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United Nations Population Fund

“Mandukhai” Chatbot Research final report

This document serves the following purposes:

1. Define chatbot requirements and overall design of a system accordingly
2. Report research track, datasets, current results and model evaluation
3. Response Policy and Post Processor
4. Admin page
5. Conclusion
6. Appendix

1. Mandukhai Chatbot Requirements and design

1.1. Requirements

We target to build an interactive chatbot system to provide online psychological services to mainly but not necessarily adolescents on topics covering pregnancy, sexual interaction and protection, social interaction and handling psychological pressure. Thus, we have listed the following requirements which are provided by UN representatives to our chatbot. The chatbot must be able to

1. Identify and answer questions related to relative topics
2. Handle minor spelling errors
3. Handle cyrillic and latin letters conversion
4. Identify questions beyond it's knowledge
5. Accessible through Facebook Messenger
6. Handle basic conversation elements including greetings, farewell, self explanation etc
7. Send pictures to express certain emotions
8. Provide address, contact of adolescent clinics
9. Voice to text recognition
10. Identify serious risk conversations
11. Supplementary way of providing service through the chat menu system.

1.2. Overall Design Architecture and Hardware Requirements

Based on the above mentioned requirements we proposed a chatbot design which is illustrated in the Figure 1. The main channel which our user will interact with is a [facebook page](#). Through Facebook API which can be configured in “<https://developers.facebook.com/apps/>” by authorized personnel, the main Mandukhai Backend Server will provide its service to users.

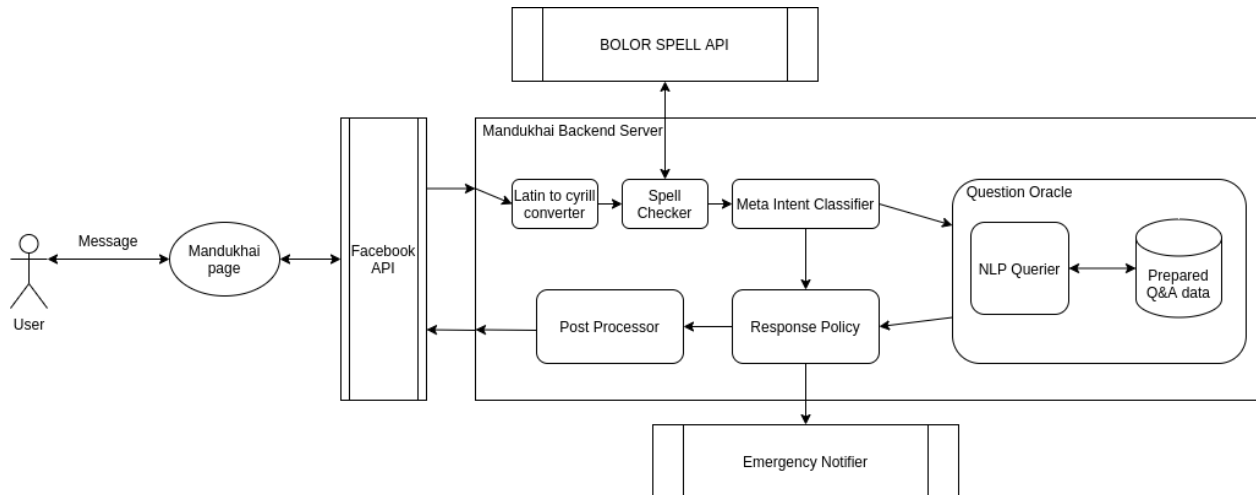


Figure 1.

1.3. Backend Server

This server will handle all user requests and respond accordingly. Please note that this server should be deployed by the UN representatives and must be connected to “Bolor Spell” API. As illustrated, user messages will be first preprocessed by latin to cyrillic converter and spell checker. Clean text input will be then fed to Meta Intent Classifier to identify whether the user is asking for advice or information on target topics or giving basic conversation inputs like greeting, farewell etc. If the user asks the former, our machine learning based solution “Question Oracle” will search the best possible answer from the prepared database and forward it. Then, response policy will handle answers or intent to modify or generate answers to keep the integrity of the conversation. Note that also in this stage our system will notify emergency cases to appropriate personnel. Finally, the post processor module will add corresponding pictures (emoji), web links and generate responses for Facebook API.

