Guardian Angels
for a smarter life

Guardian Angels White paper
Foreseen Impacts of Guardian Angels technology in different application fields
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Summary

Guardian Angels technology will enable very small size sensor and computing units to monitor the well-being of us and our environment. The Guardian Angels units will be self-sufficient with energy, and thus suitable for long term use without maintenance. Several usage possibilities are foreseen in health, well-being, safety, sustainability and empathic user interfaces.

This report introduces a collection of future visions of different possibilities to utilise Guardian Angels technology. The visions are based on scenarios gathered from Guardian Angels partners in a web survey and via email. In this report we describe the most potential application fields for Guardian Angels technology and describe some promising usage possibilities for each field in the form of usage scenarios. The following application fields have been identified: health, well-being, support for the elderly, extending human abilities, empathic human-technology interaction, safety, traffic and green solutions.

Basically, the promises of Guardian Angels technology are based on the following transitions:

- from signal capturing to decision support
- from signal capturing to feedback and back: creating sustained interactions with end-users
- from one to many sensors
- from controlled environments to mobility (GA systems can be used anywhere)
- from one day battery to fully self-sufficient energy solutions
- from reusable to disposable (size and prize)

Physical Guardian Angels have a lot of usage possibilities in health and well-being. The small size and energy-efficient solutions provided by Guardian Angels technology facilitates versatile and long term monitoring, thus giving more insight to the status of the user and the trends. In many cases emotional Guardian Angels provide additional information of the status of the patient. In fact, Guardian Angels will empower patients to understand and take greater responsibility for their own health – shifting the focus from an illness perspective where the main responsibility lies in the hands of the health institutions in our society (hospitals, company health care), to a well-being, recreational one where users themselves understand and interact with their Guardian Angels to improve their own well-being. Another wide application area is safety. Guardian Angels solutions enable early warnings of possible hazards, thus leaving time to prepare. Some of the safety related applications are based on monitoring the emotions of people in a crowd. These scenarios may be both technically and ethically doubtful.

In human-technology interaction, Guardian Angels technology may enable empathic user interfaces that involve users in experiences where they express themselves and get feedback from the system that creates for even stronger involvement. These systems will offer users “emotional mirrors” that allows them to reflect and act on their own bodily signs and signals that indicate different emotional processes.

An emotion is never a state to be recognised in a human, but instead an on-going process with ebbs and flows, highly interactive with our environment and where we, ourselves, strongly influence our own emotional reactions. These kinds of systems are currently studied quite a lot but the lack of easy wearable sensors systems has prevented wider implementations and trials.

The initial scenarios were presented to experts of the identified application fields to further improve our vision of the future possibilities of Guardian Angels technology. The scenarios were also presented to ordinary people to get their feedback and suggestions. In addition, ethical assessment was carried out with external ethics experts. The feedback is presented in Guardian Angels deliverable 3.2. The new ideas presented in these activities are added to the scenario set but otherwise the initial scenarios are kept here even if they had raised critic. For the future, it is important to be aware also of the not so acceptable usage possibilities. The ethical assessment in D3.2 is also based on the initial scenarios, and that is why it is good to keep the original scenarios here.

Contents

1 Introduction

This report introduces a collection of future visions of different possibilities to utilise Guardian Angels technology. The visions are based on scenarios gathered from Guardian Angels partners in a web survey and via email. In this report we describe the most potential application fields for Guardian Angels technology and describe some promising usage possibilities for each field in the form of usage scenarios. The following application fields have been identified: health, well-being, support for the elderly, extending human abilities, empathic human-technology interaction and human-human communication through technology, safety, traffic and green solutions.

This wide set of scenarios will be used to further refine Guardian Angels vision and to represent it in a selected set of futuristic, scientifically valid scenarios that have high business potential and significant societal impacts. The scenarios will be discussed with experts of the selected application fields to further improve our vision of the future possibilities of Guardian Angels technology. The scenarios will also be presented to ordinary people to get their feedback and suggestions.

Basically, the promises of Guardian Angels technology are based on the following transitions:

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The overall vision of Guardian Angels can be stated as:
Guardian Angels technology will enable very small size sensor and computing units to monitor, provide feedback and involve us actively in understanding and acting on our own well-being and our environment. The Guardian Angels units will be self-sufficient with energy, and thus suitable for long term use without maintenance. Several usage possibilities are foreseen in health, well-being, safety, sustainability and empathic user interfaces.

We have classified Guardian Angel sensor systems into three classes:

1. Physical Guardian Angels facilitate long-term monitoring of health parameters to predict and prevent health problems, and to involve users/patients to actively take responsibility for their own health and well-being through sustained interactions over longer time periods
2. Environmental Guardian Angels monitor the natural environment, buildings and traffic for increased safety
3. Guardian Angels technology will enable empathic user interfaces that involve users in experiences where they express themselves and get feedback from the system that creates for even stronger involvement. These systems will offer users “emotional mirrors” that allows them to reflect and even act on their own bodily signs and signals that indicate different emotional processes.

Guardian Angels project is technically focused on the above described monitoring and processing units. For actual services GA units need to be complemented with actuators to enable interactions with users. In addition to traditional text-based feedback, users can get tactual or sound feedback from actuators. An important part of the applications and services will be signal processing to analyse and integrate the measurement data into situationally relevant information. In the following we will describe the core applications fields for Guardian Angels technology and some usage possibilities for each application field.

2 Health

Guardian Angels technology has various application possibilities in health care. Physical GAs can measure various physical signals, process the measurements and analyse them to provide instant feedback to the patient him/herself or medical professionals. As GA systems are extremely small and self-sufficient with their powering, GA technology facilitates long-term monitoring without disturbing the patients. Measurements that earlier have required hospital environment can be carried out at home. And even beyond monitoring, this will allow end-users to keep track of their own illnesses over longer time periods, actively influencing their own well-being. This is particularly beneficial for people who have chronic illnesses like diabetes, rheumatism, etc. In those you need to keep track of your own life style and making behaviour changes, in order to keep your illness in a better shape. Depending on the measurement needs, GA sensor units can be implanted or they can be disposable, "smart plaster" type of devices that are used when needed. Sensors can also be embedded in clothing. Body area sensor networks can monitor e.g. ECG, EEG, blood pressure, biochemical measures, activity and position.

