

A Software Framework for Adaptive and Interoperable Internet-Delivered Psychological Treatments

Suresh Kumar Mukhiya



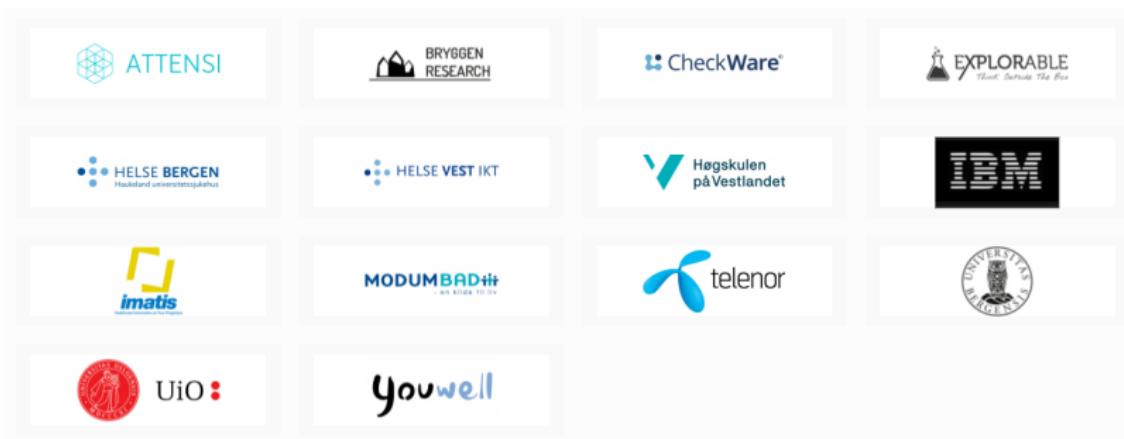
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Western Norway University of Applied Sciences**

Overview

- ① Background - Problem statement, Motivations
- ② Research Questions
- ③ Research Methods
- ④ Results
- ⑤ Conclusions and future work

Background - INTROMAT Project

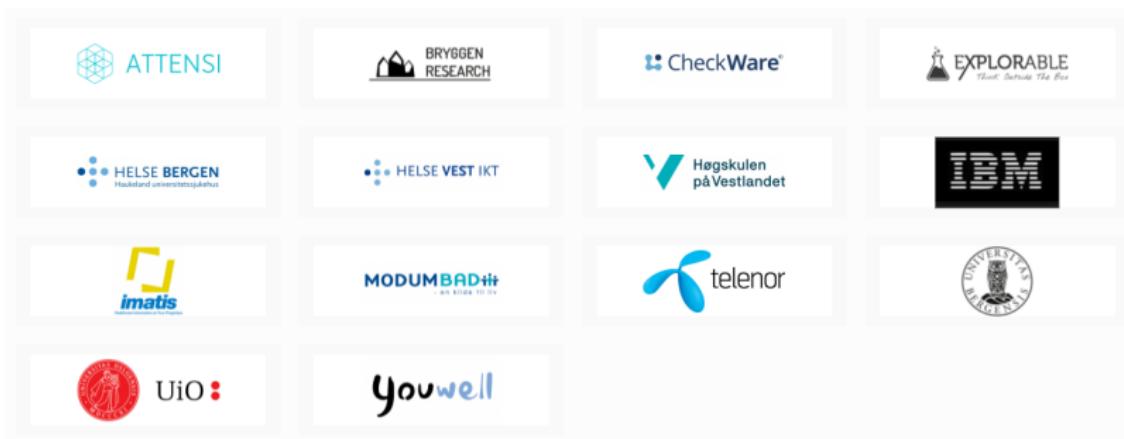
- ⑤ This study is a part of a large interdisciplinary project entitled **INTROMAT** (INTROducing Mental health through Adaptive Technology).
- ⑤ Brings together ICT researchers, ICT industries, health researchers, patients, and clinicians to reach its vision.



- ⑤ Project vision: improve public mental health treatments through introduction of innovative technologies.

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Background - What is Psychological treatments?

- ⑤ Psychological treatments refers to activities, techniques or strategies that target behavioural, cognitive, social, emotional or environmental factors to improve mental or physical health or related functioning [Holmes, 2014].



Clinical Approach

Facial Expression
Vocal Cues

- Frequency of Smile
- Dampened Facial Expression
- Avoiding Eye Contact
- Using Short Sentence with low intonation
- Using mood terms



PHQ9

BDI

MADRAS-S



Psychometric questionnaire - PHQ9 - for depression

Over the <u>last 2 weeks</u> , how often have you been bothered by any of the following problems? (Use a check mark to indicate your answer)	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself – or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or hurting yourself in some way	0	1	2	3

FOR OFFICE CODING _____ + _____ + _____ + _____

= Total Score: _____

Background - IDPT system

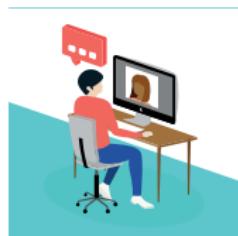
- ◎ The use of **Internet** to deliver **psychological treatments**, hereby is referred to as Internet-Delivered Psychological Treatments (IDPT).



- ◎ Concept is similar to a LMS system (Course, Chapters, Lessons, Exercises)
- ◎ Two types of contents: Psycho-educational materials and treatment exercises

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Background - adaptive IDPT system

- ④ The adaptive IDPT system **personalizes treatment** content by finding exciting and relevant information for a specific user based on the user's **needs and preferences (profile)**.
- ④ *The underlying hypothesis is that if the user finds the presented information exciting and relevant, the user will adhere to the system, thus increasing user adherence and treatment outcomes.*
- ④ Adaptive system vs self-adaptive systems.

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Motivation - Why IDPT system?

- ⑤ IDPT is claimed to be as effective as the face-to-face treatments, E.g. [Ebrahimi, 2019; Berger, 2014]
- ⑤ IDPT systems assure higher treatment availability.
- ⑤ IDPT systems help reducing stigma issues related to mental health [Sweeney, 2015].
- ⑤ Technical feasibility of personalizing intervention based on patient need (Feasible due to prevalence of IoT/AI/higher computations).

Science behind adaptiveness and IDPT

Several studies suggest adaptive treatments can increase user adherence, for example, [Christensen, 2009; Dunn, 2012]. However, very few studies formally examines the science behind it. Small groups RCTs, with the risk of statistically insignificant results.

