

**Latex Code**

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\documentclass**[**acmsmall**]{**acmart**}**

**%%** NOTE that a single column version **is** required **for**

**%%** \BibTeX command to typeset BibTeX logo **in** the docs

\AtBeginDocument**{%**

\providecommand\BibTeX**{{%**

\normalfont B\kern**-0.5**em**{**\scshape i\kern**-0.25**em b**}**\kern**-0.8**em\TeX**}}}**

**%%** end of the preamble**,** start of the body of the document source**.**

\begin**{**document**}**

**%%**

**%%** The "title" command has an optional parameter**,**

**%%** allowing the author to define a "short title" to be used **in** page headers**.**

\title**{**Poseidon – water infrastructure status prediction system **for** communities **}**

**%%**

**%%** The "author" command **and** its associated commands are used to define

**%%** the authors **and** their affiliations**.**

**%%** Of note **is** the shared affiliation of the first two authors**,** **and** the

**%%** "authornote" **and** "authornotemark" commands

**%%** used to denote shared contribution to the research**.**

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**}**

**%%**

**%%** The abstract **is** a short summary of the work to be presented **in** the

**%%** article**.**

\begin**{**abstract**}**

The project Poseidon leverage the data science **and** machine learning techniques to develop a novel solution **for** water crisis problem by predicting the status of water infrastructure of different communities across Tanzania**.** The developed model **is** deployed on a django based webapp to increase its **global** outreach**.** The project **is** develop to support UN sustainable goals of clean water **and** sanitation**,** good health **and** well**-**being**,** partnership **for** goals **and** sustainable communities **and** cities**.**One of the proposed method predicts the status of water infrastructure **with** training precision of **99** percent**.**

\end**{**abstract**}**

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**%%** The code below **is** generated by the tool at http**://**dl**.**acm**.**org**/**ccs**.**cfm**.**

\ccsdesc**{**Software **and** its engineering**~**Community oriented Design**}**

\ccsdesc**{**Human**-**centered computing**~**Collaborative **and** social computing **}**

\ccsdesc**{**Computing methodologies**~**Machine Learning**}**

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**%%**

**%%** Keywords**.** The author**(**s**)** should pick words that accurately describe

**%%** the work being presented**.** Separate the keywords **with** commas**.**

\keywords**{**Stewardship**,** Separating the concerns**,** Mis**-**information handling**,** ϖ Digital Habitat**,** Agile SDLC model **with** Bazaar Approach**,** Data transformation into knowledge**,** Gamification**,** sustainable development**}**

**%%**

**%%** This command processes the author **and** affiliation **and** title

**%%** information **and** builds the first part of the formatted document**.**

\maketitle

\section**{**Introduction**}**

The key objective of this paper **is** to propose solution **for** solving water crisis issue **in** African country of Tanzania**.** According to UN report on water **for** life**[1],** more than half of the people living **in** Tanzania are without safe drinking water**,** there **is** mind boggling funding gap of **61** percent to develop current infrastructure**,** an average person has to travel more than **30** minutes to get access to clean drinking water **and** **4000** children death every year **from** water born disease. For a country like Tanzania facing major water crisis better managing their current water infrastructure is of paramount importance. The proposed solution revolves around the **{**\bfseries community centered design**}** using **{**\bfseries false**-**consensus effect**}** where solution goal **is** to design digital habitat **for** actual needs of the community**.**The remainder of this document **is** presented **as** follows**:** section **2** presents the proposed methodology**;** section **3** presents results **and** section **4** discuss the future work **and** conclusion**.**

\subsection**{**Community **and** stakeholders**}**

To create a digital habitat that **is** habitable **and** thriving **for** its users a comprehensive study was under taken to understand communities **in** Tanzania **and** their orientations**.** The inference **from** the study **[2]** are**,** the current water infrastructure **is** managed by ministry of water**,** the **{**\bfseries north star customers**}** **for** project **is** communities across Tanzania**,** the computer literacy rate **is** low **in** the country thus we expect bulk of the customer base comprised of **{**\bfseries lurkers**},** the future work suggests creation of chat forum **for** more **{**\bfseries prosumer**-**based **}** collaborative approach moving forward **and** welcoming contributions **from** **{**\bfseries innovators**}.** Stakeholders includes communities of Tanzania **as** NorthStar customers**,** water infrastructure management Government agency**,** various local **and** **global** NGO’s**.**