GA health applications can be divided into three main groups: monitoring medication and the effects of it, monitoring early symptoms, and empowering users to take control over their own well-being, in particular for chronic diseases. Monitoring medication facilitates personalized medication as the dosage can be tuned according to the measured individual effects. The sensors facilitate monitoring both physical and mental effects of the medication. Monitoring the effects of the medication can improve the patient's motivation to take the medicine regularly. Also side effects can be identified reliably from all patients. One interesting usage possibility for monitoring medication is future doping tests for sports. Monitoring early symptoms helps in identifying diseases before they cause symptoms to the patient. This can be utilised with people who for instance have genetic likelihood for certain diseases. Early diagnosis makes treatment much easier. Monitoring physical signals is also essential when treating chronic diseases. An interesting area for applications is pain monitoring. Currently the monitoring in mainly based on the patients' own reporting. With GA technology the patient own reporting can be complemented with actual physical measures of the patient's emotions.

The scenarios in the following are presented briefly and they may give the impression of health problems as something that just has to be fixed by professionals. In practise the situation is more complex and we should think about the role of the patients as well. Users should be empowered to make their own choices; there should be support but on user's own terms. This also rhymes with the problem that our healthcare system is becoming more and more expensive. We need to push back a lot of responsibility to the patients themselves and Guardian Angels technology can help in this. But that involves a shift of authority and power. There is evidence that people with long-term chronic diseases can become more or less well depending on how much responsibility they are able to take over their own lifestyle, food intake, exercise etc.

In the following sub sections we present some scenarios of GA application possibilities in health care.

2.1 Medication

2.1.1 Monitoring medication, effects and side effects

Type of Guardian angel: Physical, emotional

User: Patients and doctors

A common problem is that patients do not take their medicine, take too large dosages or take the medicine too unregularly. For instance, for hypertension, it is estimated that 50% of patients do not take correctly their medicines. With many diseases regular dosage is crucial. Monitoring medication helps

medical professionals or the patient him/herself to check that the medicine has been taken. Monitoring the effects may motivate the patient to understand how the medicine affects and why regular dosage is important. Sometimes, patients do not take their medicines due to uncomfortable secondary effects. Monitoring systematically also side effects helps patients and doctors to understand these effects.

2.1.2 Personalized dosage

Type of Guardian Angel: physical and emotional Guardian Angels (depending on stage)

User: person with physical or mental health problems, medical practitioner, pharmacy industry

By monitoring people continuously on selected physical (and emotional) parameters the effect of a certain drug can be evaluated on a permanent basis and the best treatment for that specific person can be determined. Besides for determining the optimal dosage in general, the GA's could also be used to give triggers when medication needs to be taken based on time or symptoms.

Different stages are possible:
(1) Short term: pure physical parameters for evaluating the effect of a specific drug and determining the optimal doses for that person
(2) Medium term: extending the physical drug influence information with emotional information such that not only the physical impact, but also the way the person feels as a result of the drug delivery is taken into account
(3) Long term: instead of only evaluating the effect of drugs for treatment of physical diseases, emotional GA's could also be used to follow up "psychiatric patients" and the effect of the therapy they get.

2.1.3 Drug development

Type of Guardian Angel: physical and emotional

User: Pharmacy industry

Guardian Angels can be used in the development of drugs or treatments for specific groups of people. Guardian Angels systems enable systematic and wide monitoring of effects and side effects of the medication. This is also related to pharmacogenomics. At first the GA's could be used to better monitor "groups of people" with the same genetic 'background' and as such help the classical pharmacogenetic research. Additionally other measurable parameters can be used to categorize people into groups.

2.1.4 Automatic insulin dosage for people with diabetes

Type of Guardian Angel: physical

User: People suffering from diabetes

Diabetes is a common chronic disease that requires strict monitoring of blood sugar and insulin dosage accordingly. People with diabetes need to have a strict control on their levels of sugar in blood. According to these levels, they have to inject insulin in body before meals, and provide extra sugar to the body in case of low levels of sugar. Although this control can be done effectively by adult people, it becomes harder with kids and older people. Guardian Angels systems will enable constant monitoring of sugar in blood through in-body sensors. Automatic dispense of insulin through insulin-rechargeable actuators will improve the quality of life for people with diabetes. There already exist automated solutions in the market, but their efficiency and ease of use has shown to be insufficient. The

miniaturization of these systems and their autonomy will make a breakthrough in the quality of life of insulin-dependent patients.

2.1.5 Monitoring the efficacy of psychiatric drugs

Type of Guardian Angel: physical, environmental, emotional

User: Pharmacy industry

The efficacy of psychiatric drugs is today proven by observing and interviewing the patients. Observing does not touch the actual feelings of the patients. In interviews and surveys people do not recall all past feelings. In addition the feelings are not only dependent on the medication but also on other issues such as how well they have been sleeping or how sunny the day is. Self-reporting is also very subjective and people tend to change their assessment criteria with time. With Guardian Angels technology, physical, environmental and emotional measures provide objective and accurately timed data, showing the patient's actual activity level, sleep quality and strength and valance of their emotions in correlation with external measures such as weather data.

2.2 Monitoring early symptoms

2.2.1 Black box for the body

Type of Guardian angel: Physical, emotional

User: anyone

A black box in a human body can monitor and store long term all the necessary vital signals. In case of a disease, the causes can be tracked. Similar to the black box in a plane, that helps to reconstruct events before the disease. Also based on black box data, early warning signals can be given. The data does not need to be monitored continuously but for instance once a day is enough for many signals.

