# Cross-domain integration for the development of technology-based detection-analytics-intervention chains in the REACH project


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In REACH, an experimental, cross-domain sensing-monitoring-intervention system that can be placed unobtrusively in various care settings and living environments of elderly citizens was developed. Through multiple Touchpoints, REACH implements and systemises several instances of the early detection of physical inactivity patterns and associated risks. To achieve the set-out project goals, REACH (a multi-partner research project) requires a structured development process in combination with a consequent cross-domain integration. The paper analyses the most important areas for which cross-domain integration is required: integration of cross complex knowledge domains, integration of cross physical world and data domains, integration of cross testing and study design domains, and the integration of cross artefacts and services worlds. The paper concludes that for handling the complexity of REACH, it was necessary to split the project (for development purposes) into micro-clusters (e.g. Touchpoints, Physical Activity Dimensions, etc.) and explore the interactions of domains by systematically forming and testing micro-chains of the Sensing-Monitoring-Intervention flow.



***Keywords**: assistive technology, ageing society, innovation, and complexity management*


## Background and research goal

In REACH[1], an experimental, cross-domain sensing-monitoring-intervention system (SMI) that can be unobtrusively placed in various care settings and living environments of elderly citizens was developed. Through various Touchpoints (representing concrete innovation areas as well as various dimensions of physical activity), REACH implements several instances of the early detection of physical inactivity patterns and associated risks. Physical inactivity, for example, enhances the risk of falls which is an indicator for the development of a variety of secondary conditions such as the decline of functional ability, the onset of frailty, diabetes, hypertension, obesity, and depression[2].

The early systemised detection and intervention-based prevention of physical inactivity and sedentary behaviour in a variety of care settings (e.g., homes and everyday life, day care centres, and other geriatric facilities) will significantly reduce the risk of LTC admissions and re-admissions (and thus as targeted by REACH, lower the overall healthcare cost). Additionally, it will also increase the elderly's functional performance, social participation, independence, and quality of life.

To achieve the set-out project goals, REACH (a multi-partner research project encompassing 17 partners) requires a structured development process[3] in combination with a consequent domain integration cross 1) complex knowledge domains, 2) physical world and data domains, 3) testing and study design domains, 4) artefacts and services worlds.

## Cross knowledge domains: REACH's unique SMI activity flow:

Based on its initial SMI concept and as part of the work accomplished, the REACH consortium has detailed and taken this concept further towards a unique Sensing-Monitoring-Intervention (SMI) activity flow (*Fig.1.*).

1. **Sensing**: As part of the Sensing section, the physical activity was further detailed as the target condition and categorised into several Physical Activity Dimensions (PADs); 1) macro-mobility, 2) micro-mobility, 3) socialising and nutrition, and 4) gaming and training. In that context, several early detection regimes were defined; a) one-off alarm, b) detection of short or long-term activities and patterns, c) device integrated automatic early assessment. These regimes can be applied in specific combinations for each PAD. Based on the PAD and the selected early detection regimes, a particular set of sensors, which can serve the selected condition and detection regime, can be selected in a target-oriented manner.

2. **Monitoring**: Based on the selected sensing strategy and as part of the Monitoring section, a combination of wearable and ambient sensors (which equal the REACH Touchpoints) was chosen for each PAD. The task of the wearable sensors is to obtain multivariate physiological signals, whereas the ambient sensors supply in an automatic manner context and labelling. In the Data collation system, the acquired data is

managed and prepared for processing by various analytics methods and algorithms. Here, two major types are distinguishable; Analytics type 1 that focusses on machine learning algorithms for the detection and prediction of activities, trends, and behaviour profiles as well as Analytics type 2 which allows for the matching and optimisation of behaviour profiles and personalised intervention profiles through clustering algorithms.

3. **Intervention**: In the Intervention section, and through the analytics section, the generated output is used to select, develop, and or personalize interventions that react on the early detected trends, patterns, or deviations of physical activity in each PAD. In that context, sophisticated motivational techniques and engagement strategies are used and tailored towards PADs, individual users, and user profiles to create a highly efficient and long-lasting behaviour change[4]. Both programmed interventions, device interventions and interactions in REACH use case environments, are informed, embedded in, and coordinated behaviour change strategy identified by the analytics section. With each new data set generated, the system will learn better what behaviour change schemes and interventions work best for specific persons.