\subsection**{**Tools **and** Technologies**}**

The software development life cycle **for** project Poseidon **is** based on **{**\bfseries Agile**}** approach**.**The agile SDLC **for** this project consist of **{**\bfseries **3** sprints of one week each resulting **in** **3** MVP**}.** Using the **{**\bfseries Bazaar ideology**},** technology **and** license used to develop the **{**\bfseries end**-**end solution**}** were **{**\bfseries open**-**source**}** **for** supporting collaborative work**.** This technology includes python programming language **and** its various open**-**source modules**,** Anaconda development environment**,** Jupiter notebook Kernel running on Visual Studio code editor**,** creately **and** photo**-**shop **for** creating documentation**.** GitHub **for** version control**,** Django library deployed **in** anaconda virtual environment **for** hosting web application**.** The approach uses machine learning algorithm of random forest to predict the status of water infrastructure of the community **in** Tanzania**.**

\section**{**Proposed methods**}**

Every machine learning model needs data to make prediction**.** To leverage the machine learning technique to transform **{**\bfseries raw data into knowledge**}** we required a non**-**synthetic dataset to solve real**-**world problem **and** **not** to limit proposed method by using synthetic data**.** After browsing **for** the dataset on various data platforms like Kaggle**,** data driven**,** etc**.** The selected dataset that was used to develop the predictive model was based on data available **from** Government of Tanzania **-** Ministry of water **and** hosted by data driven organization **as** a **{**\bfseries public dataset**}.** This selection was **in** accordance of bazaar approach used **in** this project**.**For the purpose of **{**\bfseries separating the concerns**}**at various development levels prediction model **and** web interface are developed differently **and** **if** there are any future improvement **in** the model it can be easily deployed on webapp by simply uploading the model file into webapp**.**This feature also consider **{**\bfseries UFFFAA**}** **[4]** approach **in** which flagging the shortcoming of the current model can be overcome by framing knowledge**,** fixing knowledge **and** later assuring knowledge **in** later versions of upcoming models also preserving knowledge **from** previous versions aswell.

\subsection**{**Dataset**}**

The dataset comprised of **40** features **with** total of **74,000** listed rows of data **in** total**.** The **40** features include**,** amount**-**tsh**,** date**-**recorded**,** funder**,** gps**-**height**,** installer**,** longitude**,** latitude**,** wpt**-**name**,** num**-**private**,** basin**,** subvillage**,** region**,** region**-**code**,**district**-**code**,** lga**,** ward**,** population**,** public**-**meeting**,** recorded**-**by**,** scheme**-**management**,** scheme**-**name**,** permit**,** construction**-**year**,** extraction**-**type**,** extraction**-**type**-**group**,** extraction**-**type**-**class**,** management**,** management**-**group**,** payment**,** payment**-**type**,** water**-**quality**,** quality**-**group**,** quantity**,** quantity**-**group**,** source**,** source**-**type**,** source**-**class**,** waterpoint**-**type**,** waterpoint**-**type**-**group**.**The data provided **is** **in** **{**\bfseries raw CSV format**}** **with** many missing values **for** the features like funder**,** scheme**-**name **and** permit which contributed **3635,** **28166** **and** **3056** values respectively**.**

The label to be predicted has three possible values

\begin**{**itemize**}**

\item **{**\verb**|**functional**|}:** the waterpoint **is** operational **and** there are no repairs needed

\item **{**\verb**|**functional needs repair**|}:** the waterpoint **is** operational**,** but needs repairs

\item **{**\verb**|**non functional**|}:** the waterpoint **is** **not** operational

\end**{**itemize**}**

\subsection**{**Feature Engineering**}**

The feature engineering plays an important role **in** designing the model**.** Basically**,** all machine learning algorithms uses some input data to create outputs**.** This input data comprises of features**,** which are usually **in** the form of structured columns **as** discussed **in** dataset**.** Algorithms require features **with** some specific characteristic to accurately predict the result**.**

The main objective **for** using feature engineering can be summarized **as** follow

\begin**{**itemize**}**

\item **{}**To prepare the proper input data set compatible **with** the machine learning algorithm requirements

\item **{}**For improving the performance of machine learning model

\end**{**itemize**}**

To develop additional input parameters **in** the data features were engineered**.**Some of these features are

\begin**{**itemize**}**

\item **{}**Age of the pump **is** a key feature but it was missing **from** the original dataset which was computed using the values from date**-**recorded **and** construction year

features**[**'age'**]** **=** features**[**'date-recorded'**]** **-** features**[**'construction-year'**]**

\item **{}**Population served per age of the pump

features**[**'pop/year'**]** **=** features**[**'population'**].**replace**({0:1})** **/** features**[**'age'**]**

\end**{**itemize**}**

\subsection**{**Imputation**}**

Imputation **is** the process of replacing the missing values**.**They pose a huge challenge **in** creating data pipelines **and** adversely affect the accuracy of the model**.** The missing value **in** the selected dataset was replaced by mean values of respective columns which also helps to create normal distribution of values **for** these features which **is** ideal **for** obtaining better overall accuracy**.**

