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SUPPLEMENTARY MATERIAL: HMIS OPD 002 OUTPATIENT REGISTER

Figure 1: HMIS OPD 002 OUTPATIENT REGISTER.

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```

    & first name in full and Tel. contact
    "Age",
    "Sex",
    "Client Category",
    "RESIDENCE",
    "Next Of Kin Name And Contact",
    "Mid-Upper Arm Circumference (MUAC)",
    "BMI (SM/MM/N/OW/O)",
    "BMI For Age",
    "Weight For Height Z Score",
    "Weight (Kg)",
    "Weight For Age Z Score",
    "Height/Length (cm)",
    "Height/Length for Age Z Score (N/S)",
    "Blood Pressure (mmHg)",
    "Blood Sugar (mm/l)",
    "Need For Palliative Care",
    "Tobacco Use",
    "Tobacco Exposure",
    "Alcohol Use",
    "Fever",
    "Tests Done",
    "Malaria Tests Results",
    "Presumed Tuberculosis Case",
    "Patient Sent To The Laboratory",
    "Laboratory Tuberculosis Result",
    "Linked To Tuberculosis Clinic",
    "Where referred to",
    "Unit Tuberculosis Number",
    "Is this a new case of illness? (Tick Classification)",
    "Diagnosis",
    "Prescription",
    "Disability (Write code of disability)",
    "ReferralInNumber",
    "ReferraloutNumber"
}

```

Supplementary Material 2: UGANDA ANTENATAL CARE REGISTER TEMPLATE SCHEMA

"DESCRIPTION": "UGANDA ANTENATAL CARE REGISTER TEMPLATE SCHEMA GENERATED BY THE CEDAR TEMPLATE EDITOR 2.6.19"

JSON Schema

```

{
  "The date of the patient visit",

```

"Serial Number",
"PatientID",
"Ugandan National Identification Number",
"Name of Client",
"Age",
"Client Category",
"Address",
"ANC Visit",
"Gravida",
"Gestational age of the women in weeks (GA)",
"Parity",
"ANC 1 Timing",
"Expected Date of Delivery",
"Weight in kgs",
"Fundal Height in (cm)",
"Mid-Upper Arm Circumference (MUAC) of the pregnant mother using centimeter (cm)",
"INR Number",
"bloodPressure",
"eMTCT Status W Initial Result",
"eMTCT Status W STK Given",
"eMTCT Status W Age",
"eMTCT Status P Facility Result",
"eMTCT Status P Linked to ART",
"eMTCT Status P TFV Yes/No",
"eMTCT Status P Linked to ART Where",
"eMTCT Status P Linked to ART Pre-Art Number",
"CD4 count",
"Viral Load",
"has_clinical_stage",
"eMTCT Risk Assessment",
"ART Art Code",
"ART Art Number",
"Infant Arv Prophylaxis",
"Infant and Young Child Feeding Counselling and Maternal Nutrition Counselling",
"TB Status",
"WOA U/S Scan Done",
"GBV Risk Phy",
"GBV Risk Sx",
"GBV Risk Psy",
"Blood Screening",
"Hb",
"Blood Group",
"Rhesus",
"Sickle cell",
"Urine Protein",
"Urine glucose",

```

"Syphilis & Hep B Test Results W: Syphilis",
"Syphilis & Hep B Test Results W: Hep B",
"Syphilis & Hep B Test Results P: Syphilis",
"Syphilis & Hep B Test Results P: Hep B",
"Family Planning Counselling",
"Tetanus Diphtheria (Td)",
"IPT/CTX",
"LLIN",
"Mabendazole",
"Other Treatments",
"Referral in/out",
"Complications/Risk Factors",
"Number of Pills Iron sulphate",
"Number of Pills Folic Acid",
"Number of Pills Iron sulphate/Folic Acid Combined",
"Number of Pills Iron sulphate/Folic Acid Combined Misoprostol"
}

```

Supplementary Material 3: COVID 19 GENERIC REGISTER TEMPLATE SCHEMA

"DESCRIPTION": "COVID 19 GENERIC REGISTER TEMPLATE SCHEMA GENERATED BY THE CEDAR TEMPLATE EDITOR 2.6.19"

JSON Schema

