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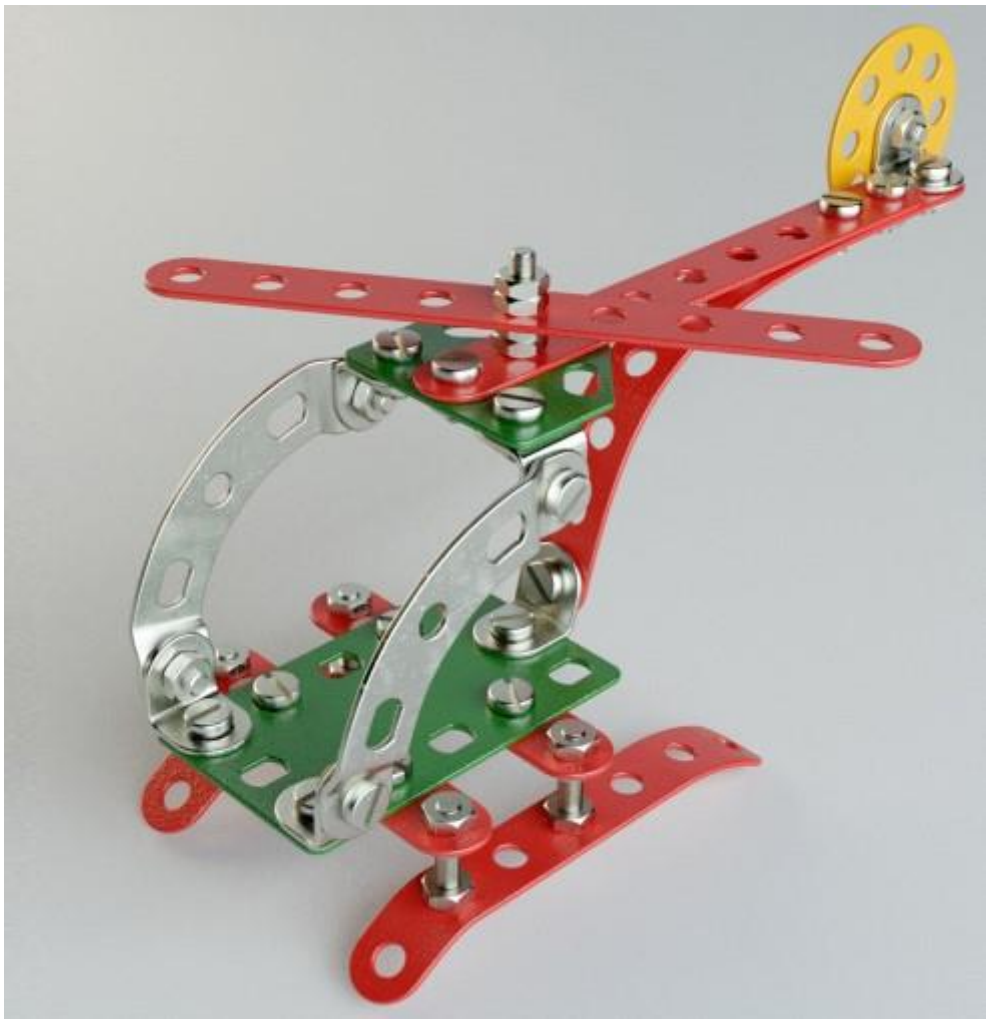

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1 Introduction

The purpose of this document is to provide a domain model for the AAL HELICOPTER project, that is, to provide a context in which the HELICOPTER system should operate. This context consists of the activities (e.g., ask guidance of the system) performed by different roles[1] (e.g., caregiver, providee), the roles themselves as well as the goals of these activities. Note that an actor such as an individual or an organization can, unless otherwise specified, play or undertake one or more roles. Further, the context also includes the main characteristics of the HELICOPTER system service such as "simplicity". This document is a result of a knowledge/requirements development process that involved integrating the knowledge of 5 different cultures (Italian, Dutch, Swedish, Danish and Romanian) as well as different knowledge domains (e.g., medicine, domotics, domestics, computer science, engineering).

1.1 Overall description

The purpose of the HELICOPTER system is to provide elderly people with support for *well-being*, that is, with an improved quality of life. In HELICOPTER, the quality of life perspectives that are emphasized is that elderly people feel safe (e.g., they are less worried about their situation) and elderly people are able to manage their own life (e.g., live in their own home longer and more independently). The reason is the shift in demographics where the population grows older, that is, there are more elderly people now who live longer than in previous decades and this group continues to increase in proportion to the younger members of the population.

There are three main roles that are addressed in the HELICOPTER project: providees, caregivers and physicians. A *providee*[2] is a user that uses the HELICOPTER system to achieve an improved quality of life as well as the ability to manage their own life to a large extent. A providee is a care recipient if, and only if, they are in a formal agreement with a caregiver providing care to the providee. In the HELICOPTER pilot study (WP5), providees must formally agree upon participating in such a way that there are no problems of any kind to perform the evaluation of the pilot study. A *caregiver* is someone who, if the providee is in need of care, provides care to the providee by doing activities that the providees cannot do themselves. A caregiver can be formal, such as a nurse or an organization (e.g., hospital), or informal, such as a relative or a friend. A *physician* is someone who has the right and ability to, for example, diagnose people, prescribe medicine etc. Note that, in general, a person or organization can adopt one or more of roles. However, there are restrictions, for example, in Sweden it is considered unethical to be your own physician, although it is not disallowed by law.

Briefly, HELICOPTER system attempts to support these roles to provide providees support in their daily tasks as well as other important activities (e.g., rehabilitation, keeping track of food consumption). There are fivemain strategies that are pursued in the HELICOPTER project (in descending implementation priority order):

1. To avoid problems or risks causing a negative lifestyle, HELICOPTER continuously performs an *automatic triage*, that is, early and coarse diagnosis of health-related problems (e.g.,

[1] Note that stakeholder is a role that is outside the scope of this document, but not outside the HELICOPTER project.

[2] The concept "providee" was chosen, to accentuate the fact that this is the main receiver of what the system provides. It follows the scheme in English: employer/employee, trainer/trainee, etc. The term "end-user" is avoided, since each of the roles are users of the system and the descriptions sometimes makes it hard to follow. Since "care recipient" has a special meaning, that is, someone who is formally receiving care from someone, "recipient" was avoided. As written, we can explain the relation between a providee and a care recipient in a precise and unambiguous way. Further, supportee was skipped, since supporter has too many connotations associated with it.

hyperglycaemia, depression). This is a required feature. If the result of this diagnosis is non-critical, then provide results upon demand to the providee. If the result of this diagnosis indicates a risk and the providee is under formal care, then the system should alert (in order of priority): the providee and, if the providee does not respond to the alert, the caregiver. To perform this automatic triage, HELICOPTER continuously monitors available information sources such as sensors (e.g., wearable devices, home automation, clinical devices), databases (e.g., past behaviors, crowd-sourced exercise advice), on-line services (e.g., weather forecasts) as well as maintains a dialogue with the providee. The dialogue is desirable, since it may be necessary to confirm information as well as ask for missing information.