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Motivation - Problem statement

- ① Lack of adaptiveness in current IDPT systems
- ② Lack of interoperability and reusability of IDPT contents

Research Questions

RQ1: *What are the state-of-the-art works done in creating adaptive IDPT systems? What are their capabilities and limitations?*

- Choices of Information Architecture (IA), adaptive elements, adaptive strategies, adaptive dimensions. Paper A, D

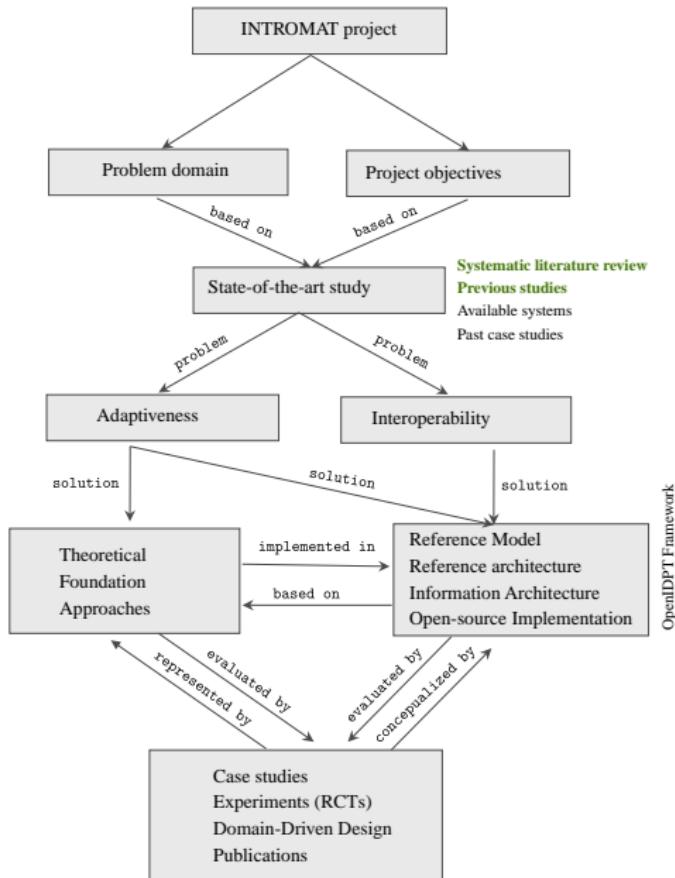
RQ2: *How can we utilize software engineering techniques to improve the architecture of current adaptive IDPT systems?*

- Usage of MDSE technique to build a RA of an adaptive IDPT systems, usage of AI-based predictive algorithms to perform adaption on IDPT systems Paper B - G

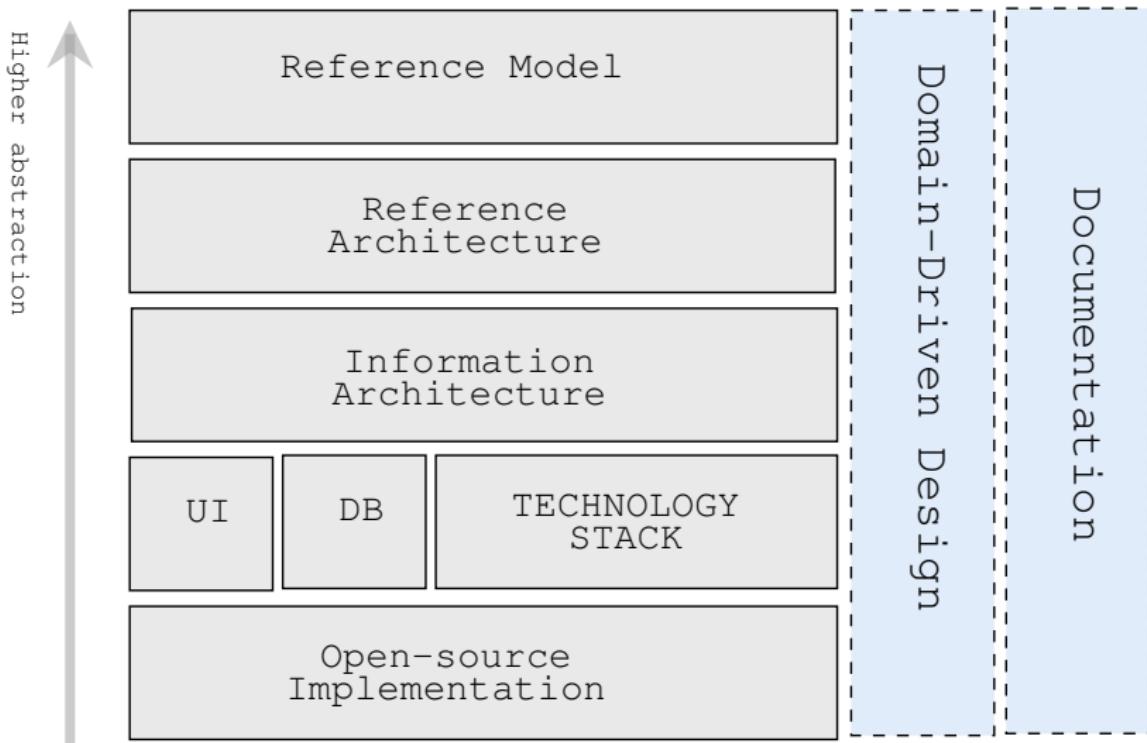
RQ3: *How can we evaluate architecture of IDPT systems?*

- Design Science Research (DSR) principles for evaluating the developed architecture, and adaptive IDPT systems in a clinical setup. Paper B-G

Research Method



Results - The OpenIDPT Framework

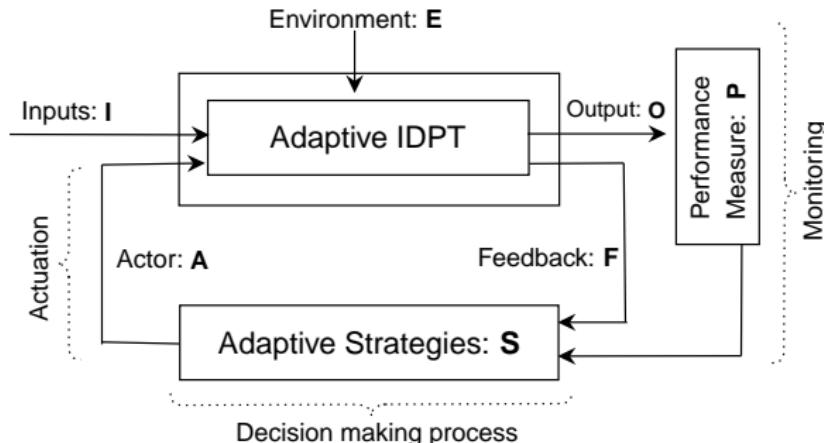


Results - Why is this OpenIDPT Framework interesting?