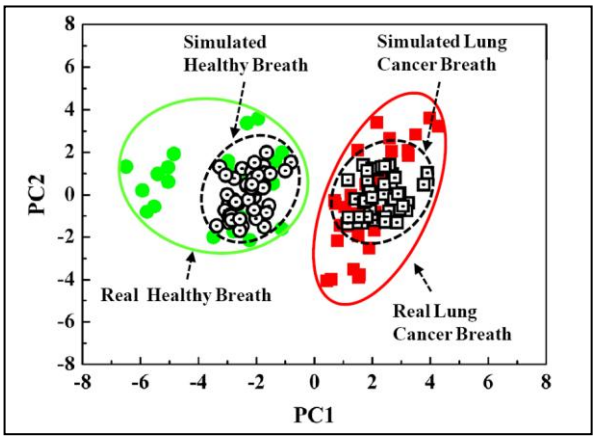
2.2.2 Early warning of cancer and other diseases

Type of Guardian Angel: Physical

User: Everybody

Many illnesses can be diagnosed before you start to feel ill. Based on genetic information, the age and gender of the patient and his/her medical history, certain diseases are more probable than others. These diseases can be monitored to identify the first symptoms and to be early in providing the care.

Cancer is a deadly disease that can strike anybody, without any generally noticeable sign when it is in an early state. As a consequence, cancer is usually detected in an advanced state when it causes obvious symptoms. An example is lung cancer which (by late onset of symptoms) is often detected so late that the average live span after diagnosis is less than 6 months. Chances for curing would be good if it could be detected in an early state.



Recent medical research shows that most cancers (similar to early states of organ failure) cause a change in the human metabolism that create volatile markers that are not present in a healthy organism. These markers can be found in human breath and emanating through our skin. Non-invasive and continuous monitoring can be done by GAs which are equipped with highly sensitive gas nano sensors that continuously monitor our body towards the onset of those marker patterns. Miniaturization and long-lifetime that GA provides are crucial for the long-term monitoring.

Early detection would be useful also with many mental illnesses such as depression and anxiety. Early warning of epileptic fit would protect the patient from hurting him/herself.

2.3 Rehabilitation

2.3.1 Rehabilitation support

Type of Guardian Angel: physical

User: People with implanted medical devices, patients in rehabilitation

Guardian angels systems can monitor electrical and chemical signals from human body. The monitored data is useful in many rehabilitation activities, e.g. in tuning of implanted medical devices, in post-surgery rehabilitation and brain injury rehabilitation. GA units can provide help to people at home after surgical treatment to find suitable level of physical exercise during the recovery.

2.3.2 Targeted brain exercise

Type of Guardian Angel: physical and emotional

User: Patients in mental rehabilitation

Guardian angels systems can monitor the emotional status of a patient and thus support mental rehabilitation. Targeted brain exercises serve both rehabilitation and detection of the status of the patient. Many neuroscientists are exploring protocols that could utilise Guardian Angels technology.

2.3.3 Pain monitoring

Type of Guardian Angel: physical and emotional

User: communicative impaired population

Pain is commonly accepted to be a subjective experience, for which the standard measure is self-reporting. In many cases people are not able to report the pain, e.g. babies, people with cognitive or

communicative impairments and intensive care unit patients. Even with people who can express themselves, it may be difficult to assess the level of the pain. If the patient is not able to express the pain, there are not many methods for determining the presence or absence of pain. Even if some behavioral tools exist (such as those assessing facial expressions, vocalizations, and body movements), they are not very reliable and do not work with individuals with paralyses or other disorders affecting motor behavior. Guardian Angels technology enables continuous, simultaneous and distributed acquisition of several bio signals (such as heart rate, skin conductance, and electroencephalography). By analyzing these signals, the level of pain can be defined subjectively and more reliably. Also long term monitoring is possible to identify trends. Pain monitoring can be combined with automatic drug dosage to improve the quality of life of the patients.

2.4 Empowering users to take control over their own well-being

For many chronic diseases, such as diabetes, rheumatism, chronic fatigue, helping patients to closely monitor the relationship between their everyday activities and their effects on their symptoms, will help them to stay in a better physical balance. Patients with diabetes that keep a detailed diary of their food intake and physical exercise, mapping it to blood sugar level, will learn to stay much more healthy than those who fail to see those connections in their everyday life. The problem is, of course, that not everyone will have the inclination to create such a detailed diary. Combining Guardian Angels for monitoring blood sugar level and bodily movement with tools to create your own diary automatically, including e.g. photographs of your food, can help patients detect their own vulnerabilities and strengths. This is particularly important as there are individual differences in how your body responds to medication, everyday activities and food intake.

Similarly, for life-style related problems, like stress syndromes, monitoring of sleep patterns, emotional arousal and other everyday social encounters, can empower end-users to find patterns in their own life, strengthening the positive patterns, and finding ways for dealing with the negative patterns. This borders on the next section – well-being.

3 Well-being & Recreation

In addition to health care, Guardian Angels technology can be used for applications, with which people can themselves monitor their physical signals or their behaviour. When people can monitor their behaviour and the consequences of it, they get motivated to themselves change their behaviour towards more healthy or enjoyable habits. In practical implementations also peer support is important part of motivation and should be included in the applications. The behaviour changes can be related to healthier eating, getting enough physical exercise, avoiding alcohol or smoking, or avoiding stress. Information may be gatherered also of the amount and quality of social interaction. Long-term monitoring helps in seeing trends and consequences of changed behaviour. Guardian Angels technology with small size and energy-efficiency enables long-term measures without disturbing ordinary life. As the devices are capable to store measured data, people can store whole sports exercises with various physical measures. GA devices can analyse monitored signals real time, and give advice on changing e.g. jogging rhythm.

An important part of well-being is to protect people from harming substances in their environment. People can get warning about allergens in the air, in the food or clothes.