1.4. Server Hardware Requirements

High-end server

min. 1 GPU with 24GB RAM (For example RTX 3090 or Titan RTX)
 2 x Intel Xeon Silver 4210R
 128 GB DDR4-2933 RAM
 1 TB Samsung SSD Pro/Evo
 PSU min. 750 Watt 80Plus
 2 Network cards (Intel)

2. Research

2.1. Latin to Cyrillic Converter

Since the number of latin letters are fewer than that of Mongolian language, often one latin letter is used to represent multiple different cyrillic letters in practice. Moreover, because there is no general rule of such conversion used in public, we had to devise a probabilistic approach. Based on 12,000 thousand mongolian cyrillic sentences converted to latin by our annotators, we generated bayesian probabilistic character to character conversion rule. To further increase our accuracy, we connected Bolor Spell Checker to validate the conversion. However, note that this approach is not suitable on a server when internet connection is low.

2.2. Spell Checking

We used two endpoints available in “Bolor” Spell Checker API. First endpoint will scan the given text and notify us of possible misspelling errors. Then the second endpoint will suggest the closest correct spelling of possible mistaken word using the fastest string matching algorithm.

2.3. Meta Intent Classification

This module is proposed to identify following meta intents such that our chatbot can handle basic conversation flow.

1. Farewell
2. Question
3. Greeting
4. Gratitude
5. Request Inspiration
6. What can chatbot do
7. Sad
8. Agreement
9. Denial

Based on the results of our previous research we used N-gram based tf-idf vector representation to convert raw text into numeric format. And finally applied a robust machine learning method “Random Forest Classifier” to classify the text.

2.4. Question Oracle

The main task of this module is to query the best answer based on the question from the database. Current question oracle is a hybrid of 2 string matching models that performed best in our various approaches.

2.5. Datasets

1. Q&A data: consists of 12000 questions with 9857 unique answers collected from professional psychologists. This data will be our main feed for answers. Provided by UN.
2. Q&A data: annotated 12000 questions. These questions are annotated by intent and slots. This data will be main feed for Q&A dataset. Provided by Bolorsoft data team.
3. Paraphrase Data: 10035 sentences hand built by paraphrasing random questions and answers selected from Q&A dataset without alternating semantic meaning. This dataset is crucial for training and evaluating models. Built by Bolorsoft data team.
4. Topic Data: 12000 questions manually tagged to corresponding topic, keywords and actions. This dataset is crucial for training and evaluating models. Built by Bolorsoft data team.

2.6. Supervised Word Moving Distance on Glove Embedding (SWMD)

Perhaps the simplest way of matching the sentences is to directly count the percentage of words which they share. However, this approach may yield comparable results on small domains; it is definitely not suitable for our Q&A data, due to its inability to evaluate word relation, synonyms, importance and order.

To alleviate these issues we propose a solution using the following methods.

1. Glove Word Embedding (Glove): By using Matrix Factorization on Co-Occurrence matrix on a raw language corpus, Glove Embedding learns to represent semantic meaning and relation of words in language vocabulary into numeric format. This method was first proposed in 2014 by Stanford researchers (<https://nlp.stanford.edu/pubs/glove.pdf>) and still used various types of modern machine learning tasks to represent words by vectors. In our research, we built Glove embedding on 5GB cleaned mongolian text extracted from mongolian wikipedia after 60 epochs of training. Example words with most similar 5 words calculated using Glove are shown below for demonstration

```
монгол -> улс, манай, үндэс, түмэн, үндэстэн
секс -> таашаал, сэрэл, эротик, эрч, эрчүүд
бэлгэвч -> хавьтах, хавьтал, хдхв, жирэмслэлт, бохь
тарилга -> вакцин, вакцинжуулалт, туулга, тариур, дархлаажуулалт
жирэмслэлт -> жирэмслэх, хөндөлт, умайх, үргүйдэл, үржихүй
ээж -> аав, эгч, эмээ, өвөө, охин
хамгаалалт -> хамгаалалттай, хамгаалах, тусгай, харуул, аюух
суулгац -> тарьц, үрслэх, тарих, тариалах, сөөг
улс -> монгол, орон, засаг, найрамдах, төр
```