- To provide shared understanding of IDPT systems. Hence, to increase interoperability among healthcare systems.
- The framework provides systematic approach for developing IDPT systems from abstract models such as reference model, to highly detailed open-source implementation.
- Helps with Rapid prototyping/ testing of new ideas related with IDPT



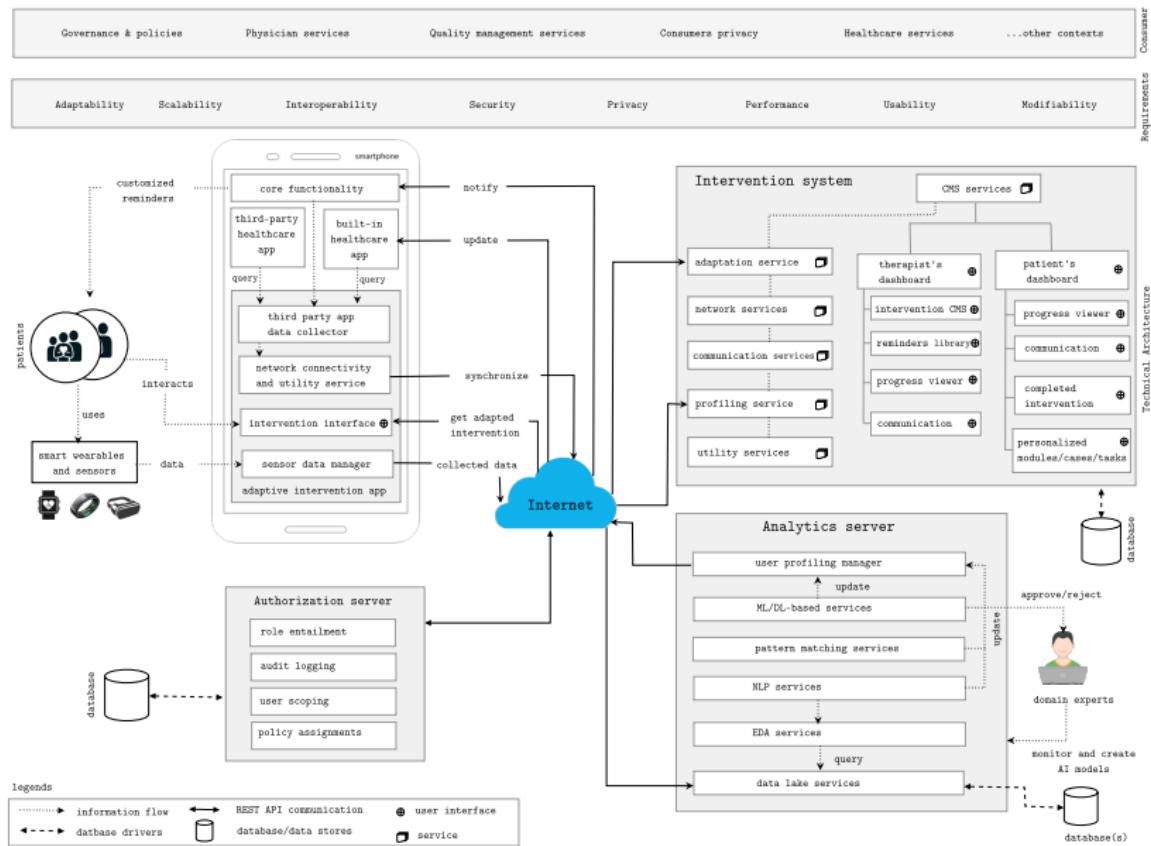
Reference model



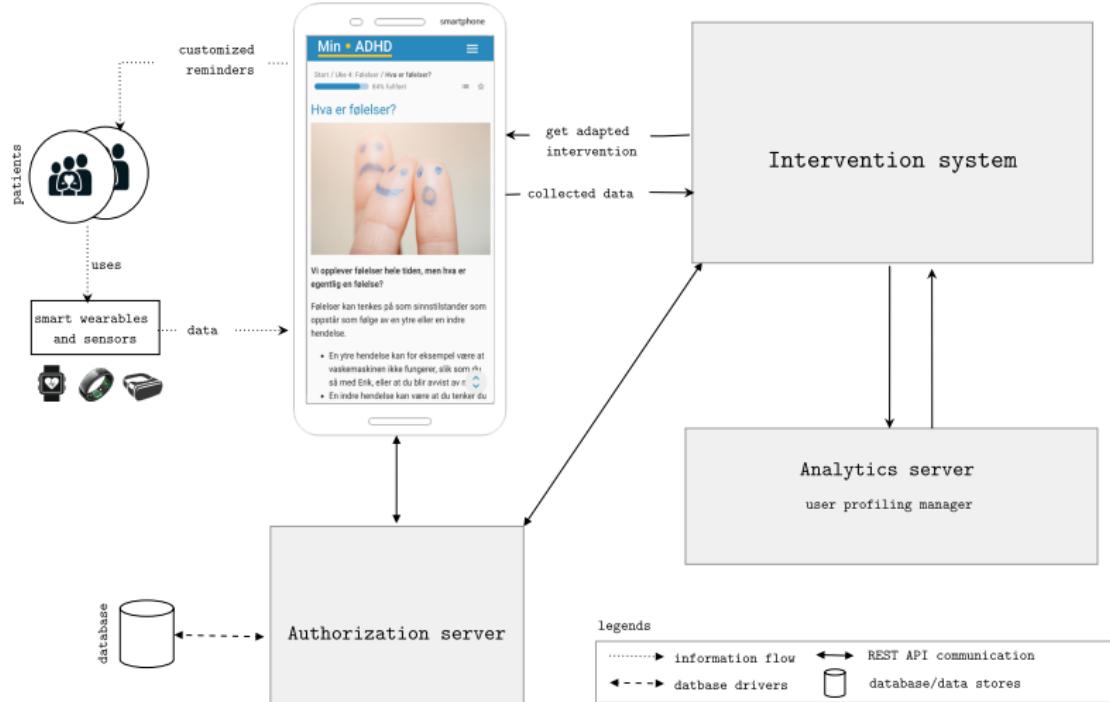
Reference Model - Paper D

- Inputs: Adaptive elements - What to adapt?
- Performance measures: On what basis to adapt?
- **Adaptive strategies:** How to adapt?
- Actors: Who triggers the adaptation?