2. To stimulate a positive lifestyle, HELICOPTER supports providees by visualizing progress towards *motivating daily goals* on activities that are easy to comprehend and easy to do something about (that is, the providee should expect themselves to be able to something and the rewards should be achievable within a short time limit such as a day). For example, by setting up goals on movement per day, it is possible to monitor the movement and feedback how much the providee has moved compared to the goal. This goal is then a motivating daily goal. The reason is that the information from the automatic triage may be unmotivating and non-stimulating and may, in the worst case, lead to that the providees feel more sick than they actually are.
3. Optionally[3], to stimulate a positive lifestyle, HELICOPTER supports providees with a community feature that allows them jointly be caregivers to each other. For example, to check that they have gotten out of bed, that they are feeling well etc.. There are open source solutions that allow you to design your own private social media, so it is mainly a configuration task rather than a programming design task to implement such a solution. If used properly, we can allow providees to set up and check each other as well as ask questions concerning the system etc.
4. Optionally, to stimulate a positive lifestyle, HELICOPTER support providees in performing daily tasks and activities by providing plans as well as functionality for following up on plans. These plans can either be maintained by the caregivers or by the providees themselves. In particular, if we can remind planners of adding challenges in the plan, then it is possible to get positive reinforcement when the providees complete planned activities that involve challenges.
5. Optionally, another possibility to stimulate a positive lifestyle is to demonstrate and compare progress of a providee compared to other providees (anonymously, of course). This is an optional feature, implemented if time allows it. This could provide a caregiver with the ability to show the results of “what if” question, for example, “what if I start exercising each week, then what will happen?” or “what if I do not start exercising each week?”. For example, the “Smoking time machine”[4] is an example to demonstrate you smokers what difference smoking makes to their visage.

[3] Only implemented if time allows it and there is a strong reason for it.
[4] http://www.changemyface.com/

1.2 Motivational issues

A key issue is to keep providees motivated to use HELICOPTER. An important model of motivation is the temporal motivational theory advocated by, for example, Steel[5] and it can be viewed as[6]:

$$motivation(individual,task) = \frac{Expectation(individual,task) * Value(individual,task)}{Delay(task,reward) * Sensivity\,to\,delay(individual,task)}$$

where the motivation for an individual to perform a task is proportional to the expectation of the individual to be able to complete the task times the value that the individual perceives in completing the task divided by how long time it takes to get a reward for completing the task times the sensitivity of the individual to complete the task. The dividend represent the rational behavior and the divisor the irrational behavior.

In essence, the key is that providees need to feel that they are in control of their situation and the HELICOPTER system, they are able to use the system (or rather, do their daily tasks with as little interference as possible and get advice when they desire it), they perceive sufficient value in using the system and there should be no unnecessary delays (e.g., if they go out for a walk, then they expect progress in terms of achieving the motivating daily goals). In case something takes a long time to process, then, preferably, feedback should be provided when result is expected and also show progress upon request.

1.3 HELICOPTER system properties

The critical HELICOPTER system properties are:

1. Usability properties, in particular:
    a. Added quality of life feeling or improved well-being. The providee should experience that the HELICOPTER system provides quality of life or improved well-being. Important parts of this experience is to feel safe as well as use technology to improve contact and communication with others (e.g., relatives, friends, caregivers, physicians). For example, there are studies concerning employing internet[7] when world wide web was in its infancy, participating in online communities[8] etc. For example, the ability to provide contact information so that the providee can find the right person to contact as well as the ability to provide message-based communication (e.g., via email or via social media) may be important details in HELICOPTER..
    b. Simplicity, as pointed out in our discussions, there are a lot of evidence that HELICOPTER should deliver results through a, from the providees perspective, simple and intuitive interface. In this interface, it should be possible to ask and receive help on various concerns.

[5] Steel, P 2007, 'The nature of procrastination: A meta-analytic and theoretical review of quintessential self-regulatory failure.', *Psychological Bulletin*, vol. 133, no. 1, pp. 65–94, viewed 11 March, 2013, <http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-2909.133.1.65>.

[6] Note that "motivation" has been used here rather than the more formal "utility".

[7] "Using the Internet to improve the wellbeing of the elderly." 2013. 12 Jun. 2014 < http :// www . mednwh . unimelb . edu . au / nar i _ education / archives / pdf _ docs /2010_6_29_ Using - the - Interne t- to - improve - the - wellbeing - of - the - elderly . pdf >

[8] O'Brien, C. "Participation in Online Communities and Psychosocial Well ..." 2012. < http :// www . matherlifewaysinstituteonaging . com / wp - conten t / uploads /2012/03 / MLWOrangePaper _ InternetUse _ 2 . pdf >

If the concern is outside the responsibility of HELICOPTER, then the providee should be directed to contact someone (e.g., in an emergency, contact 112).

One possibility is to have a ubiqutuous and unobtrusive information panel such as a digital interactive painting that shows the progress towards meeting motivating daily goals. When ever the providee passes by the painting, he or she can glance at the progress. If the providee wants to see the results of the automatic triage, then this could be displayed here upon request.

2. Technical properties, in particular:
    a. Availability[9], that is, the service of the HELICOPTER system should be available 24/7. If HELICOPTER is unavailable too frequently or when it is critical, then the providees trust in the system may decline rapidly. This implies that redundant hardware must be employed as well as technical solutions supporting dependability (e.g., usage of database management systems) are strongly desirable. Further, if something breaks, the system should degrade gracefully from the providees perspective, for example, if a sensor breaks, then the system should inform the providee that the sensor is unavailable and, in dialogue form, ask the user for necessary information. Assume that the toilet got a passive infrared sensor installed in a single household, then if it breaks, the system can inform the providee of this fact and ask if they, in their opinion, are visiting the toilet more frequently in the recent period (e.g., day); in this case, the providee may not have a clear cut answer and should be able to respond "I do not know". The early and coarse diagnostics must be able to handle this kind of uncertainty and provide reliable and robust results in the form of risks concerning the diagnostic suspicions. Further, in the fusion processing, sensor values should be possible to replace with input from the providee (or caregiver).
    b. Reliable and robust results of the automatic triage as well as other parts of the system. Reliable implies that if a physician would judge that there is a risk that a diagnostic suspicion is true, then the system should do so too (and vice versa). Robustness implies that this should not be sensitive to non-critical changes in the input to the reasoning mechanism. This implies that, for example, noise from sensor values must be removed prior to processing it. Further, as stated, missing values should be possible to handle. An important part of this property is that the HELICOPTER system must separate different providees in the same geographical location as well as disregard visitors. A part of this separation is that it is also important to ensure that HELICOPTER provides guidance based on the individuals need.

1.4 Significant assumptions

It is assumed that all information concerning providees are kept together in a model of the providee, that is, a representation of the providee containing all necessary data of the present and the past that are required to enable HELICOPTER to make automated informed decisions for the use cases detailed in the following sections. Note that some parameters in the user model are configurable (e.g., age, chronic diseases that are emphasized in HELICOPTER).

[9] Avizienis, A., Laprie, J.-C., Randell, B., Landwehr, C., 2004. Basic concepts and taxonomy of dependable and secure computing. Dependable and Secure Computing, IEEE Transactions on 1, 11 – 33. doi:10.1109/TDSC.2004.2

1.5 Layout

The rest of this document is disposed as follows: In the first section, the goal model is presented to give an overall context of HELICOPTER (what it is and what it is not). In the second section, the main activities associated with these goals are specified as a set of abstract uses cases. Finally, in the appendix, a dictionary as well as an elaboration of the diagnostic suspicions connected with evidence indicators as well as information sources are presented.