Smart furniture is used to integrate the activities and functional elements described above seamlessly into the different REACH healthcare environments. As part of the development of innovative REACH business models for data-driven and value-based care, concrete business instantiations are created for each of the 4 PAD categories[5].

#### CROSS PHYSICAL AND DATA DOMAINS: THE TOUCHPOINT AND ENGINE CONCEPT

A key achievement of the first project year by the REACH consortium was the development of a detailed and holistic conceptual solution: the "Touchpoints and Engine concept". This concept was based on an in-depth analysis of the four use case settings[6] in REACH and the identification and inclusion of internal and external consortium stakeholders (elderly, care personnel, insurances, etc.) in the system architecture development process[7]. This conceptual solution fully reflects REACH's "Product-Service-System" value proposition. Each of the 5 physical Touchpoints bound together by a cross-sectional and an integrated Engine (i.e. platform) functionality, will function as data gathering and intervention devices. Touchpoints 1-4 not only state the development of innovation clusters within the consortium but also:

a) Individually represent a specific dimension of physical activity (PAD) in general;
b) Individually implement an instantiation of REACH's unique Sensing-Monitoring-Intervention activity flow.

The Engine states a cross-sectional development area that serves these 4 PADs. A detailed description of the Touchpoint and Engine concept and the REACH partners and use case settings associated with each of its components are detailed in the REACH Deliverable T1.4/D4[8]. The "Touchpoints and