```

{
  "Reporting country",
  "Health Facility name",
  "Why tested for COVID-19",
  "Serial Number",
  "Age",
  "Name",
  "Sex",
  "Date of Patient Visit",
  "Health status at time of reporting",
  "COVID-19 Vaccination",
  "Tested on COVID-19",
  "Date of most recent COVID-19 test",
  "City of COVID-19 test center",
  "COVID 19 Result",
  "Mortality Status",
  "Cause of death includes COVID-19",
  "Is the COVID-19 case a health care worker",
  "Country"
}

```

APPENDIX B

FIELDWORK REPORT: ASSESSING VODAN-AFRICA'S DATA PRODUCTION PROGRESS AND CHALLENGES IN UGANDA

The main goal of the field work was to assess and address the progress and challenges faced by the VODAN-Africa Uganda health facilities during the data production phase of the project. The main aim was to strengthen the ongoing collaboration with the different stakeholders involved in the project, especially the deployment and data production phase of the project. On 8 May 2023, I visited the Case clinic hospital in the city of Kampala, Uganda. We had a focus group meeting with the data management personnel team spearheaded by Norbert, a one-on-one with the health facility director and addressed the technical issues faced during the data production phase of the project.

On 18 May 2023, I traveled from Kampala district, Uganda, to Ark Specialist Hospital in Wakiso district, which was about 45 minutes drive. I had the opportunity to have a one-on-one interview with the Health Facility Manager Sheeba Nasuna who expressed great interest in the current and future coordination with VODAN-Africa. We discussed the different issues the health facility was experiencing with the VODAN-Africa system during the data production phase. She mentioned that she oversaw operations, administration, and supervision. She also pointed out the need for extensive training for data management personnel. This was carried out for a duration of three days. I also had a few more interviews with the health facility receptionist Bridget Namusisi, Opio Jared, the records personnel, and two nurses.

From Ark Specialist Hospital, for about seven hours, we drove to Lira referral Hospital on 22nd, May 2023. I managed to meet the Lira Senior CDO, Francis Ifeero, who referred me to Hejang Kuman Pollyn, Dennis Olo and Sharon Akello, the data management personnel of Lira Referral Hospital. I successfully addressed the issues pushed forward during my three days stay in Lira district, Uganda.

On 26 May 2023, I went to Hoima Referral Hospital in Hoima district, which was 4 hours and a half drive from Lira district. I had a very insightful interview with Idris Muyingo. Data management personnel Hoima referral hospital. The brief encounter I had with the health facility director's secretary, Maureen Atugonza, persuaded her to schedule an interview slot with the hospital administrator who then introduced me to Livingstone Bantu, IT management personnel, Dr. Said Abdi, HRH medical doctor and Ramula Musanya, HRH hospital administrator. During my three day stay in Hoima district, I experienced some of the limitations encountered by the data management personnel during the data production phase, for example, the limited internet connectivity, electricity shortages, and lack of relevant skill set.

We arrived at the Kampala International University Teaching hospital on May 30, 2023. I conducted interviews and discussions with the hospital director, two data management personnel, a nurse during the 5 days stay in Bushenyi district. The trip from Bushenyi to Kampala was a 6 hour drive. This strengthened collaboration and trust between stakeholders in the health facility and the VODAN-Africa initiative. Below are some of the pictures from the different locations of the fieldwork.

You can scan this QR code to access the field work presentation.



Appendix B



Figure 2: KIU Teaching Hospital records storage room



Figure 3: Hoima Regional Referral Hospital



Figure 4: Case Clinic Hospital

APPENDIX C

Coding Functions

Function: Create Decision Tree model