2. Word Mover's Distance (WMD): One of the biggest advantages of Glove embedding is that word semantic meaning correlates with euclidean distance between vector representations. Word

Mover's Distance utilizes this feature to calculate semantic distance between 2 sentences described in [this publication](#) from Washington University.

- Supervised Word Mover's Distance (SWMD): The WMD with GLove embedding alone is able to calculate meaningful distance between sentences in general text. However, in this research we proposed a way to fine tune WMD to specific domains. We do so, by giving weight to individual words so that the model can learn to prioritize words specific to domain. In our case, such words may include puberty, abortion, pressure, suicide etc. Weights are initialized with Inverse Document Frequency (IDF) scores we extracted from comparing Q&A corpus against general Mongolian Wikipedia corpus. Then weights are further trained by [Basin Hopping Optimization](#) method to optimize first match accuracy on Paraphrase Dataset, which is a non differentiable loss function.

2.7. Topic BERT

The biggest weakness of SWMD is its inability to understand word semantic relations with respect to other words in the sentence. To address this issue we proposed a solution using state of the art model BERT (<https://arxiv.org/abs/1810.04805>) developed by Google researchers in 2018. We developed the BERT model for Mongolian language on 25GB of raw text private corpus we collected from various sources (Mon-BERT). Then fine tuned Mon-BERT for topic similarity estimation tasks based on the Topic dataset we built. Then, our algorithm to represent sentence is as follows

- Pick top 200 topics from Topic dataset
- Calculate the probability of a given sentence belonging to a certain topic with our custom trained Sim-Mon-BERT model for each 200 topics.
- Represent question in 200 dimension document vectors using scores from step 2
- Calculate the cosine similarity between document vectors against Q&A dataset to find best match.

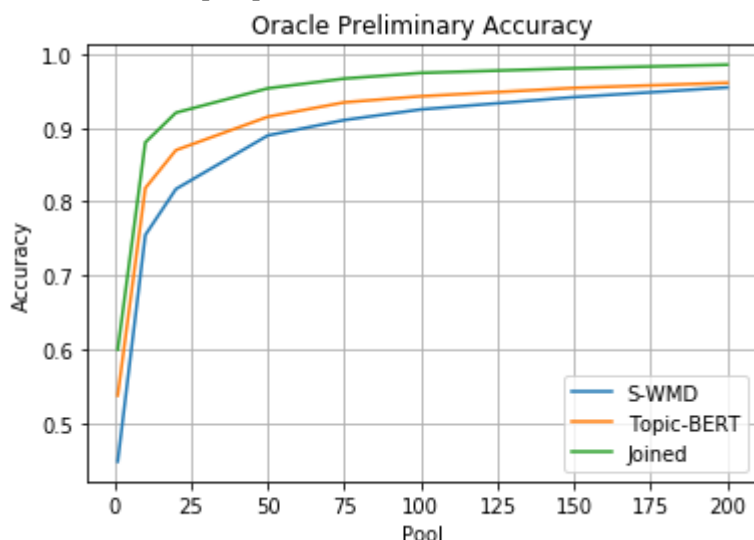
2.8. Hybrid Model

We joined our model by summing up each of their confidence scores with weight. This weight is optimized by grid search on Paraphrase dataset. Since the complexity of SWMD is $O(M \cdot N_a \cdot N_b)$ where M is number of questions in Q&A dataset, N_a is number of words in user message and N_b is average number of words in questions in Q&A dataset, running SWMD on 11910 instances is far from optimal in real time application.