We also foresee a whole class of applications bordering on sports and recreation. Through monitoring bodily movement and feeding this back to end-users, they can change their way of performing sports or recreational activities, such as horseback riding, yoga or other similar activities. People are already today willing to pay substantial amounts to be able to engage in these kinds of activities.

By combining Guardian Angels with Internet of Things, large streams of data can be sent into the cloud where we can find patterns in behaviours, which in turn can be turned into values fed back to end-users.

In the following we present some scenarios how Guardian Angels could be utilised in well-being applications.

3.1 Monitoring body data

Type of Guardian angel: Physical

User: Anyone

The Guardian Angel would be implemented to monitor body data such as hydration, body fat ratio, muscle ratio and mineralisation. Based on the measures people can pay attention to drinking and eating properly and little by little learn healthy habits. Exact monitoring and analysis of food consumption would be useful but it is unclear how it could be implemented in practise. Monitoring hydration is important for elderly people because the sense of thirst may be weakened and dehydration may lead to several well-being problems. A promising possibility is also right kind of breathing as many people can improve their breathing technique for improved wellbeing.

3.2 Monitoring environment for allergens

Type of Guardian Angel: Physical, environmental

User: allergic people, people who want to avoid certain substances

Guardian angels can monitor allergens and other substances that people want to avoid in their environment and in their food. Hypersensitive Guardian Angel systems can sense the food on the plate and give warning when needed. Based on information gathered from Guardian Angels in the environment, personal warnings can be given and local maps of current allergen situations can be provided.

3.3 Balanced food for wellbeing

Type of Guardian Angel: Physical, emotional

User: Anyone

The GA would measure the nutritious values of the food one is eating and would signal when you have had too much of one (carbohydrates for instance) and not enough of another (e.g. vitamins). This would help you to maintain a totally balanced diet which would soon become habitual.

Comment: the practical solution is unclear: where will the sensors be?

3.4 Monitoring moods or Involvement in emotional and bodily experiences.

Type of Guardian Angel: Emotional

User: People interested in self-knowledge, emotional experiences and development

Original version: Monitoring moods

Emotional Guardian Angels can be used or a mood tracker. Seeing your daily emotions and trends in them helps to learn to yourself and what issues in life affect your moods. This further helps in self-development, the user learns to identify what causes negative feelings and how to control those feelings.

Alternative version: Involvement in emotional and bodily experiences.

Emotional Guardian Angels can be used to empower users to reflect on and become more strongly involved with their own emotional processes. By employing a so-called interactional perspective on emotion, we can involve users in interesting interactions. An interactional perspective on design will not aim to detect a singular account of the "right" or "true" emotion of the user and tell them about it as in a prototypical affective computing application, but rather make emotional experiences available for reflection. Such a system creates a representation that incorporates people's everyday experiences that they can reflect on. Users' own, richer interpretation guarantees that it will be a more "true" account of what they are experiencing. This can be used simply to improve your own understanding of yourself, but also to communicate with others in richer ways.

3.5 Monitoring healthy exercise

Type of Guardian Angel: Physical

User: Individuals caring for their health

According to WHO, cardiovascular diseases (CVD) are the leading causes of death and disability in the world. Although a large proportion of CVDs is preventable, they continue to rise mainly because preventive measures are inadequate. Besides an appropriate diet, physical exercise is important preventive measure. The degree of exercise however has to be chosen carefully according to the physical status of the person. Often exercise is done too vigorously (or to weak), limiting its health effects. The best degree of exercise is attained, when the body metabolizes the fat reserves to get the energy it needs. Fat burning, according to recent medical knowledge is always associated with the production of Ketobodies, with the well-known Acetone being the most prominent representative. GAs equipped with gas sensing functionalities monitoring these gases which are present in the breath and are emanated through the skin can reliably monitor the fat burning and thus help doing the exercise at the right level.

Guardian Angels can also advise in food intake, indicating when the energy got from the last meal has been used and when fat reserves are started to come to use. This may help to decide on food intake in order to lose, maintain or gain weight. In here, it is important to develop the solutions in such a way that it empowers the user to monitor his/her habits but leaves the decision to the user. The applications need to support known theories of motivations for behavioural change,

3.6 Preventing sedentary lifestyle problems

Type of Guardian Angel: Physical

User: Individuals with drastic sedentary habits

This is a wider application of the previous concept to influence the current sedentary lifestyle trend; a medical term used to denote a type of lifestyle with no or irregular physical activity. Nowadays, people have changed dramatically their behaviour and they have become more sedentary, motivated by the short periods of free time, the long work sessions and the use of means of transport. A sedentary lifestyle and lack of physical activity can contribute to or be a risk factor for anxiety, cardiovascular disease, depression, diabetes, colon cancer and many other diseases. However, people cannot easily incorporate sport activity in their daily life. Therefore, monitoring of the common human activities can estimate the risk of sedentarism and provide simple advices to increase the mobility. The information retrieved by kinetic sensors and gyroscopes can be used as inputs to a "function of mobility" that evaluates the

amount of mobility found in common activities like walking, climbing the stairs, washing the dishes, etc. This information will be used to propose changes in these activities in order to increase the amount of mobility.

3.7 Improving sports performance securely

Type of Guardian Angel: physical

User: Professional and non-professional sportsmen/sportswomen

Wearable or implantable GAs would allow monitoring the vital signs of sportsmen during trainings and competitions in order to improve their performance as well as to prevent serious physical problems. Important measures include heart rate, breath rhythm, oxygen in blood and body temperature. For instance inner temperature of the body can reveal first signs of heat stroke. These can also be used to improve your positive experience of physical exercise. People do sports because they enjoy them. Getting an even stronger experience and feedback loop that allows you to extend on what you already enjoy in your sports is key here.