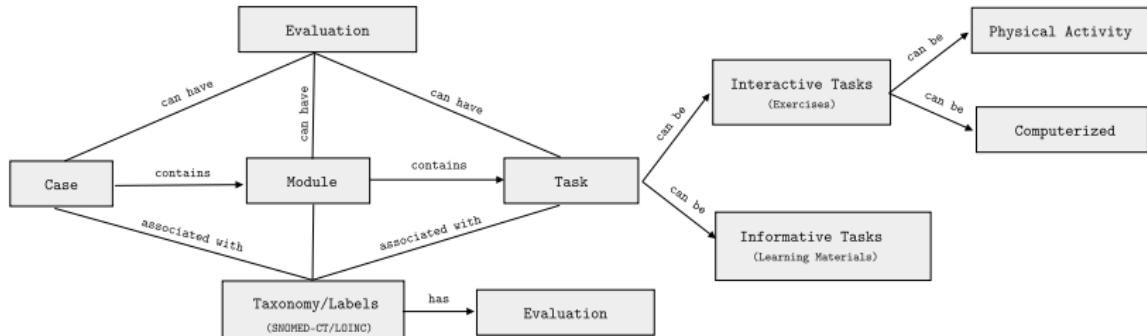
Reference Architecture



Reference Architecture - simplified



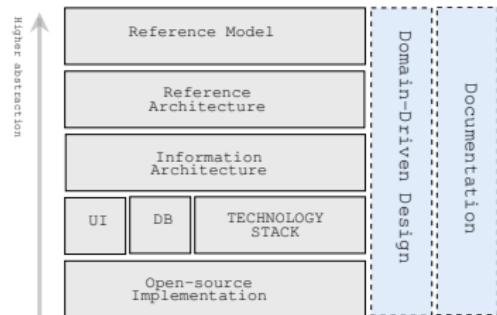
Information Architecture



- ⑤ Describes high-level software system concepts observed by a user.
- ⑤ For Example:
 - How should we structure, organize, and divide content?
 - How do we present information to the users?
 - Where should we place the navigation system?
 - Do we need to have search component in the system?
- ⑤ The main goal of IA: Make content discoverable and comprehensible to the user.

UI, DB, Technology stack

- Well designed user interface increase user interaction.
- DB Layer includes selection of appropriate database(s).
- Technology stack involves selection of appropriate system development stacks such as programming language.



For IDPT context, we used HL7 FHIR along with GraphQL for obtaining interoperability.



Demo Links

- ⑤ **Demo site:** idpt.herokuapp.com/
- ⑤ **Documentation:** <https://idpt.gitbook.io/web/>

Why did we start our own implementation?

- ⑤ Available artefacts on IDPT system were mostly proprietary.
- ⑤ Required data were not readily available
- ⑤ Provides benefits related to OSS
 - Enhances chances of collaboration
 - Potential to bring innovation
 - Cost-effective
 - Code is open-sourced, making it transparent what data is stored and used

Open-source implementation - Home page

Application

- [Home](#)
- [IAM](#)
- [Patients](#)
- [Responses](#)
- [Cases](#)
- [Modules](#)
- [Tasks](#)
- [Records](#)
- [Assignments](#)
- [Taxonomies](#)
- [Settings](#)
- [Audit Logs](#)

English itsmeskm99

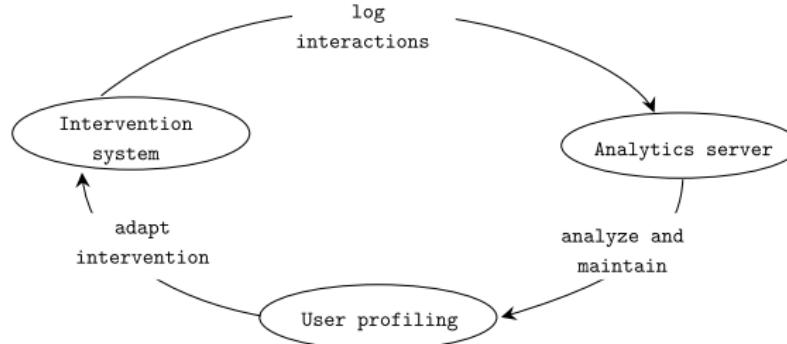
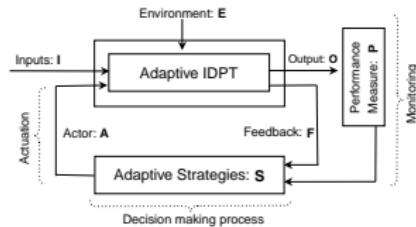
The dashboard displays nine data visualizations:

- Top Left:** Donut chart with Red (pink), Blue (light blue), and Yellow (yellow) segments.
- Top Middle:** Line chart with Orange (orange) and Blue (light blue) data series.
- Top Right:** Bar chart with Red (pink) bars.
- Middle Left:** Line chart with Orange (orange) and Blue (light blue) data series.
- Middle Middle:** Bar chart with Red (pink), Green (teal), Yellow (yellow), Grey (light grey), and Blue (light blue) bars.
- Middle Right:** Radial chart with five segments labeled 20, 15, Red, Green, and Blue.
- Bottom Left:** Horizontal bar chart with Red (pink) bars.
- Bottom Middle:** Line chart with Green (teal) data series.
- Bottom Right:** 3D wireframe plot with Grey (light grey) and Red (pink) axes.