2 Goal model

The goal model explains how the goal of well-being with HELICOPTER is achieved by recursively breaking it down into subgoals that can be achieved according to some criteria as well as address specific problems that arise when technology is introduced. It can be used to reason about what is necessary to achieve something and if we have achieved something then what do we guarantee or enable by achieving this.
In figure 1, the goal model is illustrated. The goals are divided into levels based on how close they are to the users of the HELICOPTER system. Level A and B are closest to the providee and are considered to be *environmental goals*, that is, goals relating to the environment including the providee. The following levels, C-G, are considered to be *HELICOPTER system goals* and are closely related to requirements. Level C[10] are the top goals of the HELICOPTER system. The levels C to G corresponds to various levels of the JDL model[11,10,11] of information[12] fusion processing[13], where C relates to level 5 (user interface), D relates to level 3 (impact analysis, in particular, D-1), level 2 (situation analysis, in particular, D-2 and D-5). Level E and F are in between situation assessment (level 2) and object assessment (level 1). The object assessment is mainly anchoring information to providees (e.g., localization[14,15,16], tagging[17,18]). For example,

[10] Blasch, Erik P, and Susan Plano. "JDL Level 5 fusion model: user refinement issues and applications in group tracking." *AeroSense 2002* 31 Jul. 2002: 270-279.
[11] "Data fusion - Wikipedia, the free encyclopedia." 2006. 11 Jun. 2014 < http :// en . wikipedia . org / wik i / Data _ fusion >
[12] Note that there are different but related forms of fusion, for example, information fusion, data fusion and sensor fusion. In this deliverable, we employ information fusion to address that we emphasize high-level fusion of situation analysis (e.g., early and coarse diagnostics of hypeglycemia).
[13] The JDL model can be viewed as a pipeline, where sensor data is fed into the level 0 (pre-processing which for example, removes noise). The result of level 0 is fed into level 1, object assessment (in which, for example, physical objects are identified and data is tagged to the representations of the physical objects). The result of level 1 is fed into level 2 (situation assessment, where the relation between objects in time and space is assessed). Finally, the result of this level is fed into level 3 (impact assessment, in which
[14] Savarese, Chris, Jan M Rabaey, and Jan Beutel. "Location in distributed ad-hoc wireless sensor networks." *Acoustics, Speech, and Signal Processing, 2001. Proceedings.(ICASSP'01). 2001 IEEE International Conference on* 2001: 2037-2040.
[15] Ssu, Kuo-Feng, Chia-Ho Ou, and Hewijin Christine Jiau. "Localization with mobile anchor points in wireless sensor networks." *Vehicular Technology, IEEE Transactions on* 54.3 (2005): 1187-1197.
[16] Rabaey, Chris Savarese Jan, and Koen Langendoen. "Robust positioning algorithms for distributed ad-hoc wireless sensor networks." *USENIX technical annual conference* 2002.
[17] Hansen, Frank Allan. "Ubiquitous annotation systems: technologies and challenges." *Proceedings of the seventeenth conference on Hypertext and hypermedia* 22 Aug. 2006: 121-132.

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If we have a household with multiple residents, then who is visiting the kitchen and opens the refrigerator? Level G is associated with level 0 (pre-processing).

The goals with a blue thick border are emphasized in HELICOPTER, the other goals are there to describe a sufficiently complete perspective of ambient assisted living. It allows us to make informed decisions on what to, for example, add to the design as well as what we should consider during the pilot study.

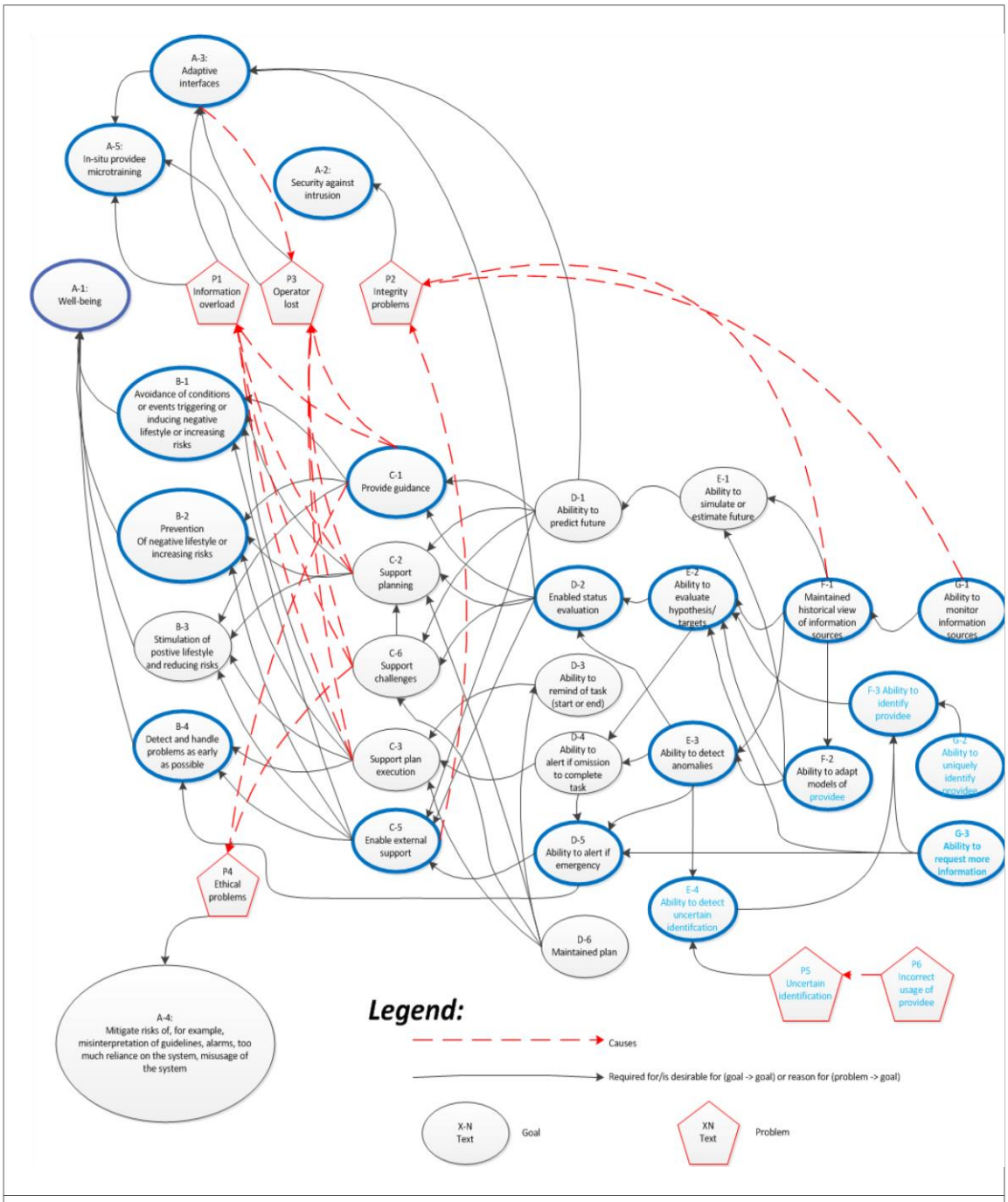

Figure 1: Goal model overview

2.1 Environmental top goals (level A)

There are five top goals, where A-1 (well-being) is the main theme and the rest are results of handling problems that are prevalent when trying to achieve A-1:

- **A-1** (well-being) that we need to achieve well-being. In particular, from a users' health perspective, but also from the related perspectives of socializing as well as performing daily tasks (e.g., shopping, exercising, preparing food).
- **A-2** (security against intrusion) is the pragmatic necessity of providing security against intrusion.
- **A-3** (adaptive interfaces) is the pragmatic need for adaptive user interfaces. For example, a frequently used feature can be made readily available to the providee, whereas a less frequently used feature can require situation-based micro-training.
- A-4[19] is the pragmatic need for handling problems that the guidance may lead to. Essentially, if HELICOPTER is viewed as a service rather than a product, then handling this problem is an organizational problem of the HELICOPTER service provider.
- **A-5** (situation-based providee microtraining) is the pragmatic need for training the providee in using HELICOPTER as well as support, for example, health-related activities such as rehabilitation

2.2 Environmental subgoals (level B)

To achieve the well-being of the providee (goal A-1), we must achieve four subgoals[20]:

- **B-1** to ensure that we try to avoid problems by guaranteeing that a necessary condition for a problem to occur cannot be true. For example, if the providee is suffering from dementia and does not have a range[21], then the providee cannot by mistake turn on the range and thereby set fire to their apartment or house.
- **B-2** to ensure that by supporting preventive measures in the lifestyle of the providee, we reduce the risks associated with a negative lifestyle. For example, by supporting exercises in terms of planning and performing the planning as well as providing challenges associated with exercises, many lifestyle problems can be avoided or reduced. The motivational daily goals[22] falls mainly under this category, for example, to prevent falling the providees exercise enough.
- B-3 to ensure that supporting a positive lifestyle by, for example, trying to support the providee in their social life. For example, by reminding of birthdays, suggesting social activities etc.
- **B-4** in case there are problems, then the system should detect these problems as early as possible and support the providee as well as alerting caregivers as soon as possible.