3.8 Monitoring the well-being of elderly

Type of Guardian Angel: Physical

User: Elderly people

Aging is a major future trend. The 65+ generation will nearly double by 2030 (from 7% to 12%) worldwide. Independent living at own home is very important for elderly people even if they would need support in some issues. Guardian angels technology can be utilised in different security solutions for elderly. Daily activities can be monitored and a warning can be given when the normal activity patterns are missing. Current assistive solutions are mainly focused on identifying accidents that have already happened (e.g. falling). To provide more preventive solutions, it is important to be able to assess the status of the elderly person. This requires long-term monitoring of the physical and emotional status that can be provided with Guardian Angels solutions. Long term data gives reliable support in assessing the status of the person, in estimating how the status will be changing in the future and in assessing what kinds of security solutions and personal support are needed.

3.9 Epidemiological analysis

Type of Guardian Angel: Physical, environmental

User: mainstream

Epidemiology is the study of health-events, health-characteristics or health-determinant patterns in a population. In an epidemiological study, a broad target population is needed, biomonitoring has to be performed during a period, and the collected data must be analyzed attending to some criteria such the geographical origin. By monitoring a large set of biometric variables of different nature (ECG, EEG, galvanic response of the skin, temperature, gases, kinetic behaviour, etc.), keeping track of the patient's geographical location, and considering some data such as the gender or the age of the subjects, a large set of epidemiological analysis can be done. For example, the world prevalence of epilepsy can be monitored, the evolution of movement disorders can be studied, the response to different treatments and therapies, etc.

3.10 Monitoring the well-being of a new-born baby

Type of Guardian Angel: Physical, emotional

User: parents of new-born babies

The parents of new-born babies are often uncertain as they do not recognize the needs of the baby: is she wet, hungry, bored or is she ill. GA units help the parents in recognizing the needs of the baby and little by little they learn to interpret the baby's cry on their own.

3.11 Stress monitoring

Type of Guardian Angel: Physical, emotional

User: mainstream

An important part of well-being is avoiding excess stress. Today's trend is downshifting: it is not trendy to be stressed and busy. That is why stress monitoring can be combined with social sharing: people can compete with their friends how free of stress they manage to be.

3.12 Sleep monitoring

Type of Guardian Angel: Physical, emotional

User: mainstream

Sleep problems are very common and often the problems can be solved if the person can improve his/her self-knowledgement. GA units can help in analysing what causes sleep problems: eating, drinking, excess stress, physical exercise too late at night etc. Understanding what causes the problems helps people to solve the sleep problems by changing their behaviour rather than with medication.

3.13 Monitoring the quality of social interaction

Type of Guardian Angel: Physical, emotional

User: consumers

The quality of social interaction can be used as a part of overall wellbeing analysis. The analysis may identify which interaction situations cause positive and which cause negative feelings. The results can be used in developing one's interaction skills; self-knowledgement and self-development by identifying which interaction situations cause stress and then analysing why. It is also important to get information on how one influences others (what kinds of feelings do I raise in the people I am interacting with).
The measurements may indicate:

- are there people around
- who are you interacting with (voice-based recognition)
- how are you interacting with them
- what kinds emotional reactions the interaction causes in you, e.g. which interaction situations cause stress reactions.
- what kinds of emotional reactions you cause in others

3.14 Analysing group dynamics at work places

Type of Guardian Angel: Physical, emotional

User: working place

Interaction can be monitored also in occupational health in analysing group dynamics. At a workplace the emotions can be monitored and the information can be used to analyse the wellbeing and the causes for problems. The results should not be presented on individual level but e.g. as general emotional barometer on the wall. The results could be presented visually in real time to give immediate feedback to all. The feedback could be used to encourage employees to e.g. spur on their colleague.

4 Extending human abilities

A quite visionary application possibility of Guardian Angels is extending human abilities and senses. This can used to replace lost abilities for disabled or elderly people but also to increase the ordinary sensing abilities of people. Guardian Angels technology can be developed to extend basically all senses: seeing better, hearing better, smelling better, tasting better or better sense of touch. With GA technology people can sense issues such as radiation, toxics or points of compass. Guardian Angels can be developed for memory support also.

4.1 Extended human memory

Type of Guardian Angel: Emotional

User: everyone

A Guardian Angels based system could be used as a backup system for human memory. On a very futuristic level - far beyond the scope of GA, this may be applicable to people with mild forms of Alzheimer's.

4.2 Augmented Reality Sensory System

Type of Guardian Angel: environmental

User: mainstream

Guardian Angels sensors in the physical environment and with the human user can help the user to detect various issues that (s)he normally cannot see, hear or smell. The user can sense different substances in the air, small movements, temperature, wind, etc. The data can be presented to the user e.g. as augmented reality. These kinds of solutions open the door to an unprecedented relationship between humans, the physical and digital worlds.

4.3 Sensors in gloves connected to GA device for medical or security applications

Type of Guardian Angel: Physical, environmental, emotional

User: persons under surveillance

Gloves can comprise many Guardian Angels sensor devices, either wearable or implantable. Applications will be health and medical (e.g. testing for bacteria, rehabilitation and restoration of

tactility), safety and security (e.g. testing for contamination, contraband, emergency shutoff of machines) and gaming (e.g. motion, tactility and emotion). The same solution can also be utilised in minimally invasive, autonomous body sensor systems for restoration of tactility and improved mobility for persons that have lost a limb or suffer paralysis.

4.4 Voice for animals, Silent voice

Type of Guardian Angel: emotional

User: veterinarians, breeders, animal trainers, pet owners

Guardian Angels technology could facilitate communication with animals and understanding their emotional state. Guardian Angel will be helpful especially in medical treatment or training of animals. Guardian Angels sensors can provide real time information on the animal's emotional status, thus helping the human being to understand the animal better. This would create a revolutionary new relation between humans and animals.
Studies of hunting and how hunters interact with their dogs, reveals that they already use quite some technology to interact with their dogs. They put GPS or mobiles on their dogs, and the result is a closer connection to the dog's activities and the nearness between animal and human (ref to Juhlin and Weilenman).
A more near future possibility would be monitoring how the pet is doing alone at home based on the pet's physical state.