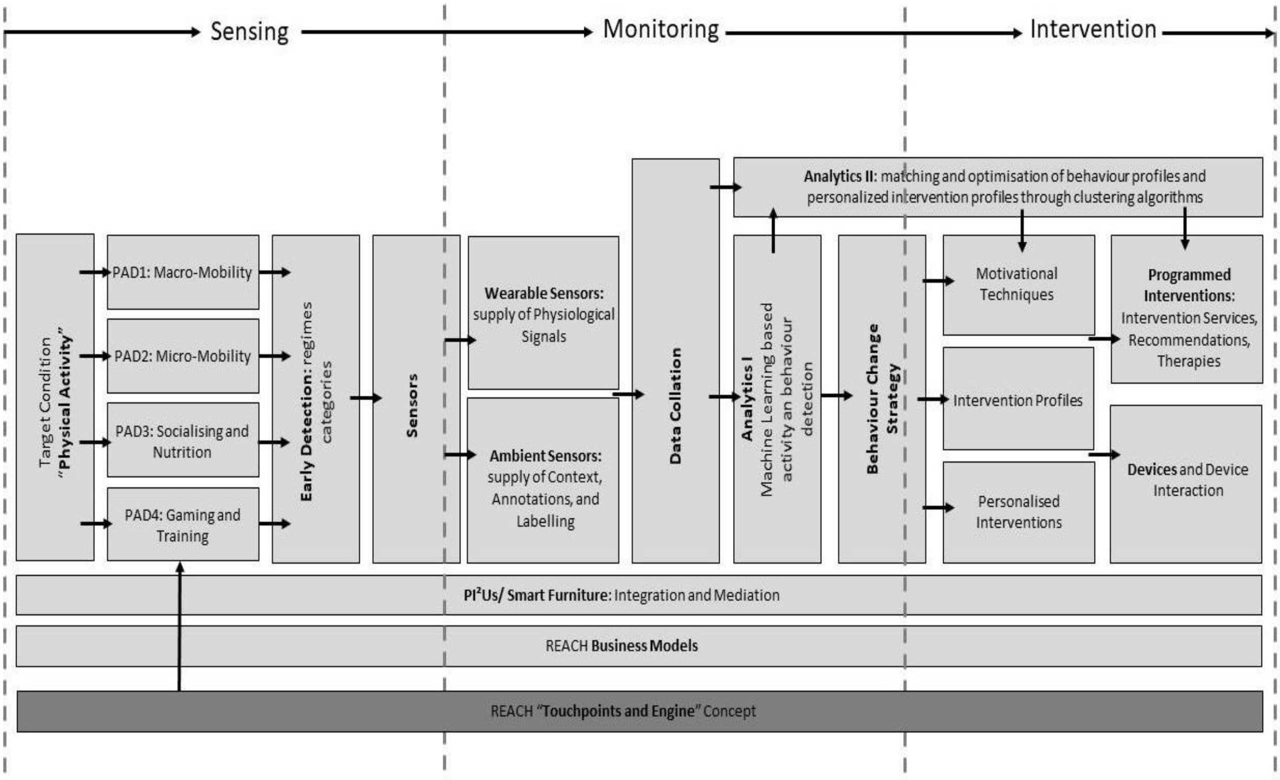


*Fig.1. REACH's detailed, unique Sensing-Monitoring-Intervention Activity Flow.*

Engine concept” structures the envisioned REACH product-service-system architecture into seven manageable research and development clusters (*Fig. 2.*). Of these, five clusters of “Touchpoints” represent any tangible connections between users (seniors, informal/formal caregivers, physicians etc.) and the REACH system. Another “Engine” cluster represents the cloud-based digital platform, and lastly, the “interface” cluster, which represents a set of specifications that allows the Touchpoints and other products/services to connect/interact with the Engine. Each research cluster is associated with a separate development team made up of consortium members and a team leader.

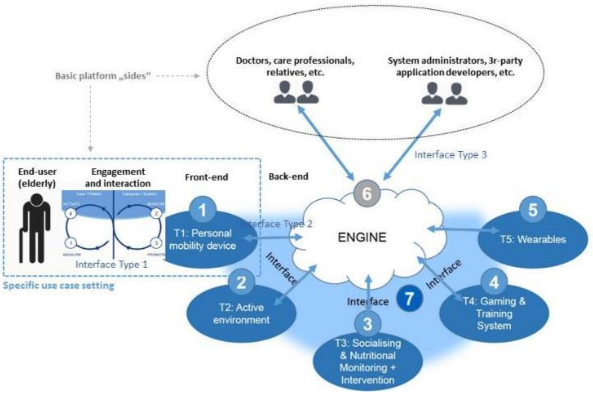


*Fig.2. REACH system architecture high-level description.*

**CROSS STUDY DESIGN DOMAINS: COORDINATION OF TESTING AROUND THE REACH PHYSICAL ACTIVITY MODEL**

Based on the rational and work outcomes outlined above, REACH will, from testing phase 2 onwards (phase 1 was mainly explorative: ethnographic studies, usability studies, etc.), structure all testing around a “REACH physical activity data model”. As outlined above, this standard data model will build the basis for the development, testing and application of various machine learning methods to detect the changes in physical activity levels and patterns early, and train clustering algorithms that help with the optimised and personalised assignment and recommendation of specific engagement strategies and interventions.

As outlined above, the Touchpoints represent complementary dimensions or views of physical activity which partition the testing and data gathering space around the core of the physical activity data model into four segments (TP1: general mobility; TP2: postures, ADLs, micro-mobility; TP3: socialising and nutrition; TP4: gaming and training). The A, B, and C ring segments indicate to which of the previously defined 3 testing instances a certain test or data gathering activity is assigned (A: Detection and Analytics; B: Motivational Techniques; C: Programmed Interventions). The various plane tests/studies (T1, T2, T3, etc.) can be allocated in this framework. Due to practicality reasons, tests will remain within a certain physical activity dimension: Touchpoints and thus these dimensions are bound to a particular test case setting such as SK or Lyngby, etc. However, the Touchpoints can transverse across testing instances and thus knowledge domains. The widths of the allocated testing segment shall indicate the size

