of event triggers without having to write the code to record data from users. It then sends the raw data to Azure Event hubs if the user does not have a history, Azure Redis cache stores and provides simulated data instead.

To deploy the Azure Function:

1. Create the Function within Azure picking subscription, resource group and region.
2. Pick the App service plan as the hosting plan
3. Use existing storage and create the function
4. Within the function platform settings and application features, use 64 bit and leave always on
5. Upload a configuration file containing key value pair of the other Azure services.
6. Within platform features, open debug console and locate the wwwroot folder.
7. Upload the azure function code. This code should contain files that act as “listeners” to events such as clickType {get; set;} to listen in on user clicks the choice of programming language can be Java, C#, and Python.
8. For both Cosmos DB and Redis Cache run a function to populate the database (ggailey777 & Microsoft, 2024)

# Compliance Measures

As a global streaming platform and tech company, Netflix utilizes a set of compliance measures to ensure it follows the legal, regulatory, and industry-specific standards, including data privacy regulations, content restrictions, and copyright laws.

### Data Privacy Regulations:

* Two key regulations that directly affect Netflix are the EU General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA) (Dhinakaran, 2024) Both of them require Netflix to prioritize user privacy, implement robust data protection measures, and provide users with control over their data.

### Security and Access Control:

* **Access Control**: Netflix enforces Multi-Factor Authentication (MFA) for access to its systems and “establish an Identity Access Management (IAM) process to appropriately manage access to all information systems.” “Only authorized personnel have access to sensitive information, and Netflix regularly reviews its data protection practices to maintain compliance with privacy regulations.” (Dhinakaran, 2024)
* **Encryption**: encrypts data stored in databases using AES-256, and TLS to secure data moving between systems and services.

# Security and Best practices.

The amount of data stored in a movie recommender system is massive and incorporating secure controls and configurations is very important. While security is a key concern in the cloud it is still important to ensure that the measures put in place in the architecture ensure the system is scalable, resilient, and secure.

## Identity and Access Management

Implementing user authentication prevents unauthorized access onto the system. Using Azure’s **IAM** capabilities, administrators can implement:

1. **Role Based Access Control –** by implementing least privilege access on different resources users can only access what they are supposed to
2. **Multi-Factor Authentication –** only authorized users will be able to log into the system

## Threat Protection

This involves implementing firewalls and network security policies and rules to protect against any threats or attacks. This can be implemented through:

1. **Firewalls –** using azure firewall to filter out malicious traffic on the system
2. **Network Security –** implementing network security groups and security rules to ensure all networks are protected and restrict unauthenticated access
3. **DDoS protection –** protects against DDoS attacks

## **Data Security**

1. **Encryption**:
   * **At Rest**: Use Azure Storage Service Encryption (SSE) or Azure SQL Database's Transparent Data Encryption (TDE) to encrypt user data stored in the database.
   * **In Transit**: Use HTTPS for API communication and Azure Application Gateway with SSL/TLS to secure traffic.
   * **Example from Netflix**: They use TLS encryption to secure data transfer between clients and their systems.
2. **Data Masking and Anonymization**:
   * Implement data masking in Azure SQL to hide sensitive data like user preferences.
   * Anonymize personally identifiable information (PII) to meet compliance standards like GDPR or CCPA.
3. **Key Management**:
   * Use Azure Key Vault to securely manage API keys, connection strings, and encryption keys.

## Compliance and Governance

This involves continuous checks on the system to ensure it adheres to company, and regulatory body policies.

### Data Compliance

The movie recommender system should adhere to regional data compliance regulations like the **GDPR** for European users and **NIST** for North America and America users. Azure’s regional capabilities will ensure that the deployed system adheres to the set standards of different regions

### Auditing and Logging

1. **Azure policy** - to enforce policies on how data is governed within the system and assessing compliance at a scale
2. **Azure Log Analytics** – to audit trails and detect any anomalies in processes

# Challenges

1. **Data integration –** Due to the amount of data collected from different regions, integrating them together into the cloud architecture requires complex processing especially in times of real time data processing

**Solution:** Use Azure services like Data Factory, Synapse Analytics, and Stream Analytics to build scalable pipelines that handle structured and unstructured data. Incorporate data lakes for storage and preprocessing, and design for hot, warm, and cold data paths for optimized real-time and batch processing (Microsoft Learn, 2024).