\subsection**{**Encoding **}**

The encoding **is** performed **for** categorical data **as** it **is** difficult **for** any machine learning algorithm to understand the categorical data**.** This process simply changes the data **with** cardinality more than **150** values into numerical format thus enabling grouping of data without any data loss **and** rest of the low cardinality variables were ordinally encoded **in** **with** string values were simply replaced by a numeric value representing that **class** of value**.** This was performed to build pipelines architecture using SKlearn module**.**

\subsection**{**Scaling**}**

The scaling helps to bring different values to the same numeric range so that a machine learning algorithm can compare different features **and** identify important features **from** the feature group. For scaling**,** transform functionality of SKlearn module was used**.**

\subsection**{**Parallelly Implemented random forest classifier model **}**

The prediction model **is** based on random forest classifier algorithm implemented using parallel programming**.** The model **is** hyper**-**tuned using gridsearchCV method of SKlearn**.** The hyper**-**tuned parameters **for** the model only consist of max depth thus resulting cluster of decision trees **with** max depth **25.** There are many methods available **for** hyper**-**tuning but to make the model simpler **and** decrease the training time only max depth was used **as** tuning it drastically impacted the accuracy**.** The n**-**tier which controls the number of combinations **is** set to **5** thus covering a wider search space**.**The value of CV **is** set to **5** **for** stopping model **from** over**-**fitting the data**.**

The project has two versions of model **with** same hyper**-**tuned parameters**.**

\begin**{**itemize**}**

\item **{}{**\bfseries Version **1}[** Deep Model **]** was trained using **40** input parameters developed **in** Sprint **1.**It has **322** computed important features to make predictions

\item **{}{**\bfseries Version **2}[** Shallow model **]** was trained using **8** input parameters developed **in** Sprint **2**

It has **9** computed important features selected using base model evaluation by using SAS miner tool to make predictions**.**

\end**{**itemize**}**

\subsection**{**Flow Diagram of the proposed method **}**

\begin**{**figure**}[**h**]**

\centering

\includegraphics**[**width**=**\linewidth**]{**MVP3 flow diagram **.**png**}**

\caption**{**Flow Diagram of project Poseidon**}**

\Description**{**A diagram depicting the pipeline architecture **for** training the prediction model **and** deploying the model on a django web app**}**

\end**{**figure**}**

\subsection**{**Web Portal**}**

To increase the **global** outreach of the model **and** to create a software based on **{**\bfseries people centric approach**}** instead of product**-**based approach**,** I have deployed the prediction model on a django based web application so **as** to test the model **with** real world data**.** This approach would also help to improve the product based on feed backs **from** people about its accuracy.

The django webapp have **2** primary components controller **and** views**.** Users interact **with** the views implementing controller **as** a backend**.** The concept of **{**\bfseries separations of concern**}** **is** used to separate the model **from** the controller code. This result in a smooth mechanism to deploy and test models with different configuration and hyper**-**tuning parameters **with** ease**.{**\bfseries Version **2}** model was considered **for** testing purpose **for** the application due to time constraints between each sprints**.**

\subsection**{**Map plot**}**

To create a better user experience the status of the pump was plotted using geopandas **and** matplotlib modules of python on map of Tanzania**.** The red spot represent water pump that are **not** functional**,** green represent water pump that are functional **and** yellow represent water pump that are functional but need repair

\begin**{**figure**}[**h**]**

\centering

\includegraphics**[**width**=0.5**\linewidth**]{**Plot\_all**.**png**}**

\caption**{**Plot illustrating status of various water pump across Tanzania**}**

\Description**{**A diagram depicting status of various water pump across Tanzania**}**

\end**{**figure**}**

\section**{**Results**}**

The developed models were compared using confusion matrix analysis**.** The criteria used **for** evaluation of the developed models are precision**,** recall**,** f1 score **and** accuracy**.**

\begin**{**table**}[**h!**]**

\caption**{**Version **1** **[**Deep Model **]** Training evaluation matrix**}**

\label**{**tab**:**freq**}**

\begin**{**tabular**}{**ccccl**}**

\toprule

Predicted outcome**&**Precision**&**Recall**&**F1**-**score**&**Accuracy\\

\midrule

Functional **&0.98&1.00&0.99&0.99**\\

Needs Repair **&1.00&0.95&0.98&0.99**\\

Not**-**Functional **&1.00&0.99&0.99&0.99**\\

\bottomrule

\end**{**tabular**}**

\end**{**table**}**

\begin**{**table**}[**h!**]**

\caption**{**Version **2** **[**shallow Model **]** Training evaluation matrix**}**