```
def create_keras_model(input_shape):
    num_classes = len(np.unique(y_train))
    model = tf.keras.Sequential([
        tf.keras.layers.Dense(64, activation='relu', input_shape=(input_shape,)),
        tf.keras.layers.Dropout(0.5),
        tf.keras.layers.Dense(32, activation='relu'),
        tf.keras.layers.Dense(num_classes, activation='softmax')
    ])
    model.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=0.0001),
                  loss='sparse_categorical_crossentropy',
                  metrics=['accuracy'])
    return model
```

Function: Create Decision Tree and SVM model

```
# Define Decision Tree and SVM model
def create_decision_tree_model():
    return DecisionTreeClassifier()

def create_svm_model():
    return SVC(probability=True)

# Function to train Decision Tree or SVM on a client's data
def train_client_sklearn_model(model, client_data, features_list):
    features = client_data[features_list].values.astype(np.float32)
    labels = client_data['fetalState'].values.astype(np.int32)

    # Handle missing values
    imputer = SimpleImputer(strategy='mean')
    features_imputed = imputer.fit_transform(features)

    model.fit(features_imputed, labels)
    return model
```

Function: Split training data into per-client datasets

```
pythonCopyclient_data = {
    client: pd.concat([
        X_train_df.sample(frac=1/len(clients),
            random_state=42).reset_index(drop=True),
        y_train_df.sample(frac=1/len(clients),
            random_state=42).reset_index(drop=True)
    ], axis=1)
    for client in clients
}
```

Function: Federated training loop for Keras model

```
for round_num in range(1, num_rounds + 1):
    print(f"Round {round_num}")

    client_weights = []
    for client in clients:
        client_model = create_keras_model(input_shape)
        client_model.set_weights(global_keras_model.get_weights())
        weights, history = train_client_keras_model(client_model,
            client_data[client], features)
        client_weights.append(weights)

    aggregated_keras_weights = aggregate_keras_weights(client_weights)
    global_keras_model.set_weights(aggregated_keras_weights)
```

Function: Train Decision Tree and SVM for each client

```
client_decision_tree_models = []
client_svm_models = []

for client in clients:
    client_dt_model = create_decision_tree_model()
    client_svm_model = create_svm_model()

    client_dt_model = train_client_sklearn_model
```

```
(client_dt_model, client_data[client], features)
client_svm_model = train_client_sklearn_model
(client_svm_model, client_data[client], features)