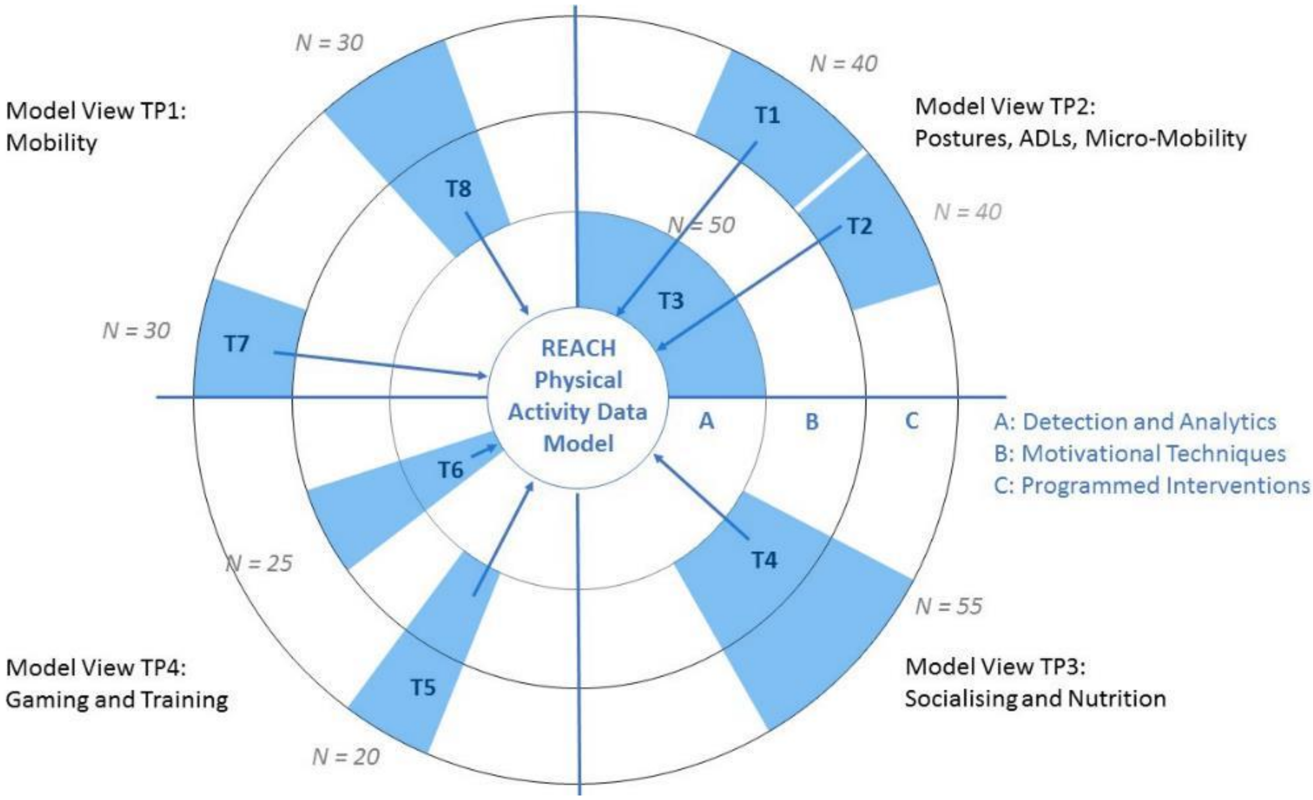


*Fig.3. REACH system architecture high-level description.*

of a specific test or study (e.g., N = 25 refers to a test involving 25 test subjects, see *Fig. 3.*).

### Cross artefacts and services: Personalized Intelligent Interior Units

In the context of REACH's SMI activity flow, PI²Us (Personalized Interior Intelligent Units/ smart furniture) are used to integrate the activities and functional elements described above seamlessly into the different REACH healthcare environments. These PI²Us are conceptualised in a way that they both serve as add-ons to existing furniture and as standalone units that contain physical and virtual services to increase activity level. Specifically, they are PI²U-Stander, PI²U-Bed, PI²U-silverArc, and PI²U-miniArc. These PI²Us will be designed in a curved, natural design language to enhance user acceptance. Furthermore, smart furniture products will allow for additional value creation through furnishing, and building renovation markets, and turn built environments into service platforms. The design of the PI2Us embraces a platform strategy which is useful for mass production, allows savings and ease of manufacturing. The platform strategy also provides structured modularity and a high degree of standardisation.

### Conclusion

To handle REACH's complexity, it was necessary to split the project, (for development purposes) into micro-clusters (e.g. Touchpoints, PADs, etc.) and to explore the domain interactions by systematically forming and testing micro-chains of its SMI flow. The REACH "Touchpoints and Engine" concept is entirely in line with the four PAD categories. This alignment allows that the SMI flow is developed, demonstrated, and exemplarily evaluated as a specific instantiation based on the four use case settings of REACH (Geneva Hospital, Schön Klinik Bad Aibling, ZuidZorg, and Lyngby) and eventually as personalised instantiation within each use case setting.

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