\label**{**tab**:**freq**}**

\begin**{**tabular**}{**ccccl**}**

\toprule

Predicted outcome**&**Precision**&**Recall**&**F1**-**score**&**Accuracy\\

\midrule

Functional **&0.60&0.97&0.74** **&0.63**\\

Needs Repair **&0.00** **&0.00** **&0.00** **&0.63**\\

Not**-**Functional **&0.82** **&0.27** **&0.41&0.63**\\

\bottomrule

\end**{**tabular**}**

\end**{**table**}**

We can observe **from** table **1** **and** table **2** that version **2** have lower accuracy than version **1.**It was expected **as** version **2** only uses **8** features to predict the value **as** compared to original **40** features used by version **1.**We can observe a **{**\bfseries trade off between accuracy **and** model size**}** **while** comparing accuracy of the two versions of model **for** this dataset**.**

The front end design of the web application **as** displayed **in** **{**\bfseries figure **3}** **is** responsive **and** designed to minimise **{**\bfseries gulfs of interaction**}** **for** users**.**The website has a simple form design **with** precursors **for** aiding **in** filling the form**.** The button clearly state what action **is** to be expected once it **is** clicked**.** The predicted result clearly provide prediction **with** accuracy of the information thus handling **{**\bfseries misinformation **}in** the application**.**

\begin**{**figure**}[**h!**]**

\centering

\includegraphics**[**width**=0.8**\textwidth**]{**UI**.**png**}**

\caption**{**User interface of web portal **}**

\Description**{**image displaying the user interface **for** web app**}**

\end**{**figure**}**

\section**{**Future Work **and** Conclusion**}**

The present document provide insight into predictive machine learning approach to provide a novel solution **for** solving water crisis **in** Tanzania**.** The proposed method discuss various design aspects **and** technology concepts used to develop two versions of predictive model **and** webapp used to deploy these models**.** The result **from** the study prove that version **1** **-** Deep model has better accuracy than version **2** **-** Shallow model**.**

The future work include functionality of chat forum**,** announcement page **for** NGO**,** Donate page **for** the community**,** Award section **for** recognizing efforts **from** community members**,** live senor data integration **for** providing real time status prediction **and** deploying a deep model on web interface**.**Using concepts of gamification i**.**e**.** guessing which pump will be non operational today**,** can help to rise awareness **in** the community to forge a stronger resolution **in** working towards solving water crisis through collaborative efforts of comunities**.**

**%%** The acknowledgments section **is** defined using the "acks" environment

**%%** **(and** NOT an unnumbered section**).** This ensures the proper

**%%** identification of the section **in** the article metadata**,** **and** the

**%%** consistent spelling of the heading**.**

\begin**{**acks**}**

\begin**{**itemize**}**

\item **{}**To Government of Tanzania **-** ministry of water **for** providing the dataset**.** \item**{}**To Datadriven organization **for** hosting the dataset

\item **{}**To Dr**.**Timothy Maciag **for** reviewing my idea**.**

\end**{**itemize**}**

\end**{**acks**}**

**%%**

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**%%** the bibliography file**.**

\bibliographystyle**{**ACM**-**Reference**-**Format**}**

\bibliography**{**sample**-**base**}**

\begin**{**enumerate**}**

\item United Nations**.** **(**n**.**d**.).** Water **for** Life**.** Retrieved June **20,** **2021,from** https**://**www**.**un**.**org**/**

\item Patel**,** D**.** **(**n**.**d**.).** Activity **1** **-** ENSE **885.** Retrieved June **20,** **2021,** **from** https**://**github**.**com**/**Dhaval**-**B**-**Patel**/**ENSE**-885---**spring**-2021/**blob**/522763601394**b79914e59ee50c9aba06bdad1a8d**/**Activity**%201%20-%20**Requirement**%20**Analysis**/**Activity**%201%20-%20**Requirement**%20**analysis**%20**complete**%20**merged**%20**document**.**pdf

\item Macaig**,** T**,** **2021,** Class Notes**,** People Centered Design**,** University of Regina**,** delivered May **2020**

\item Macaig**,** T**,** **2021,** Class Notes**,** Topics **in** Computer**-**Supported Collaborative Work**,** University of Regina**,** delivered May **2021**

\item Towards Data Science **.** **(**n**.**d**.).** Fundamental Techniques of Feature Engineering **for** Machine Learning**.** Retrieved June **20,** **2021,** **from** https**://**towardsdatascience**.**com**/**feature**-**engineering**-for-**machine**-**learning**-3**a5e293a5114

\item Towards Data Science **.** **(**n**.**d**.).** Hyperparameter Tuning the Random Forest**.** Retrieved June **20,** **2021,** **from** https**://**towardsdatascience**.**com**/**hyperparameter**-**tuning**-**the**-**random**-**forest**-in-**python**-**using**-**scikit**-**learn**-28**d2aa77dd74

\end**{**enumerate**}**

\end**{**document**}**

\endinput

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**%%** End of file `sample**-**acmsmall**-**conf**.**tex'.