client_decision_tree_models.append(client_dt_model)
client_svm_models.append(client_svm_model)
```

APPENDIX D

ETHICAL CLEARANCE AND APPROVAL AND DATA AGREEMENTS

Ethical approvals were provided by all organisations required. These are available on request.

- Ministry of Health Approval Letter
- Ethical Clearance Renewal of Approval 2019
- Ethical Clearance Renewal of Approval 2021
- Ethical Clearance Renewal of Approval 2023
- Ethical Clearance Renewal of Approval 2024
- Signed Hoima Regional Referral Hospital Uganda Data Use Agreement Microsoft VODANA 28.4.24
- Signed KIU Teaching Hospital Data Use Agreement microsoft VODANA 28.4.24
- Uganda LU Data Processing Agreement

You can scan this QR code to access the documents mentioned above.



APPENDIX E

Heat map generation using Python with FAIR Antenatal care health data

The analysis focused on examining the relationship between the Mebendazole proxy and HIV status to assess potential co-occurrence. More granular FAIR antenatal care register data was retrieved from the allegro graph triple store using the Python API. The Python API allowed us to query the data using SPARQL. The inspect triples functionality in AllegroGraph helped to determine the URIs of the patient properties we were interested in. Using these, we were able to use SPARQL to return data on the patient prescription, Mebendazole in our case, patient HIV status, and patient address, without the patient's name or identification number. Being able to retrieve this information without patient names or patient IDs was critical, as it shows that it is possible to obtain data for analysis without compromising patient data privacy. With more granular FAIR data, the workflow for generating heat maps is not so different from the aggregated data. However, since it's on the granular level, the patient addresses were used instead of district coordinates. The relevant rows and columns were used to plot the addresses, these were translated into relevant DD coordinates using the geopy library for folium to create maps. Out of 500 patient entries, only 40 entries had valid addresses and could be plotted into the map.

1. Isolate various areas of Uganda and medical info (Mebendazole)
2. Use Geopy to validate city addresses and plot them using Folium
3. View the HTML output

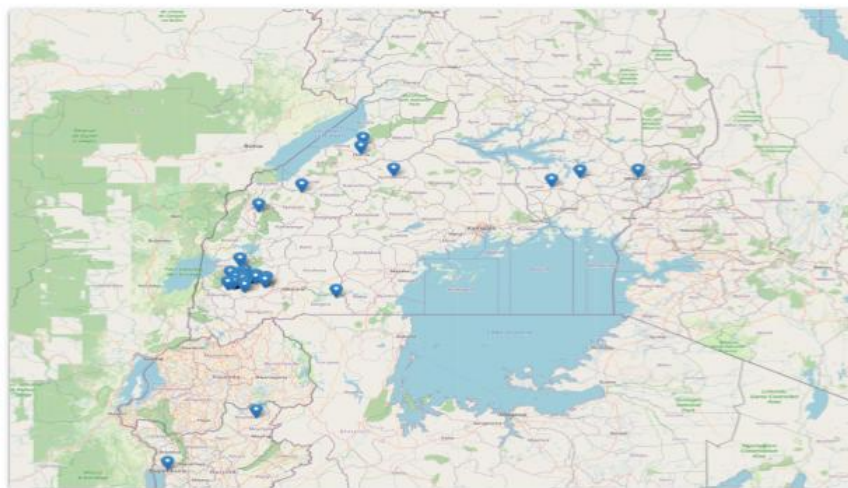


Figure 5: HTML output showing the use of Mebendazole - Uganda

Limitations of FAIR Antenatal Care Health data

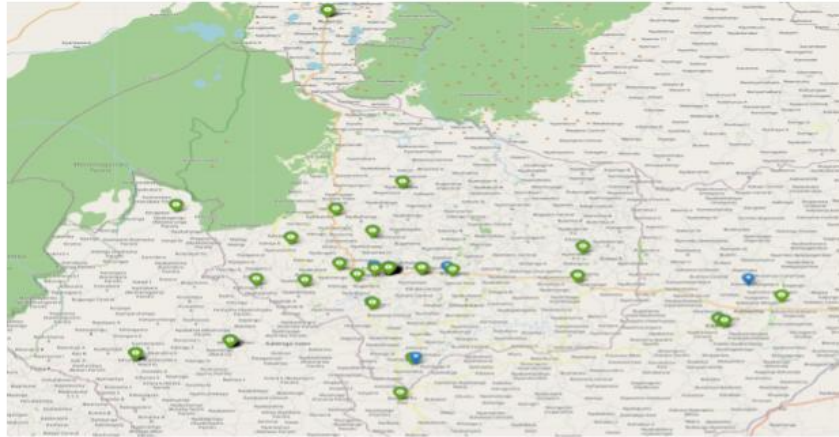


Figure 6: Bushenyi District addresses - Use of Mebendazole Yes (Green) or No (Blue)

The FAIR antenatal care dataset was more relevant to this analysis as data contained much more detailed information on HIV status and treatment than the DHIS2-generated aggregate dataset. However, data on Female genital schistosomiasis, HPV vaccination status, and treatment or diagnosis for schistosomiasis are not collected by the care providers.

Given the limitations of our data, we utilized antiparasitic Mebendazole treatment as a proxy for schistosomiasis infection, due to the unavailability of Praziquantel which is the preferred treatment for schistosomiasis. It is important to note that this approach was more a proof-of-concept than a reliably accurate method to determine schistosomiasis infection rates. The analysis focused on examining the relationship between the Mebendazole proxy and HIV status to assess potential co-occurrence.