Thus we used Topic-BERT model first where the complexity is $O(N_a^2)$ to rank top 256 answers with 99.6% probability of containing the correct answer. Then applied scores from the SWMD model to further increase matching accuracy.

2.9. Evaluation

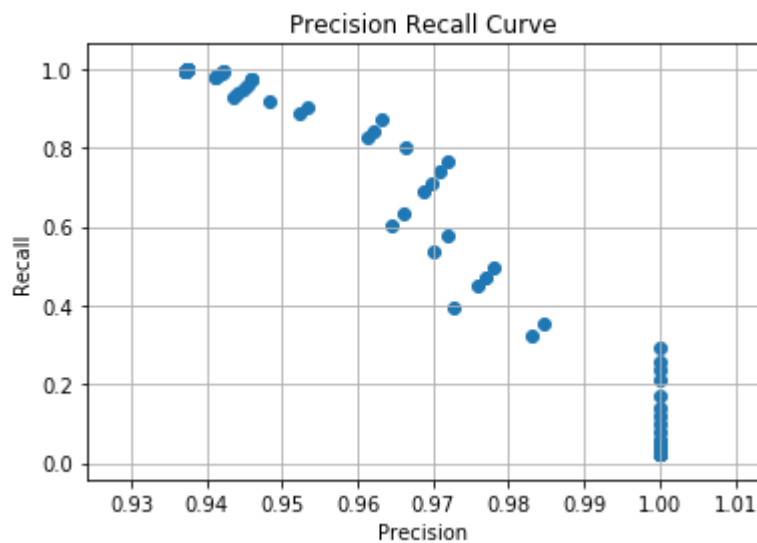
The graph below depicts the relation between accuracy and size of answers picked by our model as the most relevant on paraphrase dataset.



- Our joined approach yielded a significantly better score where top1 accuracy reached 60% while each of the models separately reached 44.5% and 53%.
- Within the 200 range, our best model picks the correct answer with 98.57% accuracy.
- However we observed that evaluating matches by comparing answers exactly, does not correlate to real accuracy, since our database consists of many semantically similar answers.
- Thus we used human testers to manually evaluate our model.
- Our final solution is manually tested by our annotators with 192 questions and achieved 96% top-1 accuracy and 98.5% top-10 accuracy.