1. **Security and compliance –** Compliance requirements from different regions with different data protection laws makes it a bit challenging to implement data management strategies

**Solution:** Implement end-to-end encryption (data at rest and in transit), classify data by sensitivity, and apply the principle of least privilege for access controls. Use tools like Azure Policy and Microsoft Defender to enforce compliance and monitor potential violations in real time (Microsoft Learn, 2024).

1. **Ethical challenges –** circling back on security and compliance it is important to implement structures on: how the system handles user data, how fair it predicts different recommendation and transparency in how it came to a certain decision

**Solution:** Integrate explainable AI (XAI) frameworks to make recommendation logic transparent. Regularly audit models for bias and fairness and incorporate ethical guidelines into your machine learning pipeline (Jayalakshmi et al., 2022).

1. **Design challenges –** with the current trends in market trends and technology enhancements it is important to ensure effective CI/CD streams with minimal downtime and maximum flexibility.

**Solution:** Leverage Azure DevOps to automate CI/CD processes and use blue-green deployments for seamless updates. Adopt containerized microservices (using Azure Kubernetes Service) for scalability and flexibility (Microsoft Learn, 2024).

# Cloud Governance

For the movie recommendation system, it’s crucial to have cloud governance policies and regulations implemented to ensure there is security, efficiency, and compliance. The following policies and regulations should be followed:

Policies

1. **Identity and Access Management (IAM):** Although we mentioned IAM previously, it is an important part of cloud governance to implement strict IAM policies to control who can access and manage the cloud resources in the system. Role based access control can be used to authorize only those who need to be when accessing parts of the system.
2. **Resource Tagging:** Resource tagging should be used to organize and manage the resources in the cloud. Implementing monitoring and alert systems to track usage, performance, and security risks is also crucial.
3. **Document Changes:** Implement a structure within the company for a change management process to manage updates and changes to the cloud environment. This means all employees will have to document testing, approval, and all changes made.

Regulations

1. **General Data Protection Regulation (GDPR):** Given that a large amount of the population using the platform will likely be from Europe, Following the GDPR is standard and a must for handling data from users within the European Union. This compliance shows user consent, providing data access rights, and implementing data protection measures.
2. **California Consumer Privacy Act (CCPA):** To satisfy our user base in California, complying with CCPA requirements is a requirement. This includes providing transparency about how data is collected in our system and allowing users to choose whether they want their data shared or used for analytics.

Following these policies and regulations, the movie recommendation system should be available to accessing most customers and provide a cloud governed environment that shows compliancy.

# Conclusion:

This project highlights the architecture for a Movie Recommendation Engine using many Azure AI services such as Azure Personalizer and Azure Intelligent Recommendations. By analyzing user activity data, the system provides personalized movie suggestions and detailing relevant use cases such as Netflix’s recommendation engine.

We went over the Cloud Service Models, and proposed architecture for the system and provided cost predictions to ensure financial viability. We also considered optimal regions for the deployment to make sure performance and availability for the infrastructure was ideal, while emphasizing the importance and steps to have security and compliance to protect user data.

Some of the major challenges facing our system, such as data integration, design, security, and ethics, were discussed and provided solutions, as well as Cloud Governance to follow to maintain compliance and reliability. However, it is important to note that personalized and intelligent recommendation technologies can quickly become outdated as technology evolves. Staying ahead of advancements and continually updating the recommendation algorithms are crucial to maintaining effectiveness and user satisfaction.

In our findings, we found that both Azure Personalizer and Azure Intelligent Recommendations can be important tools to use to speed up deployment of a movie recommendation system architecture. We have learned about the compliance methods and what legal regulations are required for movie recommendations and we discussed best security measures and practices, such as Encryption and IAM policies. We have found to use services such as Data Factory to build scalable pipelines, tagging to organize the cloud and monitor resources, and lastly ethical challenges that may pose a risk when obtaining user data or transparency with AI.

# Group Meeting Log

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Meeting** | **Date** | **Caleb Watson-Danis** | **Catherine Daigle** | **Elias Ngugi Kariuki** | **Yue Gao** | **Attendance Notes** |
| **In Person Meeting** | Nov 22 | Present | Present | Present | Present | Everyone contributed, Work distribution completed |
| **In person meeting** | Nov 28 | Present | Present | Present | Present | On the track! |
| **Zoom meeting** | Dec 4 | Present | Present | Present | Present | On the right track for researching. |
| **Zoom meeting** | Dec 8 | Present | Present | Present | Present | On the right track for the research assignment1. |
| **Zoom meeting** | Dec 13 | Present | Present | Present | Present | Happily, contributed, everyone is ready for the final report submission |

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