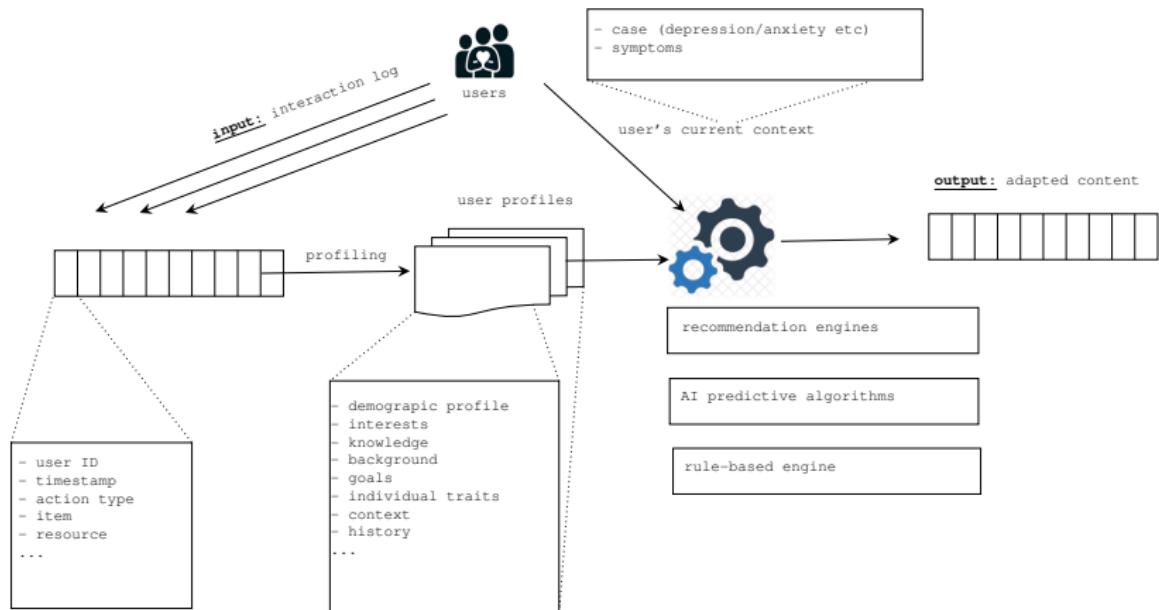
This page uses fake data for demonstration purposes only. You can edit it at [frontend/view/home/HomePage.js](#).

Adaptive strategies

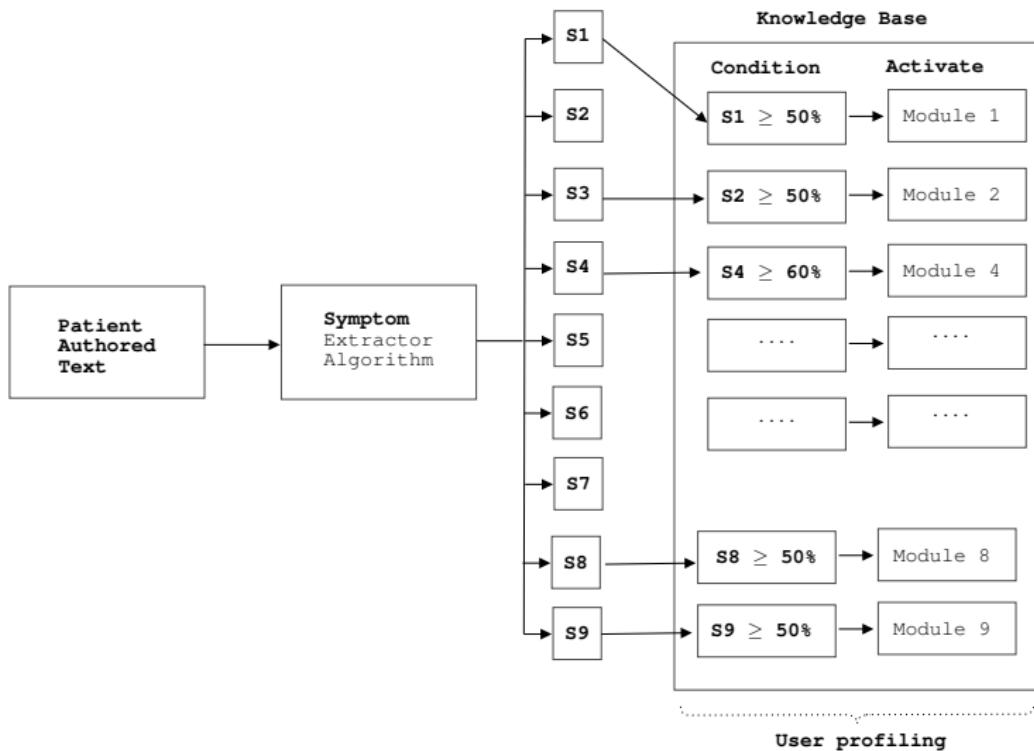
- Adaptive strategies answers the question "*how does an IDPT system adapt intervention?*"
- Examples: Rule-based adaptation, adaptation through predictive algorithms, goal-driven adaptation
- **User profiling** forms the basis of adaptation.



User profiling and adaptation



Profiling and Adaptation through Predictive Algorithms



S1- S9: symptoms corresponding to PHQ-9. Paper E

Interoperability

*Interoperability is achieved when two or more systems or the systems' components **can interchange data/information** and **utilise the data/information** being interchanged. (IEEE 1990).*

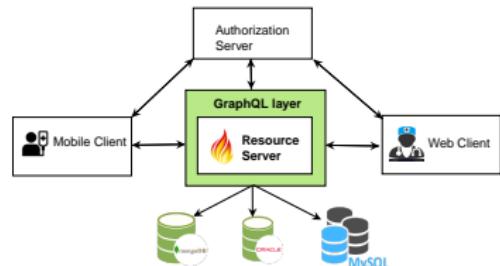
Our approach to achieve interoperability?

- ⑤ Follow Open Healthcare IT Standards - HL7 FHIR, along with LOINC Codes, SNOMED-CT.
- ⑤ By embracing Open-Source Software (OSS) in the healthcare systems.

Interoperability - Resource server

- Resource server is HL7 FHIR (Version 4, latest) compliant web server powered by GraphQL. [Paper C](#) [Paper G](#).

```
{  
  "resourceType" : "Patient",  
  "identifier" : [ { Identifier } ], // An identifier for this patient  
  "active" : <boolean>, // Whether this patient's record is in active use  
  "name" : [ { HumanName } ], // A name associated with the patient  
  "telecom" : [ { ContactPoint } ], // A contact detail for the individual  
  "gender" : "<code>", // male | female | other | unknown  
  "birthDate" : "<date>",  
  "deceasedBoolean" : <boolean>,  
  "deceasedDateTime" : "<dateTime>",  
  "address" : [ { Address } ],  
  "maritalStatus" : { CodeableConcept },  
  "multipleBirthBoolean" : <boolean>,  
  "multipleBirthInteger" : <integer>,  
  "photo" : [ { Attachment } ], // Image of the patient  
  "contact" : [ {  
      "relationship" : [ { CodeableConcept } ], // The kind of relationship  
      "name" : { HumanName }, // A name associated with the contact person  
      "telecom" : [ { ContactPoint } ], // A contact detail for the person  
      "address" : { Address }, // Address for the contact person  
      "gender" : "<code>", // male | female | other | unknown  
      "organization" : { Reference(Organization) },  
      "period" : { Period }  
    } ],  
  "communication" : [ {  
      "language" : { CodeableConcept },  
      "preferred" : <boolean>  
    } ],  
  "generalPractitioner" : [ { Reference(Organization|Practitioner|PractitionerRole) } ],  
  "managingOrganization" : { Reference(Organization) },  
}  
}
```