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[19] This is more of an organizational issues than technical issues that the service provider has to face in providing the HELICOPTER service to the providees.

[20] In general, a goal can be achieved by avoiding conditions for not achieving it, by preventing a providee from entering a situation (a negative lifestyle) where the goal cannot be achieved or by detecting that the providee is in a situation (a negative lifestyle) from which he or she cannot achieve the goal and how to move towards a situation (a positive lifestyle) where he/she can achieve the goal. Apart from avoidance, prevention or detection & recovery to handle a bad situation (e.g., a negative lifestyle), we can stimulate a positive lifestyle.

[21] Also known as "stove"

[22] Note that they can also be part of B-3, but we generally consider the problem (risk of falling, risk of chronic diseases) and use some known stragey that prevent this (e.g., exercises).

2.3 HELICOPTER System top goals (level C[23]) and related problems

To achieve B-1, B-2 and B-3, we need to achieve the following subgoals:

- **C-1** to provide guidance, since this is desirable to avoid problems. For example, the providee should be able to check their progress with respect to motivational daily goals as well ask for advice concerning how to avoid increasing the risk of diagnostics suspicions (if they explicitly request so) and, if planning is supported, trends in their own exercises, in how they eat.
- C-2 to support planning of activities, that is, to support the user in a wizard-like fashion, where the system can suggest activities, perform sanity checks if it is feasible to do the activities at some time or in some order etc. It can employ historical data about the providee as well as predictions (e.g., weather forecasts, information about social activities etc.) in this process.
- C-3 to support execution of plans, that is, to remind providees of planned activities as well as keep track of if any essentially activities has been initiated. In case there is a critical activity, then the system should alert the providee if they fail to complete it. For example, essential activities are cooking food, washing clothes etc. The commonality is that the activity does not require the full attention of the providee during the activity, but it if it is unfinished, then there may be severe consequences. For example, if you forget to that you started cooking and leave the range on, then this may result in a fire. If you forget wet clothes in the washing machine, then the clothes may be destroyed or, at least, the clothes has to be washed again.
- **C-5** is desirable since most old people come to a point where they need more support. Further, there are always risks in life and in case something bad happens, then you need support. We need to enable external support for various roles such as care givers, physicians, etc. That is, the caregivers and physicians must get support from the system in their activities (e.g., examining users, supporting users, etc.)
- C-6 is desirable, since it can be useful to consider activities, goal and milestones in a plan from a challenge perspective. That is, if a providee gets a tangible and feasible challenge, then this can stimulate positive reinforcement of a positive lifestyle. Note, however, challenges must not be too hard or too easy, in the former case, the providee may have to give up and it may become negative reinforcement of a positive lifestyle (i.e., I am useless) and, in the latter case, if the goal is too easy to achieve, then there is a risk that the providee does not feel that he or she has really achieved anything. The planner, typically the caregiver, must be careful and the HELICOPTER system should only remind the planner of considering things as challenges.

To achieve B-4, the following subgoals should be met:

- C-5 Enabled external support, that is, if the providee does not respond to the alert, then contact a caregiver.
- D-5 outlines under HELICOPTER system subgoals.

2.4 HELICOPTER system subgoals (level D)

The achievement of the goals

- **C-1** is based on the achievement of

[23] Note that goal C -4 has been deprecated and replaced with C-6.

  - D-1 (optional) since it may be necessary to support speculative what-if queries from the user. For example, if I plan my food in a specific way, what are the potential consequences in terms of risks. It is optional, since D-2 is more well-understood topic, the speculative nature of what-if questions requires a high-level of understanding of the providee.
  - **D-2** (status evaluation of diagnostic suspicions)(required) since we need to know the current state of well-being of the providee to be able to reason about potential guidelines. These guidelines are based on decisions based on the status. For example, if the providee has eaten too small rations, then they might have to increase the amount of food they have to eat each day.
- C-2 is based on the achievement of
  - optionally **D-2** and D-1, see C-1. D-2 is conditional, if and only if we have a health-related plan associated with a diagnostic suspicion that the HELICOPTER system continuously evaluates, then D-2 is required.
  - required D-6, since the system need to maintain plans to be able to support planning.
- C-3 is based on the achievement of
  - D-3 (required) since the providee may want to have reminders of planned activities
  - D-4 (desirable) since providee may start to forget things and may need alerters that, for example, there is wet clothes in the washing machine.
  - D-6 (required), see C-2
  -
- **C-5** is based on the achievement of
  - D-1 (optional), **D-2**(optional)
  - **D-5** (required) in case the system deduces that there is an emergency (e.g., the providee has fallen) or there is an increased risk for an emergency (e.g., the providee shows signs of being dizzy and may fall), then it is at least desirable to alert someone (e.g., a caregiver) of the situation.
- C-6 is based on the achievement of
  - D-1 (optional), D-2 (optional)
  - D-6 (required),

Note the D-5 is required for B-4 as well. It is connected via C-5, since, if the providee does not respond to an alert (which should only be sent if strictly necessary to avoid that providees tire of the HELICOPTER system), then caregivers (which as mentioned can be informal) should be contacted.

2.5 HELICOPTER system strategic techniques (level E-G)

The achievement of

- D-1 requires
  - E-1, since we either need predictive models to estimate the future or we have to resort to simulations. ● **D-2** requires
  - **E-2** since we need some kind of inferences system to reason about the information from the information sources in an reliable and robust way
- D-3 requires
  - D-6 since we need a plan to enable reminders ● D-4 and **D-5** require

- **E-3**, since we need to be able to detect anomalies in the information, which may be an indicator of problems in their lifestyle, health etc.

- E-1, **E-2** and **E-3** require
  - **F-1** since we need a historical view of the information to enable reasoning about this
  - **F-2** since the system should adapt to changes and these affect E-1, E-2 and E-3
- **F-1** require
  - **G-1** monitoring of information sources

Problems

The problems of integrity (P2) stems from trying to achieve goal F-1 and G-1 as well as C-5. The problems of handling information (P1 & P3) stems from achieving the goals C-1 to C-4. Problem P4 stems from achieving goals C-1 to C-4 too. Finally, P5 (and P6) stems from the fact that we can only stand a chanse to correctly identify someone if and and if they follow the requirements of the HELICOPTER system (e.g., the providee should wear the appropriate automatic tag most of the time during a day).

2.6 Main subgoals/problems of Security (A-3), Adaptive interfaces (A-2), Situation-based providee microtraining (A-4) and Risk mitigation (A-3)

These three goals are driven by the problem caused by trying to achieve A-1. Essentially, A-2 and A-4 is required to handle P2, whereas A-3 is required to handle P1 and P3. Note that while trying to achieve A-2, this may cause the problem that the user is lost (P2). Finally, the risk mitigation goal[24] is there to handle problem P4.

3 Main activities (use cases)

The activities associated with the goals in the goal model can be summarized as a set of use cases describing the default usage of HELICOPTER as well as specifying critical exceptions to the default use case.

3.1 Significant assumptions

As mentioned, each providee is represented with a model in HELICOPTER. Each set of related use cases require a section in this model. For example, we need to maintain information about sensor data as well as evaluation of diagnostic suspicions. Essentially, this is the *health status* of the providee from the HELICOPTER perspective. Additionally, we need to keep track of motivational daily goals, which is referred to as *motivational goal status*. Further, we need to keep track on the learning by keeping track on what training they have gone through as well as the result of this training. This is referred to as the *training status*. Further, if planning is supported, a *plan status* has to be maintained.