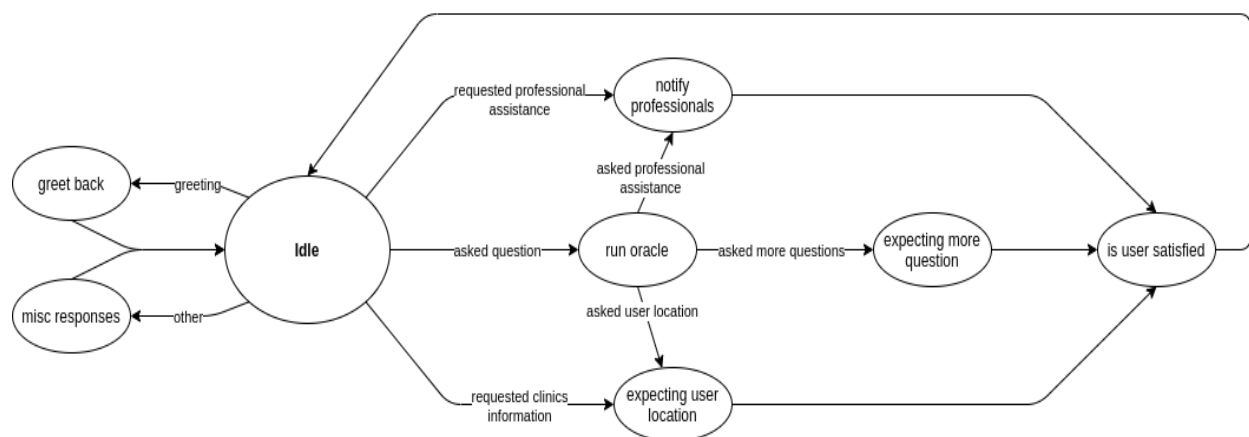
2.10. Thresholding

To handle incorrect matches or question which answer is not provided before, we put a hard threshold to confidence of a best match. Based on statistical analysis we currently apply a threshold of 0.52 to prioritizing to minimize false positives as it can result in fatal consequences. Following is precision, recall curve through different thresholds. With the selected threshold our model achieves 0.967 precision and 0.8 recall rate.



3. Response Policy and Post Processor

In this project we aim to assist (but not to replace) professionals by handling elementary level conversations and deliver prepared answers to specific issues Mandukhai is certain of. With this and the importance of predictability and stability of our system we chose finite state machine policy. Guided by the user's message state machine will traverse over it's states and perform actions defined in each state which may include either deliver predefined response or run Oracle model. Full state diagram is shown below.



As inferred in state diagram we included following features

1. Ability to handle basic conversation messages including greeting, farewell, gratitude, explain Mandukhai etc.

2. By user request provide nearby clinics location based on provided location.
3. Ability to notify professionals by email in case of emergency conversation (which may include suicide, sexual harassment and other perilous topics).
4. Drive conversation further by asking if use has more question related to topic.
5. Finalize conversation by requesting evaluation from user.

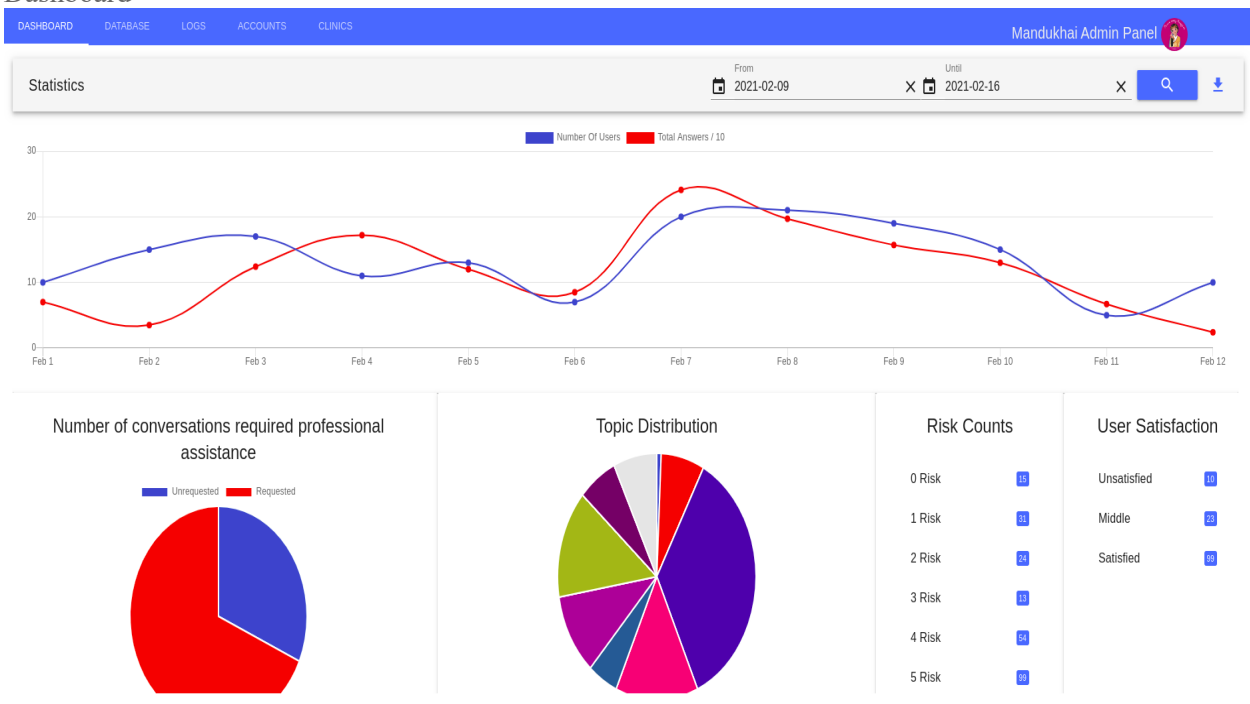
Find detailed state definitions from Appendix A.