- Mapped HL7 FHIR to GraphQL schema.
- REST vs GraphQL approach
- Resource server in mUzima Project

Publications - 1/2

- ⑤ Paper A Journal S. K. Mukhiya, J. D. Wake, Y. Inal, K. I Pun, and Y. Lamo. *Adaptive Elements in Internet-Delivered Psychological Treatment Systems: Systematic Review*. J Med Internet Res. 2020 Nov 27;22(11):e21066. doi: [10.2196/21066](https://doi.org/10.2196/21066).
- ⑥ Paper B Workshop S. K. Mukhiya, F. Rabbi, K. I Pun and Y. Lamo, *An Architectural Design for Self-Reporting E-Health Systems*, 2019 IEEE/ACM 1st International Workshop on Software Engineering for Healthcare (SEH), Montreal, QC, Canada, 2019, pp. 1-8, doi: [10.1109/SEH.2019.00008](https://doi.org/10.1109/SEH.2019.00008).
- ⑦ Paper C Conference S. K. Mukhiya, F. Rabbi, K. I Pun, A. Rutle, and Y. Lamo. *A GraphQL approach to healthcare information exchange with HL7 FHIR*. The 9th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH-2019), Coimbra, Portugal, November 4-7, 2019, volume 160, pages 338–345. Elsevier, 2019, doi: <https://doi.org/10.1016/j.procs.2019.11.082>
- ⑧ Paper D Journal S. K. Mukhiya, J. D. Wake, Y. Inal and Y. Lamo, *Adaptive Systems for Internet-Delivered Psychological Treatments*, in IEEE Access, vol. 8, pp. 112220-112236, 2020, doi: [10.1109/ACCESS.2020.3002793](https://doi.org/10.1109/ACCESS.2020.3002793).

Publications - 2/2

- ⑤ Paper E Conference S. K. Mukhiya, U. Ahmed, F. Rabbi, K. I Pun and Y. Lamo, *Adaptation of IDPT System Based on Patient-Authored Text Data using NLP*, 2020 IEEE 33rd International Symposium on Computer-Based Medical Systems (CBMS), Rochester, MN, USA, 2020, doi: [10.1109/CBMS49503.2020.00050](https://doi.org/10.1109/CBMS49503.2020.00050).
- ⑥ Paper F Journal S. K. Mukhiya, Y. Lamo , F. Rabbi , *A Reference Architecture for data-driven adaptive Internet-Delivered Psychological Treatment Systems*, submitted on 8th June, 2021 to Journal of Medical Internet Research, 2021.
- ⑦ Paper G Journal S. K. Mukhiya, Y. Lamo, *An HL7 FHIR and GraphQL approach for interoperability between heterogeneous Electronic Health Record systems*, Health Informatics Journal. doi: <https://doi.org/10.1177/14604582211043920>

Contributions to Software Engineering

- ④ *Reference Architecture* for adaptive and data-driven IDPT system.
- ④ Depression2Vec word embedding to extract Depression Symptoms
- ④ Application of GraphQL/HL7 FHIR for scalability and interoperability in Healthcare applications
- ④ Tools for rapid prototyping

Contributions to Health Informatics

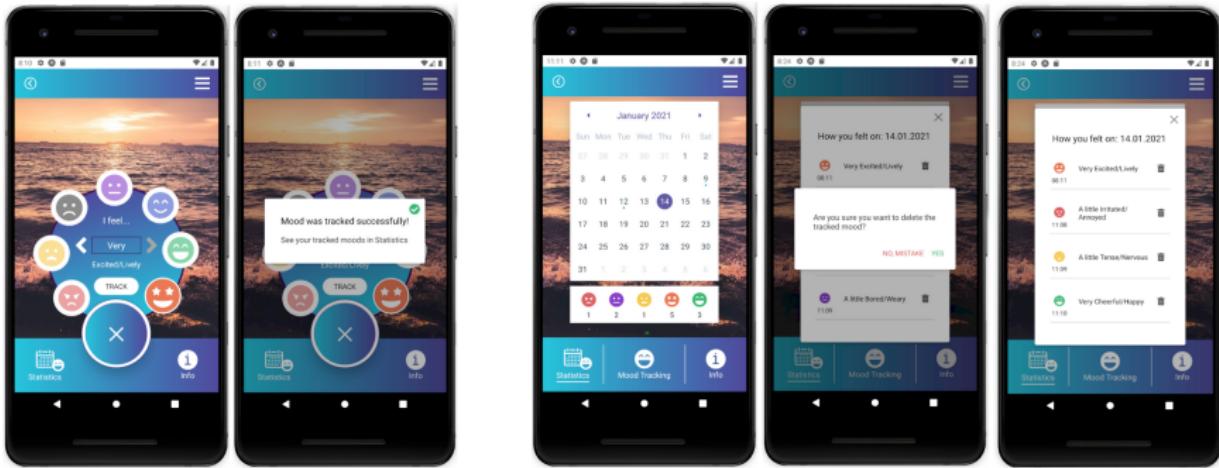
- *The OpenIDPT Framework* (Reference architecture and Reference Implementations)
- *A comprehensive guidelines on developing an adaptive IDPT system based on the Person-Based Approach (PBA)*
- *Open-source Resource server*

Summary of Contributions - Artefacts

Table: List of artefacts produced as the result of this research

Artefacts	Available at
Open-source IDPT	https://github.com/sureshHARDIYA/idpt
Depression2Vec	https://github.com/sureshHARDIYA/phd-resources/
Resource server	https://github.com/sureshHARDIYA/intromat-fhir/
Self-assessment app	https://github.com/sureshHARDIYA/anxiety
Authorization server	https://github.com/sureshHARDIYA/authserver
Web client	https://github.com/sureshHARDIYA/fhir-client
User Profiler	https://github.com/sureshHARDIYA/tracker
Documentation	https://github.com/sureshHARDIYA/phd-resources

Who is using OpenIDPT Framework? - Master Thesis -1



- Ⓐ Astrid Hamre-Os, a master student at the University of Bergen.
- Ⓐ Thesis topic: *A mood tracking interface for a mobile application - to help assess well being in students.*
- Ⓐ Extended Self-assessment app for mood tracking, and OSAIS for backend.