Finally, the context of a providee includes everything that is necessary to make informed decisions in these use cases. For example, sensors and processing are part of this for reasoning concerning diagnostic suspicions as well as hardware through which the providee interacts with the HELICOPTER system to make informed decisions concerning learning.

[24] This goal need to be deconstructed as well as associated with relevant activities and actors.

3.2 Performing daily tasks (providee): required

The providee perform their daily tasks and the HELICOPTER system is, in the background, performing necessary tasks. Alerters and reminders from the system should be kept to a minimum to avoid tiring the providees and making them distrusting of the system or too dependent on the system.

3.3 Progress on motivational daily goals: required

The providee should receive information concerning progress towards simple daily goals such as total amount of movement per day in an unobtrusive way, for example, via an interactive painting in their home. The providee should expect themselves to be able to meet these goals and the reward should be within a short time frame (e.g., hours or, at most, a day). This use case is connected to achieving goal C-1.

3.4 Ask for guidance (providee, caregiver): required

As a part of a periodic routine (e.g., daily routine), the providee or the caregiver asks the system for guidance (C-1). If there is risk of that the providee may fulfill the requirements of some diagnostic suspicion, then the system should report this. The system should report this either directly to the providee or to the caregiver, depending on the agreements with the providee and the caregiver. The system should ask for more information, if there are uncertainties. This information gathering is guided by the expert knowledge captured in the hypothesis testing of HELICOPTER (in achieving E-2). For example, in the diagnostic suspicion of hyperglycaemia, an evidence indicator is “eating more food”. This may be hard to tell from sensor data, but of we get an indication of increased diuresis frequency from sensor data (e.g., visiting the toilet and flushing the toilet often), then we may ask the providee or caregiver if they have eaten more food than normal lately.

The caregiver may get access to more advanced presentation including trends of, for example, the weight. It is also possible to get a view on the trends on reasoning w.r.t. to the diagnostic suspicions. Advanced providees may also get access to this upon request. Note, however, that presenting the result of the evaluation of diagnostic suspicions can be easily misinterpreted, since the thresholds for risk of different hypothesis may vary. For example, for hyperglycemia, if it is 0.502[25] or more, then there is a risk for that a diabetic person is suffering from hyperglycaemia, but for hypoglycaemia, the threshold is at something else (maybe 0.702). So, if you check the trend of the evaluation, it is necessary to make this evaluation with regards to the threshold for each diagnostic suspicion. Further, the scale type may disallow even the simplest arithmetic operations (e.g., addition and subtraction). For example, in the hyperglycemia reasoning, 0.502 implies a risk, whereas 0.602 implies a significant risk. The difference of 0.1 in this case may be meaningless, that is, we cannot relate to it to any valid reasoning that is applicable to the real world.

How this information is presented and the actual interaction is part of another work package and is therefore left out of this document. In this document, we emphasize what is needed and why it is needed.

[25] The scale is 0-1, where “0” implies not at all and 1 implies definitely. The interpretation of the number depends on numerous issues and it is hard to compare the result of different reasoning mechanisms.

3.5 Situation-based microtraining (providee): required

Upon request from the providee or as a result of a suggestion from the system that the providee accepts, it should be possible to enter situation-based microtraining. The providees should get meaningful options based on the context as well as previous results in the microtraining. Important parts of the context are the learning style of the providee as well as competency and skill of the providee. Important features of the situation-based microtraining are:

- it is based on context of the question or suggestion
- it is based on the history of prior use and micro-training
- if repeated failures are detected, then the HELICOPTER should suggest appropriate microtraining
- the microtraining should emphasize, among other things, the main use cases: ask guidance of the system, communicate with others through social network (optional), follow-up and planning (optional). In particular, support for learning is desirable in the following examples:
    - how to
        - ask guidance of the system
        - interpret the results
        - improve achievement of motivational daily goals
        - respond to a dialogue
        - act on an increased risk of diagnostic suspicions being true
        - ask for further explanations and how to interpret these explanations
    - what diagnostic suspicions the HELICOPTER system continuously evaluates
    - how the HELICOPTER system operates
    - how can I be certain of that it HELICOPTER is dependable, in particular, how is 24/7 ensured and how is the results made reliable

3.6 Planning (caregiver, advanced providee, physician): optional

The user should be able to reason about priorities, time constraints by, in its simplest form, specifying and maintaining both schedules of activities or a list of tasks to be performed. This service should be possible to integrate with other calendar tools via subscription links. According to the responses questionnaire, we should emphasize health-related activities as well as daily tasks.

Some critical risks that were addressed in the responses to the questionnaire are:

- CIID addressed that it may be premature to add planning now, since it may be confusing to the providees Planning can definitely be relevant in a future context, but should follow insights from a (“ prototyping and pilot phase. Adding on to the sensor service at this point, we could risk acting without understanding the behaviours of the community we are operating within.”)
- VSRO addressed that the providees may become overwhelmed (“One risk, if we introduce in the project a big amount of planning features, might be that the platform can become overwhelming for the elder people.”)
- LABIDEE emphasized that it has to be focused on particular parts of planning (“The domain is very large. We should address specific issues.”)

- JIBS emphasized that the providee may become too dependent (“There's always the risk of loosing reflexivity from the users i.e. getting to system dependent. Risky if there is some sort of malfunction/breakdown”). So, if this feature is addressed, then these risks must be mitigated in some way.

3.7 Follow-up on planning (caregiver, providee): optional

If there are plans (schedule of activities or list of tasks), then it is useful to follow-up on the completion of activities and tasks. This can provide information concerning the behavior of the providee and, perhaps, capture early indications of illnesses, for example, dementia.

In its basic form, the providee should see some indication of completion. In a more advance form for the caregiver and advanced providees, it should be possible to check trends, completion degree etc. Note that this is dependent on the planning use case and all risks mentioned for the planning is applicable here too. In particular, it may be confusing to the providee and thereby introduce unnecessary complications to the pilot evaluation (work package 5) within the project.

3.8 Continuous evaluation of status (hypothesis testing and anomaly detection) (system): required

As stated in the Introduction, the HELICOPTER system continuously evaluates hypothesis (E-2) of diagnostic suspicions as well as check for anomalies (E-3) in the daily behavior based on available information sources.

As illustrated, HELICOPTER observes information sources, pre-processes the values and stores the intermediate result in the database. Then, object assessment takes place, where data is anchored to models of the providees. It is desirable to assign certainty to the assocation between providees and sensor readings, for example, if someone who is tagged with an RFID passes by a sensor then we can now with more certainty compared to if we only rely on a passive infrared sensor. Finally, situation assessment takes place, where diagnostic suspicions are evaluated, motivational daily goal progress are evaluated as well as anomaly detection is performed. In the evaluation of diagnostic suspicions, it may be the case that knowing some evidence indicators may tip the evaluation of the diagnostic suspicion one way or the other. When the providee asks for guidance, the system can ask for confirmation as well as for additional information. These questions can be guided by the evidence indicators necessary for the reasoning; for example, see table in appendix “ Connection between diagnostic suspicions and evidence indicators ”

Apart from asking for further information, the resulting action can be to alert or prepare risk presentation by updating it so it is available upon request from the providee. Note that asking for information means that the HELICOPTER system asks the providee, but the rest of the system continues to observe and process while it is asking for further information.