4. Admin page

Real time monitoring and analysis was equally important to health professionals who are administering the chatbot system. Thus, we developed a web application that enables not only a way to monitor chatbot systems but also to adjust and modify chatbot responses in a flexible way. The admin page has following 5 main sections handling separate functions:

1. Dashboard - contains visualization of key statistics of the system
2. Database - flexible way to modify answers
3. Logs - real time chatbot conversation monitoring
4. Accounts - modifies contact information of certified professionals
5. Clinics - location and description of adolescence clinics

Dashboard



From dashboard admin users can monitor the number of users and total number of questions asked by users on a specific selected date range. Also, the Topic Distribution, Number of conversations required professional assistance, Risk Counts and User Satisfaction info can be seen.

Database

Dashboard

Database

Logs

Accounts

Clinics

Mandukhai Admin Panel

Edit

Answer

Яг одоогоор харилцаа үүсгэх бодолгүй байгаа гэдгээ илэрхийлээрэй

Short Answer

Follow up question

Үерхлийн талаар өөр ямар мэдээлэл авахыг хүсэж байна

Additional Link

Risk

0

Emoji

thinking

Topic

үерхэл

SAVE CHANGES

Keywords

ID

Risk

Emoji

Topic

Q

Download

Upload

Answer	Emoji	Risk	Type	
Яг одоогоор харилцаа үүсгэх бодолгүй байгаа гэдгээ илэрхийлээрэй	thinking	0	үерхэл	
Сарын тэмдгийн үед хэрэглэх ариун цэврийн хэрэгслэлийн нэг төрөл юм	none	0	сарын тэмдэг	
Жирэмслэхээс сэргийлэх эмийн найрлага дахь дааврын үйлчлэлээр зарим хүнд жин нэмэгдэх шинж илэрч ...	thinking	0	жирэмслэлтээс хамгаалах	
Та 2 ярилцах нь хамгийн чухал. Ярилцаж асуухаас бүү эмзэгээрэй.	thinking	0	үерхэл	
Хооллолтын гэр зөвлөмж гээд байдаг ш дээ, 10-н жилийн хичээл дээр ч үнээ. Тэр гэр зөвлөмжинд заас...	thinking	0	жирэмслэлтээс хамгаалах	
Үр дүнтэй байдал нь хэрэглэгчээс хамаарна: шинэ наалтыг хугацаанаас хожуу наасан тохиолдолд жиром...	thinking	1	жирэмслэлтээс хамгаалах	
Харьяа аймаг, дүүргийн сэтгэцийн эмч болон Сэтгэцийн эрүүл мэндийн үндэсний төвийн Хүүхэд, өсвөр ...	worrying	4	үерхэл	
этгэдэл төрүүлэх үү?	Үгүй ээ тэгэхгүй. Бэлгээн харин ч ухаалаг сонголт шүү.	none	бэлгийн харилцаа	
эн үг үү?	Үгүй дээ цаг гаргаж өөртэйгөө ярилцдаг байх хэрэгтэй шүү	thinking	2	үерхэл
	Тийм төрлийн эрчүүд байдаг ч бүх хүн тийм гэсэн үг биш ээ.	thinking	0	бэлгийн харилцаа
яагаад болохгүй гэж байж болно шдээ тэгэхдээ чамд өмсөхөд зөтэйхэн байх хэрэгтэй	none	1	бэлгийн харилцаа	
Гар хангалта байгаа хийх нь хурдан тавилтанд нөлөөлдөг байх бололгүй	none	0	бэлгийн харилцаа	
Гар хангалта хийснээр өөртөө бэлгийн таашаал өгөх мөн дүр тавина.	none	0	бэлгийн харилцаа	

This page displays answers in the database. Users can query and edit desired answers by keyword, ID, Risk level, Emoji and Topic from around 10000 entries. Moreover we included the excel file interface to download and upload a batch of changes in a single run.