FAIR data made it easy to extract the relevant information, so it is possible to run co-occurrence analysis with this type of FAIRified data. However, we ran into limitations of the second data set size; we had about 1000 total data points, 500 of which had any entry for both Mebendazole and HIV status, but there were no patients who were both HIV positive and being treated with Mebendazole. Unfortunately, this made it impossible to run any sensible co-occurrence test. Despite limitations, our efforts do demonstrate the potential of FAIRifying these data, and the viability of this type of co-occurrence analysis in the future, provided enough data. This illustrates the value of the FAIR principles for large data-driven projects. If the data was first, Findable, Accessible, Interoperable, and Reusable by design it would have mitigated the problems of our initial uncertainties and enabled us to plan effectively.

Appendix A

Abbreviations

- **eCRF** – electronic Case Report Form
- **AI** – Artificial Intelligence
- **API** – Application Programming Interface
- **ML** – Machine Learning
- **FAIR** – Findable, Accessible, Interoperable, and Reusable
- **SDG** – Sustainable Development Goal
- **ICT** – Information and Communication Technology
- **NITA** – National Information Technology Authority
- **MoH** – Ministry of Health
- **UCC** – Uganda Communications Commission
- **CHWs** – Community Health Workers
- **HRH** – Human Resources for Health
- **HIPAA** – Health Insurance Portability and Accountability Act
- **GDPR** – General Data Protection Regulation
- **UIRI** – Uganda Industrial Research Institute
- **EAC** – East African Community
- **BD2K** – US-based Big Data to Knowledge
- **EAOSCH** – East Africa Open Science Cloud for Health
- **EAHRC** – East African Health Research Commission

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- **VODAN** – Virus Outbreak Data Network
 - **IFDS** – Internet-based FAIR Data and Services
 - **HIS** – Hospital Information System
 - **EMR** – Electronic Medical Record
 - **EHR** – Electronic Health Record
 - **PHR** – Patient Health Record
 - **SARS-CoV-2** – Severe Acute Respiratory Syndrome Coronavirus 2
 - **PNFPs** – Private-Not-For-Profit Health Providers
 - **PHPs** – Private Health Practitioners
 - **TCMPs** – Traditional and Complementary Medicine Practitioners
 - **VHTs** – Village Health Teams
 - **RRHs** – Regional Referral Hospitals
 - **HMIS** – Health Management Information System
 - **DHIS** – District Health Information Software
 - **KIU-TH** – Kampala International University Teaching Hospital
 - **HSDP** – Health Sector Development Plan
 - **NDP** – National Development Plan
 - **NIN** – National Identification Number
 - **OpenMRS** – Open Medical Records Systems
 - **DHA** – Digital Health Atlas
 - **MAPS** – mHealth Assessment and Planning for Scale
 - **HRHIS3** – Human Resource for Health Information Software 3
 - **UDHD** – Uganda Digital Health Dashboard
 - **ViB** – VODAN in a Box
 - **SWOT** – Strengths, Weaknesses, Opportunities, and Threats
 - **WHO** – World Health Organization
 - **IFDS** – Internet of FAIR Data and Services

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- **CEDAR** – Center for Expanded Data Annotation and Retrieval
 - **REST** – Representational State Transfer
 - **SNOMED CT** – Systematized Nomenclature of Medicine – Clinical Terms
 - **LOINC** – Logical Observation Identifiers Names and Codes
 - **ICD** – International Classification of Diseases
 - **HIS** – Health Information System
 - **FAIRDOM-SEEK** – Findable, Accessible, Interoperable, Reusable DOMain