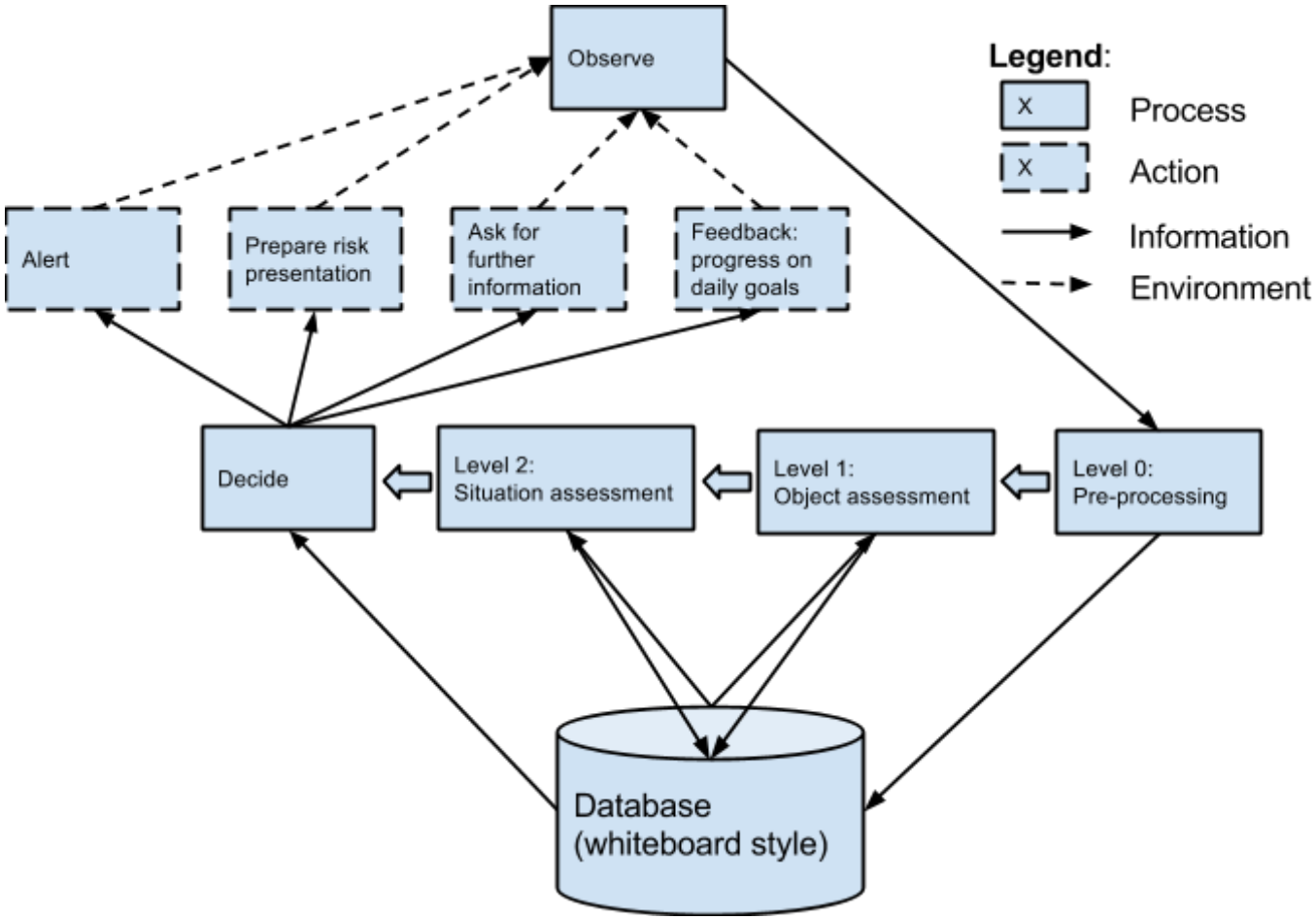

Figure 2 Information flow in HELICOPTER

Important issues are

- to remove noise in the pre-processing,
- anchoring information to providees,
- handling uncertainty in a sufficient way,
- ask for confirmation or additional information from the providee (or caregiver, if applicable), if there are missing information in the information sources (e.g., sensors). Information may be missing due to that *(i)* it is not possible to capture this from existing sensors (e.g., eating more food than usual is hard, if not impossible to check) and *(ii)* unavailability of information source (e.g., a sensor may have run out of power or broken down, the internet may be inaccessible)
- present the results in a useful way to the providee (see ask for guidance use case)

3.9 Reminding and alerting (system): required

If planning is supported, then the HELICOPTER system can remind the providee in a similar fashion to an ordinary calendar service.

Irrespective of if planning is supported, then the system can alert the providee or the caregiver if necessary. Since we do not want the HELICOPTER system to avoid alerting someone unless we are sufficiently certain of that there is a significant risk in not alerting someone. The default is to notify the providee if there is an increased risk of something (e.g., heart failure), and, if the providee does not acknowledge the notification, then notify caregivers (if applicable). Notification of caregivers is applicable if and only if the providee is under formal care of a caregiver or has agreed upon to be supported by someone (e.g., relative).

3.10Configuration, maintenance and support: required

When the HELICOPTER service is deployed in a household, it is desirable to configure and tune the service to, for example, the number of inhabitants in the household, if the provide is suffering from chronic condition etc. to optimize the performance of HELICOPTER. For example, if the provide is a known diabetic, then it makes sense to evaluate the diagnostic suspicions of hyperglycemia and hypoglycemia, otherwise it is not necessary.

Tuning is important to, for example, set the normal rate of toilet visits during the day, how the providee is using electricity etc. While HELICOPTER is being tuned, it will run with limited reasoning capability and ask for confirmation and additional information from the providee or caregiver.

Further, HELICOPTER deployments need to be maintained, for example, regular replacement of batteries as well as replacement of broken units. Special attention has to be paid to adding and removing sensors, preferably this should be possible to be performed in a plug-n-play fashion with as little configuration as possible. For example, the sensors should, at least, have a unique identity and a type so that the sensor specification can be retrieved. Preferably, the sensors should be self-contained and, upon request, present its specification. The SensorML[26] and TransducerML are potential candidates for this. Sensors must be phased in, for example, anomaly detection based on new types of sensors or new sensors in different locations will not provide meaningful results until a sufficient long period of data has been collected (e.g., a week).

Software updates should preferably too be phased in, that is, the old and the new software should preferably work side by side until the database for the new software is sufficiently complete to function by itself. The reason is that the new software updates may required different historical data in the database and will not work properly until it has been filled with data from a sufficiently long period.

3.11Fault management: required

It is assumed that components are either fail-silent, that is, if there is an internal error in the component, then it keeps silent or that redundant components are employed so that we can disregard byzantine failures in components as outliers.

Oversampling[27] and techniques such as Kalman filters[30] are used to handle omissions and timing failures in components and networks. By using time-series analysis based on state-space methods, it is possible to build general models based on several information sources and, if some sensor value does not correlate

[26] http ://www .opengeospatial .org /standards /sensorml and http://www.sensorML.com

[27] If we need to collect data every T seconds, then collect them at least with (T/2-ε) seconds (where ε is a small value). This is according to the Nyqvist theorem to be able to reproduce a signal of frequency 1/T. [30] A Kalman filter can be used to estimate missing values.

with the others, then anomalies can be detected. Under the assumption that multiple sensors are available in a location, then if and only if a majority of these sensors indicate something is it considered true. As a last resort, the system can ask for confirmation of the providee or caregiver.

3.12Support diagnostics (physician): required

The HELICOPTER system should be possible to use for physicians to support diagnostics. For example, to enable checks for trends in movement. This can be viewed as an advanced “ask guidanceof” feature for an expert.

3.13 Community support

To enable a group of providees to act as caregivers for each other, support for a communities similar to social media is desirable. This community support requires special features such sending messages to the providees as well as allowing them to answer. Further, it is desirable to add possibilities to check issues as well as ask questions regarding the HELICOPTER system, the results of the continuous evaluation.