Logs

Dashboard

Database

Logs

Accounts

Clinics

Mandukhai Admin Panel

Logs

From

2021-02-09

×

Until

2021-02-16

×

SEARCH

User	Latest Message Time	Latest Topic	Max Risk	Satisfaction
Beku Ch	2021-02-16 11:48:10	жирэмслэлтээс хамгаалах	2	2

Conversation

Download

сайн уу

2021-02-16 11:47:00

Сайн уу? Beku Ch

2021-02-16 11:47:00

бэлгэвч хаанаас авах вэ?

2021-02-16 11:47:14

Дэлгүүр, ТҮЦ, эмийн санд бий. Өсвөр үеийн төвүүд, сум, өрхийн эмнэлгүүд, бэлгийн замаар дамжих халдварын кабинетаас үнэгүй бэлгэвч, бас зөвлөгөө авах боломжтой шүү.

2021-02-16 11:47:14

Жирэмслэлтээс хамгаалах аргын талаар өөр ямар мэдээлэл авахыг хүсэж байна.

2021-02-16 11:47:14

72 цагийн эм хэр үр дүнтэй вэ?

2021-02-16 11:47:29

Нэр нь өөр өөр ч гэсэн агууламж үйлчилгээ нь адилхан.

2021-02-16 11:47:29

Чамд би өөрөөр яаж тусалж чадах вэ?

2021-02-16 11:47:29

яаралтай эмийг эмчийн жороор олгох уу?

2021-02-16 11:47:58

Заавал эмийн жортой байх албагүй

2021-02-16 11:47:58

Жирэмслэлтээс хамгаалах аргын талаар өөр ямар мэдээлэл авахыг хүсэж байна?

2021-02-16 11:47:58

байхгүй

2021-02-16 11:48:10

Би асуултанд чинь хангалттай хариулж чадсан уу?




2021-02-16 11:48:10

From logs section admin can access and download all conversation data of every interaction with Mandukhai.

Accounts

DASHBOARD
DATABASE
LOGS
ACCOUNTS
CLINICS

Mandukhai Admin Panel

Name ↑	Position	Email	Phone	Action
Name Bilguun	Position Psychatrist	Email bilguun@num.gov.mn	Phone 88126057	 
Name	Position	Email	Phone	

Admin can add, delete or update contact information of professionals from this panel.

Clinics

DASHBOARD
DATABASE
LOGS
ACCOUNTS
CLINICS

Mandukhai Admin Panel

Area	Name	Phone No	E-mail
Arkhangai	Ireeduin bosgo adolescent center	70332304	adyasuren2010@yahoo.com
Bayan-Ulgii	Ireeduin bosgo adolescent center	70424299	info@bayan-olgi.gov.mn
Bayankhongor	Ireeduin bosgo adolescent center	70443712	baagii.2242@yahoo.com
Bulgan	Adolescent cabinet	99348226	butamir60@gmail.com
Darkhan	Adolescent cabinet	70375759	sugamaa0203@yahoo.com
Dornogovi	Adolescent cabinet	nan	zdtg@dornogovi.gov.mn
Zavkhan-Uud	Adolescent cabinet	70527771	Z.Negtsenemneleg@gmail.com
Dundgovi	Adolescent cabinet	89921088	s.zoljargal83@gmail.com
Govi-Altai	Ireeduin bosgo adolescent center	99287399	ariunboldzandansuren@gmail.com
Govi-sumber	adolescent cabinet	99167536	govisumberemneleg@gmail.com
Khovd	Adolescent cabinet	95660272	zulaa_mc77@yahoo.com
Khentii	adolescent cabinet	354587	nan
Khuvsgul	Adolescent friendly center	95514188	oyunaa_6221@yahoo.com
Orkhon	Eruul Ireedui adolescent cabinet	99630351	laku_321@yahoo.com
Sukhbaatar	Ireeduin bosgo adolescent center	99251821	boloroo_5181@yahoo.com