4.5 Sixth digital sense

Guardian Angels can enhance human senses in several ways: people can see round the corner, sense allergens, sense electromagnetic radiation, sense UV radiation, sense toxics, sense points of the compass etc. This phenomena can be described as the "sixth digital sense".

5 Emotionally involving human-technology interaction

Guardian Angels that interact with and spurs human emotions and experiences can be used as the basis for highly involving applications – both in entertainment, but also in serious work environment where emotion needs to be regulated (see studied by Mentis on emotion regulations in the Emergency Room of hospitals, or studies of control room work where boredom creates huge risks for security failures).

We can never know the full complexity of human emotion, but only pick up on aspects of signs and signals emitted as part of the emotional process development. In fact, any system that attempts to reduce what it means to be human to what can be picked up by a sensor on our body, risks dehumanising our understanding of ourselves. Instead, our designs employ a non-reductionist perspective, encouraging expressions that involve body-mind as whole. We need to encourage deeply meaningful, human-centred ways of communicating with ourselves and others, involving our bodies, movements, bio-data, emotions, sociality, empathy in a non-dualistic whole. Here we can envision many different applications that make use of Guardian Angels to:

- Deepen our understanding and empathy with ourselves
- Increases our communication channels with one-another through technology
- Adds to the *value* of both entertainment and serious work-related applications

5.1 Emotion and attention detection

Type of Guardian Angel: Physical and Emotional

User: Depends on the application

Emotion and attention recognition is one of the key steps towards advanced human-machine interaction. Recently, several engineering approaches have been used in order to guarantee acceptable emotion recognition, along with high accuracy, robustness, and adaptability to practical applications. Today emotion detection systems are rather bulky and detection rates are quite low. Guardian Angels technology facilitates easily wearable sensors that pave the way to the development of reliable sensors-fusion-based emotion detection algorithms. Guardian Angels based system can e.g. help in recognizing aspects of emotions of an autistic person, and thus help people to interact with him/her. The same techniques can be utilized in attention monitoring in demanding work tasks for security as described in 8.1. The physical and emotional state can also be used to adapt the level of demand in work tasks or games.

5.2 Technology adapting to human emotions

GA sensors can measure physical signals that indicate emotions such as boredom, anger, joy, fear, excitement and immersion. If technology can adapt to the emotional status of the user, the user will get better user experience. For instance, the emotions may reveal that the user might have done an error even before the user actually makes the error and the technology can prepare for corrective actions. A bored user may not easily react to warning signal or may not read through long instructions. If the user seems to be afraid of the technology, (s)he may need special support.

5.3 Shared experiences

There are several possibilities to enhance the above described applications by sharing experiences with peers. Sharing data will allow for data mining and pattern detection, which in turn can be fed back to users to evoke reflections on their everyday behaviors and bodily reactions. Engaging experiences can also be created by aesthetic, bodily and value-oriented interactions around environmental choices for everyday activities such as choosing food and drinks, hobbies and sports, and daily transportation. Crowd sourcing based on shared sensor data will give several possibilities for sharing experiences.

5.4 Situationally relevant inspiration

Elderly people are often obliged to stay in their beds because of their inability to move. Situationally relevant inspiration can be given to them in the form of personal photos or videos.

6 Safety

Guardian Angels in indoor and outdoor environments provide many ways to improve people’s safety. Sensor networks in outdoor environments can continuously monitor different hazards such as pollution and hazardous gases, radiation or early symptoms of nature phenomena. Outdoor safety can be improved also by permanent monitoring of the mechanical condition of key infrastructures such as bridges and roads. In indoor environments sensor networks can monitor e.g. air quality, allergens or fires. Individuals can be monitored e.g. to inspect if they are carrying explosives or drugs.

Safety solutions include also monitoring the physical and emotional status of people who are working in safety critical environments such as traffic or power plants. These systems help in avoiding human errors. An arguable possibility is monitoring the emotional status of people in a crowd. Can this be done

with Guardian Angels technology? Physical signals of individuals may be monitored if people wear GA sensor units. A more probable solution is to monitor other issues such as movement patterns. These kinds of safety systems can be used e.g. at airports, concerts and sports events.

6.1 Work environment guardian

Type of Guardian angel: Environmental

User: work force

Guardian Angels systems can monitor the environment at the work place for hazards (hazardous gases, acids, temperature, radiation, magnetic fields etc. etc.). Sensor units can be designed for specific purposes and certain risks. There can also be general purpose devices that you can always carry with you and which monitor the most common hazards. Similar system can be useful also at home to monitor allergens, moisture and toxins.

6.2 Monitoring toxins in air

Type of Guardian Angel: environmental

User: Everybody

It is an inconvenient truth, that in modern free democracies terroristic attacks impose an increasing danger to the public Besides work on the political roots, a protection shield against this attacks is an effective technical and mental (discouraging terrorists) means to improve our security. Target is the detection of toxins as well as of explosives (via their emanations, also dogs can sniff explosives). A dense and self-organising network of GAs can be deployed in buildings, public places and transportation facilities. They are networked, quickly detect the dangerous zones and provide a warning to the public and security forces. Early detection of the location of the source gives warnings, before toxins reach adjacent areas and the source can be encapsulated. Primary medium to be monitored is the air, but also drinking water has to be monitored.

6.3 Pollution monitoring

Type of Guardian Angel: environmental

User: Control authorities and possible rescue teams

Chemical-sensing, zero-maintenance Guardian Angels systems, may be conveniently exploited to record level of pollution or presence of dangerous substances in hazardous conditions. As an example, GAs may be left floating along the whole path of a river to monitor its status all the way to the sea. Gas can be used even in larger water bodies to test water conditions close to areas that are critical either for human activities or for wildlife preservation. Accidents such as gas leak can be monitored by distributing GA units to the environment. The GA units will help in monitoring how the leak proceeds and to which directions the gas is floating. Similar solutions can be used in sea accidents such as oil leaks.