4 Appendix

In this appendix, necessary concepts are listed in a dictionary, diagnostic suspicions are defined, the connection between the diagnostic suspicions and the evidence indicators are listed as well as how these evidence indicators can be connected to different information sources.

4.1 Dictionary

Concept	Type of concept	Description
Providee	Role	See "Overall description".
Caregiver	Role	See "Overall description".
Physician	Role	See "Overall description".
Diagnostic suspicion	Concept	A suspicion of that a diagnosis may be applicable to a providee. See diagnostic suspicions for more information.
Alert	Concept	An audio or visual cue of something is, typically, critical with respect to the activities in question (e.g., forgotten to turn off the range or indication of reduced physical autonomy that significantly increase risk of heart failure). This cue is delivered even though the providee is not actively using the HELICOPTER system.

Concept	Type of concept	Description
Reminder	Concept	A visual cue (or audio cue if this is what the providee wants) when the providee is requesting guidance from the system concerning a task or activity that need to be performed in the near future.
Information source	Concept	Anything that can provide information about the past, the present and speculations about the future. It can be databases, web services, sensors, and simulations.
Evidence indicator	Concept	An indicator of some evidence necessary for the medical reasoning of diagnostic suspicions. For example, “drink more soft drinks” is an evidence indicator used in the diagnostic suspicion “hyperglycemia”. In many situations, it is our contention that we can employ anomaly detection to translate from collected information (e.g., pre-processed sensor data) to evidence indicators.

4.2 Diagnostic suspicions[28]

[33] Dr. Melissa Stöppler. "Hypoglycemia - MedicineNet." 2004. 11 Jun. 2014 < http :/ / www . medicinene t . com / hypoglycemia / article . htm >

[28] The original text was introduced in “ Domain mode l and ontology : System scenario descriptions ”

Diagnostic suspicion	#	Description (what it is and why it is important and feasible)
		the needs of the body

An example of a Bayesian Belief Network for testing the risk of Hyperglycemia looks like:

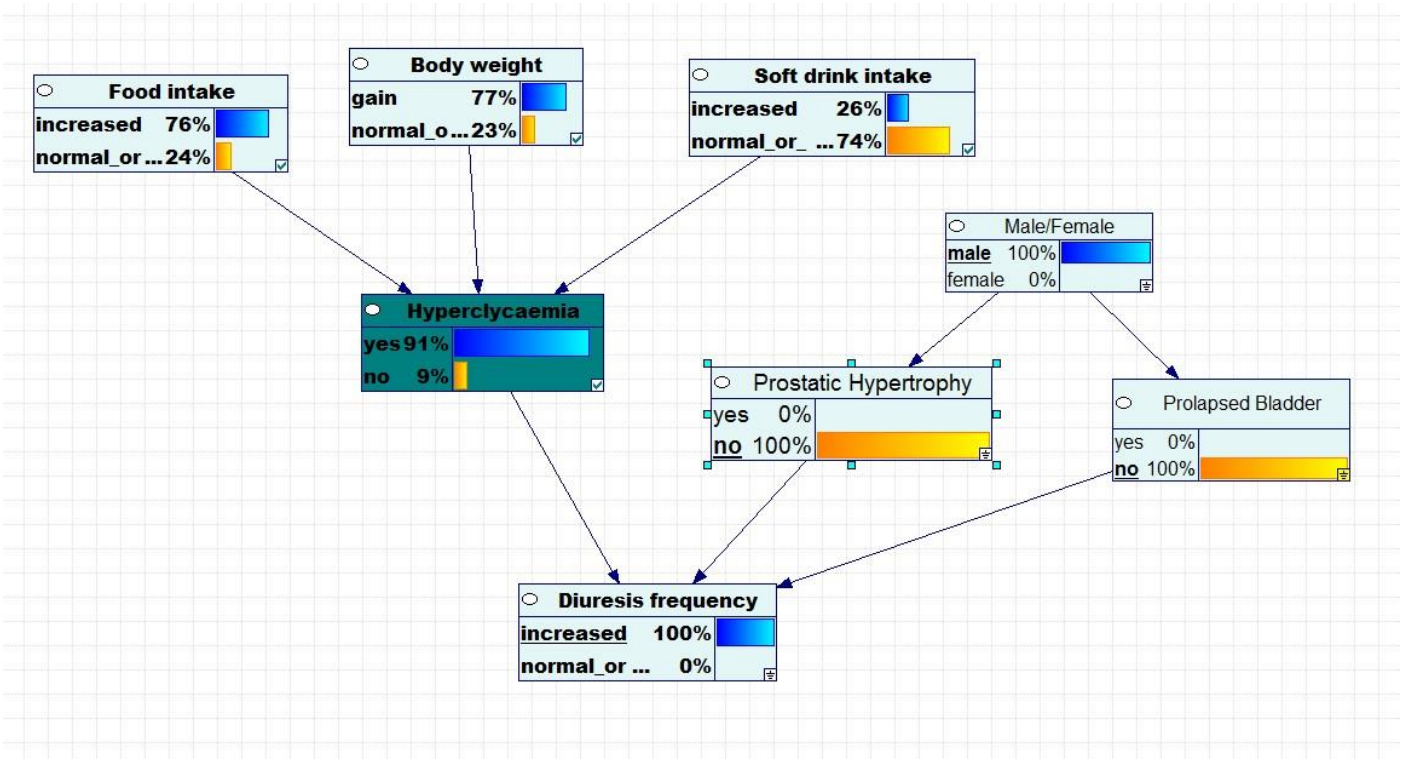

Figure 3: Example of Bayesian Belief Network (partially confirmed validity)

In this example, we have one hypothesis (the diagnostic suspicion hyperglycemia) and the rest are evidence indicator nodes. In this particular query posed to the network, we can see that it is a male diabetic not suffering from prostatic hypertrophy that has an increased diuresis frequency. The other evidence indicators are unknown. The hypothesis yes is 91% (or 0.91), which is above the threshold of 50.2% (0.502) in this particular example. Even if we set normal in the other evidence indicators:

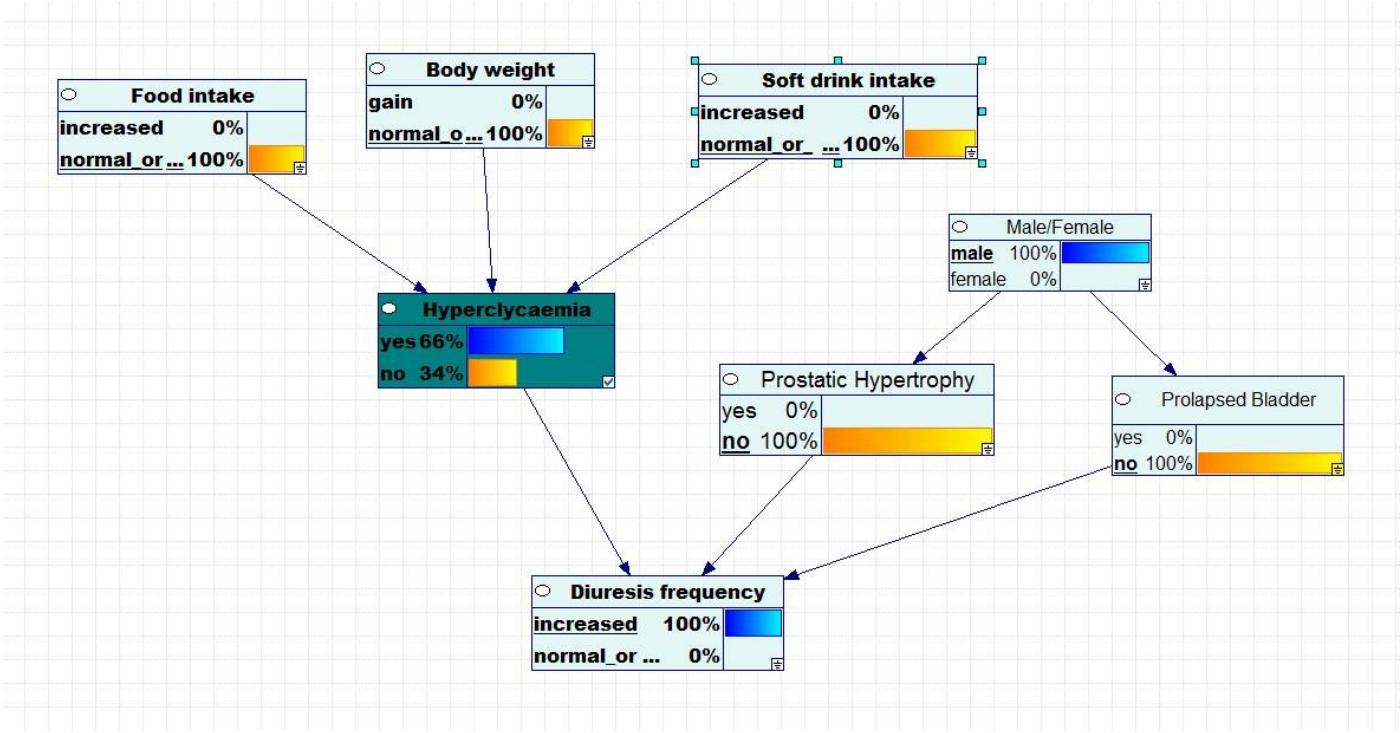

Figure 4: Same as in figure 3, different evidence indicator settings.

it is above the threshold. If the person is suffering from prostatic hypertrophy, then increased diuresis frequency is not in itself a sufficient evidence indicator of increased risk of hyperglycemia:

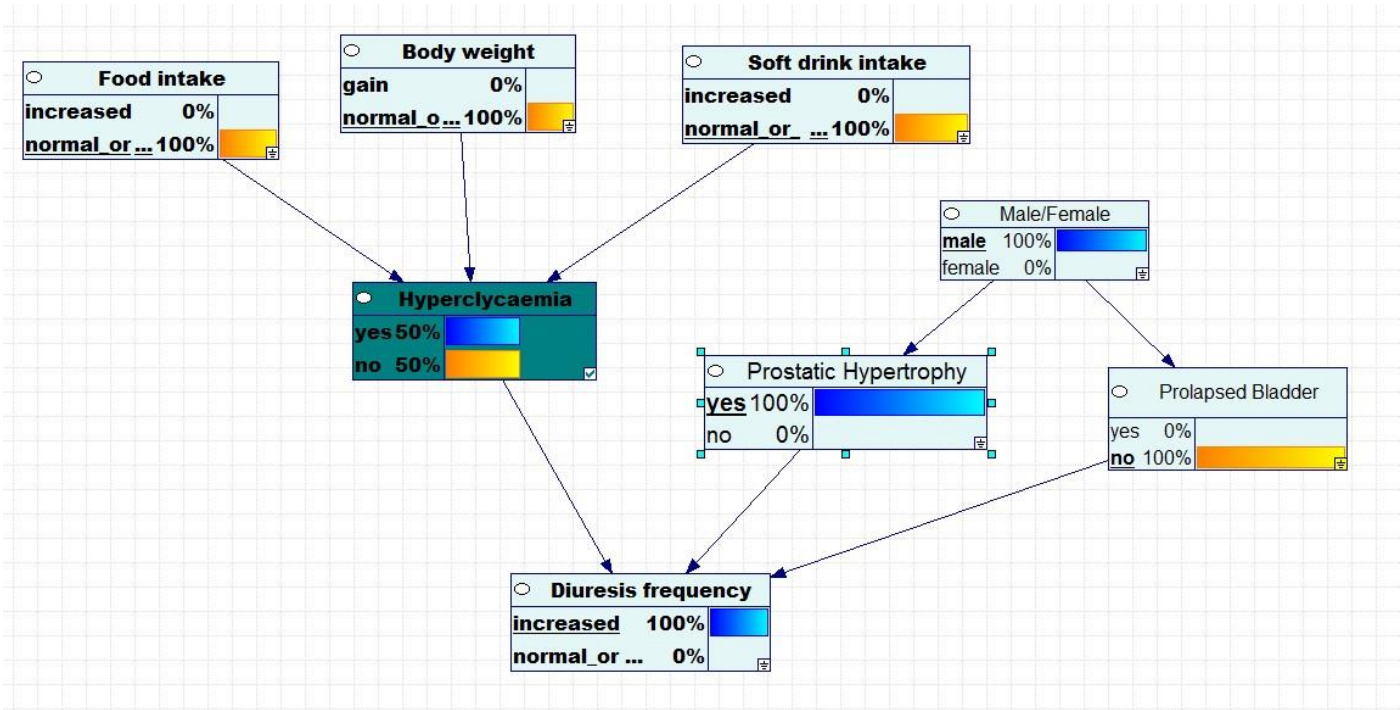

Figure 5: Same as in figure 3, different evidence indicator settings

Note that these are examples and not fully validated yet, this will appear in future documents. In the following tables, we list the connection between diagnostic suspicions and sensors based on the work on Bayesian Belief Networks in this project.

4.3 Connection between diagnostic suspicions and evidence indicators

In HELICOPTER, the following evidence indicators are used to reason about the diagnostic suspicions:

	Hyper-glycemia	**Hypo-glycemia**	**Depression**	**Urinary tract infection (cystitis)**	**Reduction of physical autonomy**	**Benign prostatic hyperplasia**	**Bladder prolapse**	**Clinical heart failure**
Accelerometer		X						
Age			X	X	X			X
Catheter				X				
Diabetes	(X)	(X)						X
Diuresis frequency	X			X	X			X
Fever				X				
Food intake	X							

	Hyper-glycemia	Hypo-glycemia	Depression	Urinary tract infection (cystitis)	Reduction of physical autonomy	Benign prostatic hyperplasia	Bladder prolapse	Clinical heart failure
Food intake: confirmed		X						
Food quality			X					
Gender	X			X				
Hypertension								X
Insuline or insuline stimulating medicine								
Laying			X		X			X
Moving speed					X			X
Open fridge at night		X						
Physical activity		X						
Renal failure								X
Self monitoring not requested			X					
Sitting			X		X			
Soft drink intake	X							
Weight	X		X					X

4.4 Evidence indicator to information source possibilities

This an alphabetical table of information source possibilities such as types of sensors, configuration, humans etc. It is an incomplete list and should be considered as the information sources that are of interest in the HELICOPTER project.

	MuSA[41]	**Scale**	**Configuration**[42]	**Dialogue**[43]	**Passive infrared sensor (toilet)**	**Toilet flushing**	**Food diary**	**Pressure sensor**	**Wireless gate**
Accelerometer	X								
Age			X	X					

[41] Multisensor assistance (e.g., https://www.researchgate.net/publication/220726465_MuSA_a_multisensor_wearable_device_for_AAL)

[42] The parameter can be set in the configuration of the HELICOPTER system.

[43] The parameter can be requested or confirmed via a dialogue with the providee. Should be used with care.

	MuSA	Scale	Configuration	Dialogue	Passive infrared sensor (toilet)	Toilet flushing	Food diary	Pressure sensor	Wireless gate
Catheter			X	X					
Diabetes			X						
Diuresis frequency				X	(X)	X			
Fever				X					
Food intake				X			X		
Food intake: confirmed				X			X		
Food quality				X			X		
Gender			X						
Hypertension									
Insuline or insuline stimulating medicine				X					
Laying	X			X				X	
Moving speed	X								X
Open fridge at night				X					
Physical activity	X			X					X
Renal failure									
Self monitoring not requested			X	X					
Sitting	X			X				X	
Soft drink intake				X					
Weight		X		X					

Edit this form