Edit Arkhangai

Name
Ireeduin bosgo adolescent center

Address
Health department building, Arkhangai province

Latitude
47.474962

Longitude
101.448436

Timetable
09:00 AM to 17:00 PM

Phone
70332304

Email
adyasuren2010@yahoo.com

Website
http://ar.mohs.gov.mn/

SAVE CHANGES

Admin can edit location, contact info and other descriptions related to each clinic belong to each district or province.

5. Conclusion

Under the noble aim to help and advise adolescents on the most vulnerable issues during their crucial period of intellectual and psychological development, The Mandukhai project challenged us and the current state of Mongolian Language Processing research to the limit. The task of querying semantically correct answers from a pool of around 12 thousand possibilities is a challenging task for even well studied languages like English. However since the issue that Mandukhai project is addressing can have real life impact on kids and their future we pushed our research that more by building current state of the art model architectures like BERT, Word Embedding and WMD from scratch on Mongolian language. We then further improved the novel method to fine tune word moving distance metric for our specific use case. With aforementioned research efforts the top-1 accuracy of our best joint model reached ~70% which is 25% more than simple word matching. We further confirmed our result based on our human evaluators which resulted in a top-1 accuracy of 94%. These results implies that our model successfully learned to capture semantic meaning by numerical encodings. However note that these results do not guarantee to hold on real life conversations since such data can only be collected through Mandukhai bot itself during production.

By understanding health professionals' concerns we designed a conversation model based on a state machine to prioritize predictability. Our model will be able to not only drive the conversation in an intuitive way but also evaluates risk level and decides whether to notify professionals automatically. Lastly, we have developed an admin page to provide a highly accessible way to monitor or interact with databases to boost flexibility in possible future changes. Thus it is safe to assume Mandukhai is current state of the art chatbot system with lots of smart features to work in Mongolian language and made solid step forward on Mongolian Language Processing research.

Appendix A

Here we listed detailed description of every possible state supported by Mandukhai chatbot in following format

- State Name
 - User Intent #1
 - Action Name
 - User Intent #2
 - Action Name

And so on.

1. **Idle:**
 - a. Greet:
 - i. do: action_greet
 - b. Question:
 - i. do: action_oracle
 - c. Farewell:
 - i. do: action_goodbye
 - d. Default:
 - i. do: action_not_understood
 - e. Thanks:
 - i. do: action_thanks
 - f. Dont_tell_anyone:
 - i. do: action_cheer_up
 - g. Inspiration:
 - i. do: action_inspiration
 - h. What_can_you_do:
 - i. do: action_what_can_you_do
 - i. Sad:
 - i. do: action_sad
 - j. Ask_clinic_location:
 - i. do: action_ask_location
2. **Expecting_more_questions:**
 - a. Affirm:
 - i. do: action_affirm
 - b. Deny:
 - i. do: action_finish_conversation
 - c. Default:
 - i. jump: idle
3. **Expecting_satisfied:**
 - a. Default:
 - i. do: action_user_satisfied
4. **Expecting_want_hospital_location:**
 - a. Affirm:
 - i. do: action_ask_location
 - b. Deny:
 - i. do: action_finish_conversation
 - c. Default:
 - i. jump: idle
5. **Expecting_location:**
 - a. Default:
 - i. do: action_give_location
6. **Expecting_connection_from_professional:**
 - a. Affirm:
 - i. do: action_connect_professional
 - b. Deny:
 - i. do: action_affirm
 - c. Default:
 - i. jump: idle