Who is using OpenIDPT Framework? - Master Thesis -2

Case: "My ADHD program"

└ taxonomies:

 └ Diagnosis: ADHD

modules:

 └ Module 1:

 └ taxonomies:

 └ ADHD symptom: Inattention

 └ Age group: Adult

 └ tasks:

 └ Exercise 1.1:

 └ taxonomies:

 └ Age group: 18-25

 └ ADHD symptom: Inattention

 └ Exercise 1.2:

 └ taxonomies:

 └ Age group: 40-60

 └ ADHD symptom: Inattention

The screenshot shows the 'Taxonomies' section of the OpenIDPT Framework. On the left, a sidebar menu includes 'Home', 'IAM', 'Patients', 'Responses', 'Cases', 'Modules', 'Tasks', 'Records', 'Assignments', 'Taxonomies' (which is highlighted in green), 'Settings', and 'Audit Logs'. The main area has a header 'Home / Taxonomies' with buttons for '+ New', 'Import', 'Delete', 'Audit Logs', and 'Export to Excel'. Below this is a search bar with fields for 'Name:' and 'Parent:', and buttons for 'Search' and 'Reset'. A table lists taxonomies with columns for 'Name' and 'Parent'. The first row is 'ADHD symptoms' under 'ADHD symptoms'. The second row is 'ADHD symptom: Inattention' under 'ADHD symptoms'. The third row is 'ADHD symptom: Hyperactivity-Impulsivity' under 'ADHD symptoms'. At the bottom right of the table are buttons for 'View', 'Edit', and 'Delete'.

- ① Marianne Luengo Fuglestad, a master student HVL.
- ② Thesis topic: *A Dimensional Modeling Approach to Internet-Delivered Psychological Treatments.*
- ③ Extended OSAIS and included Dimensions.

Who is using OpenIDPT Framework? - Projects

- ⑤ Master Thesis - 3 Roger Wisnes, a master student at HVL, is extending the OSAIS to facilitate the dynamic assessment of the psychological intervention. The working title of his master thesis is "*Dynamic assessment of psychological interventions*".
- ⑥ We used the Resource Server and Authorization server in mUzima Project. [Paper G](#)
- ⑦ Headless CMS API by Helse Vest IKT: Based on the OpenIDPT Framework, their team developed a headless CMS API¹ for healthcare providers.

¹<https://dev-content-intromat-apim.developer.azure-api.net/api-details#api=intromat-content-api&operation=GetMyToken>

Future Work - Software Engineering

- ⑤ Improve the proposed models, RM, RA, and open-source framework of IDPT system based on current technology.
- ⑥ Our current open-source framework lacks unit testing in several modules. The inclusion of extensive Test-Driven Development (TDD) and its empirical measures are an interesting direction to explore.
- ⑦ There is a need for visualization tools that assist therapists and other medical practitioners to comprehend the patients' history, current context and the possible presence of patterns

Future Work - Health Informatics

- ④ Patients' privacy
- ④ Factors associated with user adherence
- ④ Interoperability
- ④ Clinical trials: It is essential to test the developed system with actual users.

Future Work - Artificial Intelligence

- Conversion of the IDPT system into **conversational agents**, could increase user adherence.
- AI-practitioners in both Researchers and industry open-sources trained model, for example, models by **AI Hub**.² These models provide opportunities for using user profile data to build predictive models, recommendation engines or pattern mining.
- Humans should understand the results of AI-based models. This concept is advocated by **Explainable AI (XAI)** and is relevant in the current HIS.

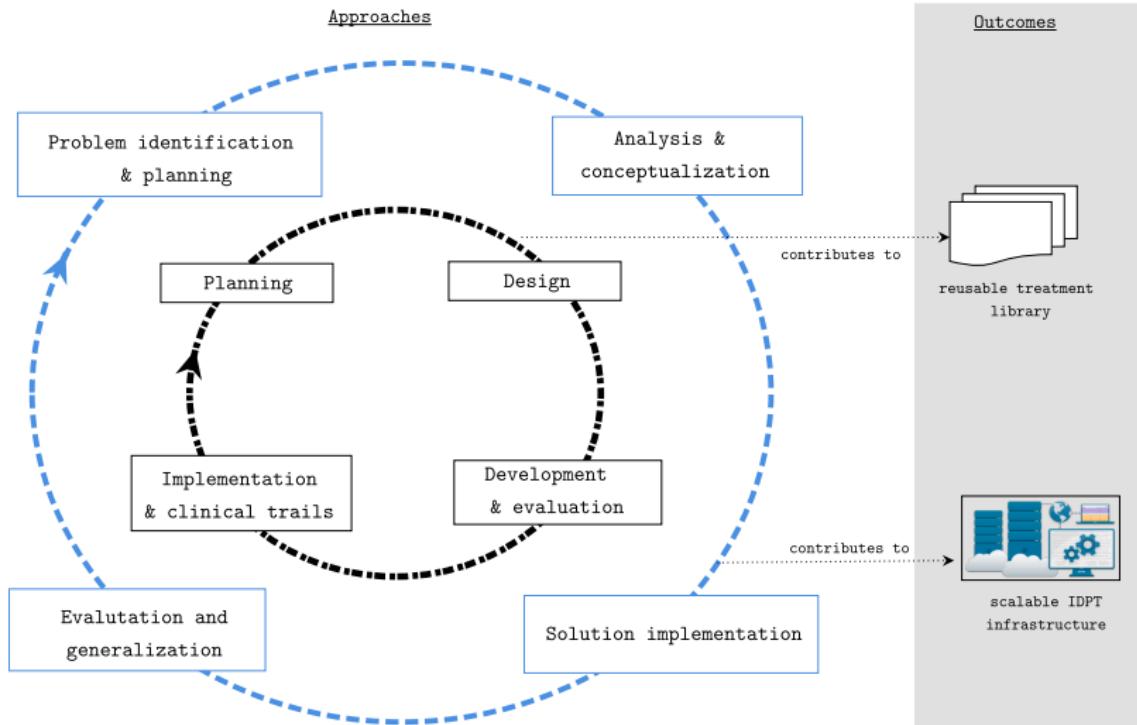
²<https://cloud.google.com/ai-hub/docs/use-model>

Future Work - Human-Computer Interaction

- ⑤ When designing and developing software systems, usability plays an essential role in determining user adherence to it. Extend the current work is to perform extensive **usability evaluation** and enhance the system.
- ⑥ **Interaction design (IxD)** is another field that fits well in the current study and worth extending.