6.4 Smart and safe structures

Type of Guardian Angel: Environmental

User: Professional operating personnel

Big industrial structures (excavators, turbines etc.) and also means of transportations (trains, ships or airplanes) require permanent monitoring of their mechanical condition. Early detection or prediction of the failure of the structure will decrease the cost of repair but what is more important may help in preventing the disaster. One example application is easy and reliable monitoring of the mechanical stress in railroad tracks – todays still unsolved. Environmental Guardian Angels will act as a set of sensors measuring and storing the level of mechanical stress, temperature or vibration in vital parts of the structure. These zero-power sensors could be integrated with the structure already at early stages of the construction. This technology can be utilised for all infrastructures: roads, rails, buildings, as well as distribution of water and electricity. Guardian Angels technology can be embedded in materials such as asphalt, rails and pipes. For instance water pipelines can monitor the quality of the water, both fresh water and waste water. GA units can be embedded in the pipes and installed already at the pipe factory. The safety of the fresh water can be ensured and for waste water hazardous chemicals and the source of them can be identified early to be able to prevent fatal consequences. With the distribution of electricity, there is a need e.g. to monitor the tension of cables to identify ice or a fallen tree on the cable before it causes power failures.

6.5 Monitoring visitors at safety critical places

Type of Guardian Angel: Emotional

User: Doctors, nurses, guards, patients

Doctors often feel unsafe when they are on emergency duty at night. Some patients may be under the influence of drugs and they may be aggressive and potentially dangerous. Emotional guardian angels at the waiting room identify potentially dangerous patients in advance and guards can be called out in advance to protect the medical personnel. Same kind of system could be utilised at airports. The monitoring in a safety critical place can be organised so that each visitor gets a wearable Guardian Angels system at the reception. The system can also be used for access control and presence monitoring in the building.

6.6 Guardian Cloud

Type of Guardian Angel: Physical, emotional, environmental

User: People in a crowd

The safety of people in crowds e.g. in concerts, sports events or airports can be improved with Guardian Angels solutions. Data of the individuals wearing GA sensors in the crowd could be gathered to the cloud without singling out individuals. The data could be utilised to assess the overall situation within the crowd to predict panic or just to assess how happy the audience is. The GA systems could also be used as feedback channels in the event, thus increasing the motivation of the audience to wear them. Today the movement of masses is monitored based on camera technology. GA technology may give new possibilities to monitor and forecast the movements.

6.7 Guardian Angels as “disaster managers”

Type of Guardian Angel: all three types of Guardian Angels could be used here in cooperation

User: visitors of big events and rescue teams

Suppose that at a big event where a lot of people are gathered (e.g. a concert, an airshow, …), an event suddenly happens (fire, shooting, storm, terroristic attack, plane crash, …) causing people to get injured

and/or killed and causing a lot of panic. GA's could be of great help for the rescue teams in getting an overview of the situation: both of the people as well as of the environment.
By means of GA signals coming from physical and emotional GA's people could be located and the severeness of their situation (are there still life signals, are they panicking, ….?) could be determined. Environmental GA's could provide additional information on environmental circumstances (e.g. smoke, fire, …). Based upon an analysis of this information, the rescue teams could better organize themselves and work more efficiently. GA's could also guide the 'victims' themselves when they are in panic or hurt, e.g. guiding them to safe places and providing them info about their friends/relatives.

Remark 1: such scenario implies that a lot of 'personal' information is made available for the rescue teams. Information that one does not want to be freely spread in normal situations. So special security/privacy schemes should be put in place.

Remark 2: The easiest place to implement such a scenario would be in a "closed" environment (e.g. on a festival domain, …) where you have some kind of control on the people being there. It becomes much more difficult when you try to implement this as well on more public places, such as shopping malls, and market places where people can pass whenever they like.

In retail, the scenario can be extended for commercial purposes. For the retailer it is interesting to know how people move at the store and which items they study.

7 Lifecycle management and Internet of things

Guardian Angels embedded in everyday items make it possible to monitor and store information of the manufacturing, transportations and usage of them. This enables tracking the whole manufacturing and logistics chain and to monitoring how and how much the item has been used. Maintenance guidance can be provided based on actual need. With GA units condition management can be based on actual wear rather than estimated usage time, thus saving resources in maintenance and improving reliability of machines. The possibilities provided by current RFID and NFC tags will be extended as sensors, memory and processing power can be integrated to the tags.

Exact information of the CO2 foot print can be provided to let people make environmentally sustainable choices. Smart fresh labels on food items can tell people not only best before date but also whether the food is safe to eat, as the GA system can smell the quality of the food. Today, technology is available to identify problems in the cold chain or to tell whether the temperature of a beer bottle is optimal. These kinds of solutions will be extended to many more features with Guardian Angels solutions.

7.1 Manufacturing and Product Lifecycle Management

Type of Guardian Angel: environmental

User: Industry

Physical items can be equipped with embedded Guardian Angels systems. This makes it possible to optimize production processes and to monitor the entire lifecycles of objects, from production to disposal. By tagging items and containers, greater transparency can be gained about the status of the shop floor, the location and disposition of lots and the status of production machines. The fine grained information serves as input data for refined production schedules and improved logistics. Self-organizing and intelligent manufacturing solutions can be designed around identifiable items.

As an object and the attached information processing component are inseparable, from production to the end of the lifecycle, the history of an item and its current status can be continuously monitored and stored. The data reflects a product's usage history which includes valuable information for product design, marketing and the design of product related services. The data also serves in end-of-life decision-making for safe and environmentally friendly recycling, remanufacturing or disposal of the product.

Smart wireless and zero power devices are necessary for implementing these functions and GA technologies have to be considered as key technologies for future RFID and tags in this area.

7.2 Lifecycle management of consumer products

Type of Guardian Angel: Environmental

User: Consumers

Embedded tags and sensors can provide useful functions for consumers by maintaining easily accessible and reliable data of the usage history of everyday products. Bike or skiing helmet could tell if it has been in a shock and thus is not safe anymore. Motorbike could similarly tell if it has fallen and may be damaged. People buying second hand sports equipment could check the amount of usage hours and how mush usage hours are to be expected. This would encourage reuse of everyday items as people can easily check their condition.

7.3 Safe and sustainable food

Type of Guardian Angel: Environmental

User: Consumers

Safety of food can be extended with Guardian Angels units monitoring the cold chain and possible damages. Information of the production and logistics is important for consumers to make environmentally sustainable choices based on the carbon footprint, locality or ethical production.

7.4 Condition management in industry

Type of Guardian Angel: Environmental

User: Industry

Wireless solutions for the condition monitoring of work machines are currently studies a lot. These kinds of solutions are needed as it is crucial to ensure 24/7 operation of the machines. Currently spare parts are changed based on estimated wear. With GAs the maintenance can be based on actual measured wear, thus saving costs and avoiding unnecessary maintenance operations. In these solutions energy self-sufficiency is needed to avoid batteries and extra cables that hinder maintenance operations.

7.5 Checking the origin of goods

GA technology can be used to check and verify the origin of different goods, e.g. spare parts for machines.

8 Traffic

Many of the Guardian Angels solutions presented in the earlier sections have usage possibilities in traffic. Safety solutions can provide drivers and passengers information on road and traffic conditions. Empathic technology in cars and other vehicles can monitor and adapt to driver's emotional status.

8.1 Secure driving, piloting, flying

Type of Guardian Angel: physical/emotional

User: Professional drivers and pilots

Bus and train drivers, airlines pilots and air-traffic controllers among others are professionals with a high level of responsibility since many lives depend on them. A combination of physical and emotional, wearable or implantable GAs would allow monitoring the physical and emotional state (e.g. stress, sleepiness…) of these professionals preventing fatal accidents. The emotional condition of the driver, tiredness in particular, is in current solutions identified based on the pulse getting even and slow and on eye motions. Future solutions could not only identify that the driver is about to fall to sleep but also that his/her ability to concentrate is distracted. Current research is arguing about the roles of automation and driver, e.g. can the car be automatically stopped if the driver seems not to be in the condition to manage the situation him/herself. These kinds of solutions raise also ethical concerns.

8.2 Monitoring road conditions

Type of Guardian Angel: physical/environmental

User: Car drivers

Tires are the car's "interface" to the road infrastructure, so GA units in tries would be especially beneficial. They could monitor both the condition of the tire itself and the road condition, especially slipperiness and bumpiness and keep the driver informed.

8.3 Identifying pedestrians in traffic

Type of Guardian Angel: physical/environmental

User: Car drivers/pedestrians

An important issue is identifying pedestrians in traffic. One solution could be GA-based intelligent cat's eye that could directly inform the driver about approaching pedestrian. However, the scenario requires quite long reading distance.

8.4 Preventing drunken driving

Special systems could be developed to monitor if the driver is drunk or has been using drugs. Drivers with previous court decisions could be obliged to wear GA sensors to prevent drunken driving.

8.5 Other traffic scenarios

Some of the scenarios presented in the earlier sections are especially valid for traffic applications. These include e.g. 5.1 – Emotion and attention detection and 6.4 Smart and safe structures.

9 Green solutions

Many of the Guardian Angels solutions presented in the earlier sections can be used for sustainable solutions that help to protect our environment by saving water and energy or by minimizing waste.

9.1 The caring building

Type of Guardian Angel: Environmental

User: Owners and inhabitants of climatised office and industrial buildings

The air quality within buildings strongly affects or well-being. On the other hand, we use excess energy for climatisation of our buildings. A close and wireless networked system of GAs will be deployed within buildings, so close that is able to monitor the local air quality. This information will be used to make the climatisation intelligent, i.e. to exchange the air where and when it is needed. So overall climatisation energy can be significantly reduced without compromising air quality and avoiding the sick-building-syndrome (which appears in well encapsulated buildings with too low ventilation). Estimations predict a potential of 30% total building energy saving in modern buildings. Moreover the GA network will also monitor the presence of harmful gases (like solvents emanated from carpets, furniture or isolation), will temporarily increase local ventilation and issue a warning that actions have to be taken. The GA network can also monitor the quality of the outside air to decide at which time it is appropriate to bring outside air into the building.

Energy autonomous and wireless devices are required to avoid excess installation and cabling costs for a dense network in buildings. In a next generation, the GAs will also be able to smell dangerous situations, like a beginning fire or the presence of explosive substances.

10 Conclusions

As can be expected, physical Guardian Angels have a lot of usage possibilities in health and well-being. The small size and energy-efficient solutions provided by Guardian Angels technology facilitates versatile and long term monitoring, thus giving more insight to the status of the user and the trends. In many cases emotional Guardian Angels provide additional information of the status of the patient. Another wide application area is safety. Guardian Angels solutions enable early warnings of possible hazards, thus leaving time to prepare. Some of the safety related applications are based on monitoring the emotions of people in a crowd. These scenarios may be both technically and ethically doubtful.

In human-technology interaction, Guardian Angels technology may enable empathic user interfaces that adapt according to the emotional status of the user. These kinds of systems are currently studied quite a lot but the lack of easy wearable sensors systems has prevented wider implementations and trials.

The initial scenarios were presented to experts of the identified application fields to further improve our vision of the future possibilities of Guardian Angels technology. The scenarios were also be presented to ordinary people to get their feedback and suggestions. In addition, ethical assessment was carried out with external ethics experts. The feedback is presented in Guardian Angels deliverable 3.2. The new ideas presented in these activities are added to the scenario set but otherwise the initial scenarios are kept here even if they had raised negative feedback. For the future, it is important to be aware also of the not so acceptable usage possibilities. The ethical assessment in D3.2 is also based on the initial scenarios.