References |

- [1] Emily A. Holmes, Michelle G. Craske, and Ann M. Graybiel. Psychological treatments: A call for mental-health science. *Nature* 2014 511:7509, 511(7509):287–289, jul 2014.
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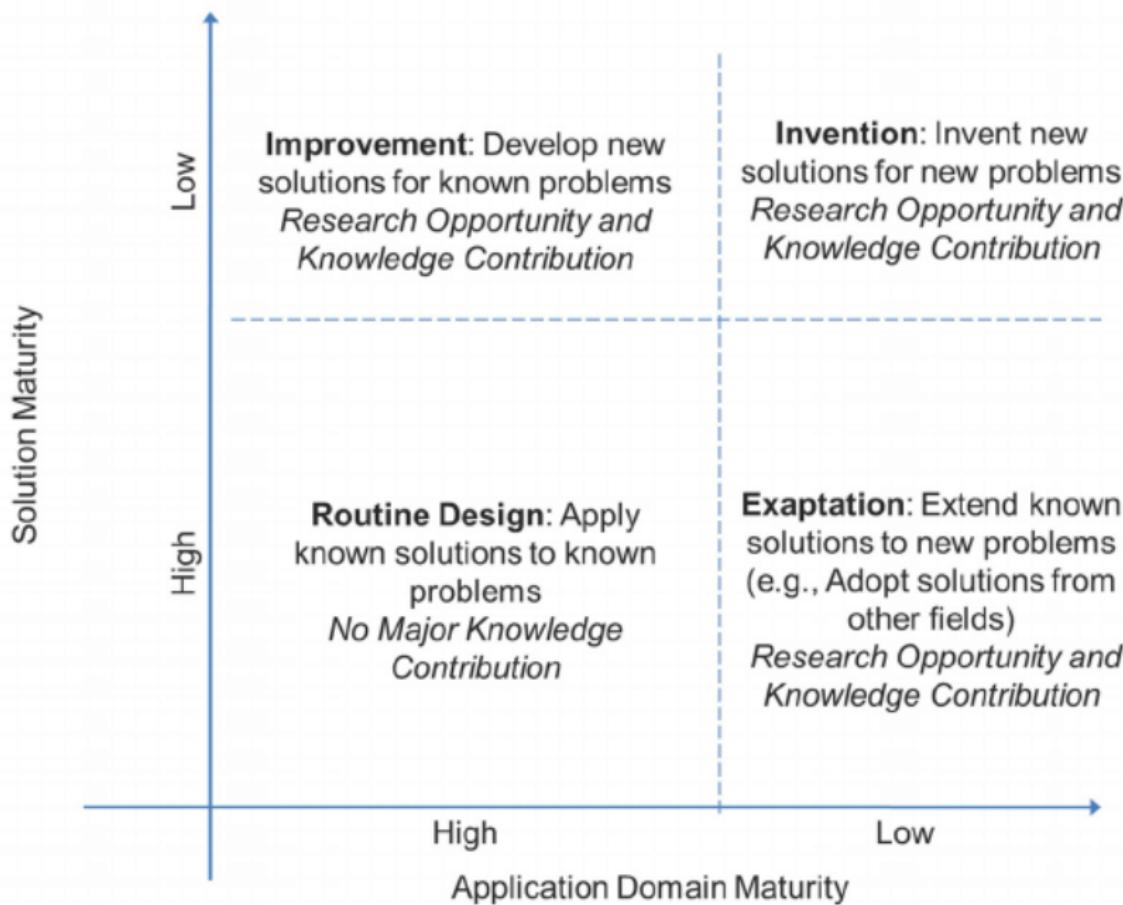


..... Treatment development cycle (PBA Approach)

..... Software infrastructure development cycle (DDD approach)

Papers	DSR artefact types	DSR evaluation methods used
Paper B	Instantiation and method	Case study
Paper C	Instantiation, method and model	Prototype, technical experiment and expert evaluation
Paper D	Model and method	Illustrative scenario
Paper E	Algorithm and method	Technical experiment
Paper F	Framework	Action research, prototype, illustrative scenario, and expert evaluation
Paper G	Instantiation and method	Prototype, technical experiment, expert evaluation, and case study

- Peffers et al. [7] reviews 148 different DSR articles to develop taxonomies and mentions six different DSR artefacts, *including algorithm, construct, framework, instantiation, method, and model.*
- The study outlines DSR evaluation types, including *logical argument, expert evaluation, technical experiment, subject-based experiment, action research, prototype, case study, and illustrative scenario.*
- Sonnenberg et al. [8] outlines measure of several QA. For e.g. ease of use, completeness, effectiveness, efficiency, robustness, scalability, understandability and others.



	Select Psychometric Score	Operator	Select Value	
BC1	GAD (GAD7.)	Greater than (>)	21	AND
	User Activity	Operator	Select Value in Hour	OR
BC2	Last logged in	Greater than (>)	72 hours ago	
	Goals	Operator	Select goal	THEN
BC3	User goal	Equals to (=)	decrease anxiety	
Action	Create Alert	Select Role	Select Email Templater	
	Email	Therapist	Template Alert The.	

Chrome File Edit View History Bookmarks Profiles Tab Window Help

defense - Online LaTeX Editor | Ka I Pun | Microsoft Teams | WP3: Core clinical process - In +

intromat.no/workpackages/wp3/

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INTROMAT

WP3: Core clinical process

WP3 will provide a modular and flexible ICT infrastructure with corresponding tools that supports the core clinical processes in the mental health domain. The research will be performed by combining state of the art techniques from the fields of Model Driven Software Engineering (MDSE), Interaction Design(ID) and Software Language Design(SLD). The infrastructure will be used both for conducting research with ICT in mental health and as a reference architecture for development of e-health services. Objectives: (1) Establish the necessary infrastructure for experimenting with the use of new ICT for mental health. (2) Establish infrastructure to carry out clinical trials to test new ICT in mental health herein establishment of a high level reference architecture for mental health including the description of the interoperability with the clinical support systems (EHR, Medical Research Databases etc.). (3) Transition of knowledge to the health sector and provide means such that the ICT industry could develop new ICT solutions for mental health by offering domain specific APIs and domain specific development tools.

Leader:



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Team

