Transformation and New Topics in Health Care: A Short Overview on mHealth and AAL with Example Projects

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Abstract

Health care is in a phase of transition from an analogue system to a digital system. The implications are far beyond the technical aspects. The use of mobile devices is changing health behaviour and brings monitoring functions to the center of attraction for low cost diagnostic processes. Already in some research projects, this is an idea instrumentalised to identify changes in health of elderly people. Also the use of wearables and the use of personal health data for individualizing health and care interventions is needing theories and strategies to support a new health system with a wider health economy. With concepts of health data and a methodological approach of *transponding*, a practical approach is at hand. All developments summarized that are at hand lead to a number of assumptions that describe the drive of the developments in health care. Health will be understood as a construct of several components and behaviour will be a chance for early detection of diseases and help in chronic disease management. This paper tries to provide a short overview of developments, approaches, method and thesis that are characteristic for the work in R&D projects.

Keywords: health care, systematic construction of health, frailty prevention, behaviour monitoring, transponding

List of Abbreviations

AAL	Ambient Assisted Living
eHealth	Electronic Health (focused on electronic health records)
mHealth	Mobile Health
AHA	Active and Healthy Ageing
ECG	Electrocardiogram
MCI	Mild cognitive impariment
WHO	World Health Organization
MRI	Magnet resonance imaging
RCT	Randomized controlled trial

Introduction

Between 1990 and 2000 literature about eHealth increased dramatically as medical informatics started to position itself (Mihalas et al. 2014) and the dot com era was causing big waves. eHealth as electronic supported health was a trigger for improving efficiency in health care (Meier, Fitzgerald, and Smith 2013). The early adopters could be found at hospitals. The need for documentation and the request to get information faster was a major driver for the development of electronic documentation systems and electronic health records. With the first image processing of MRI and the digitalisation of diagnostic machines eHealth became more and more oriented towards management of electronic records and diagnostic results. In 2002 the term Ambient Assisted Living (AAL) started to bring digitalization towards ageing and age-related health problems (J.C. Augusto, M. Huch et al. 2012). With the first step of supporting hospitals having been completed, the target group of vulnerable people became more attractive. Especially the term Ambient Assisted Living takes into account a specific target group: the seniors. As a target group with a high potential in terms of market figures, they became the focus of specialized developments with a major focus on usability and easy access for lay persons. Since then, the AAL has adjusted and broadened to a redefined target group and the meaning of AAL has changed to Active and Assisted Living as the market, which everyone was expecting to explode, did not get running. Since 2012, body worn sensors have become more interesting to the lifestyle target group. Starting with step counters, the development rapidly evolved until a selection of mobile pulse oxymeters, wireless blood sugar measuring devices, 24/7 heartrate monitoring and shirts with woven in ECGs became available to the broad customer. Furthermore, sensors within mobile devices like smartphones are becoming ever more accurate and can therefore be considered an additional potential source of data. This started the time of mobile health (mHealth).

Alongside these technological developments, a strategic aim for Europe was launched in order to catch up the spirit of health as a lifestyle and the term Active and Healthy Ageing (AHA) became popular. This concept aims at maintaining the idea that keeping up a good level of health is a positive experience for as long as possible. With people in mind that run Marathons at the age of 80 and beyond, fighting lifestyle related diseases like diabetes or hypertension, the AHA movement was an economic need as well. Costs started to explode with better health treatment and better chances for acute interventions in hospitals. The better such medical treatment become, the more expensive the follow up costs appear to be. To re-balance this in an ethical way, active and healthy ageing is the hope of many.

Together with these developments, the interaction system between medical staff and their patients is changing. In (European) Health Care, the medical doctor is the main authority in therapy, the role of patients is the one to follow the prescription. Health Care is a hierarchical system that demands compliance. With new sensor technology in the area of AHA, the role of patients can change.
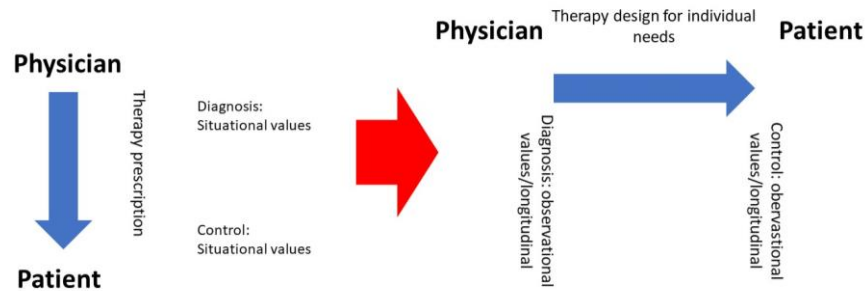
Figure 1. Transformation process through information.

The data collected by patients through wearables is changing the information level from a top-down relation between physician and patient towards an equal information level with two different kinds of information types: data from the patient side vs. experience from the physician side (see Figure 1). Data has to be interpreted, which makes the physician the backbone of health systems in modern medicine, only in the role of a supporter rather than in the role as a commander. This mind set is already more established.

Following this development, a problem is likely to develop when dealing with patients with neurodegenerative diseases, as the expectation of these patients is to be accepted as an equal to the physician, but they usually lack the cognitive resources to fully understand the situation and their arising limitations.

The concept of using sensors to support therapy can help in such situations as well providing data instantly to the patient and being able to directly provide a report on the situation through these means provides direct report on the situation. This probably makes it easier for people with mild cognitive impairments (MCI) to understand their own changing state of mental health.

Overview over Topics in Nowadays Health Care

 The development from Ambient Assisted Living towards Active and Assisted Living did not take a long time to progress but a change in mind set of people in research, industry and stakeholder did. Although the acronym has stayed the same, the meaning has changed dramatically. The main development in understanding AAL was to go from a device oriented approach towards and end user driven support. Although it must be noted, that it is not the primary end user that is the main target group but rather the secondary and tertiary end user. So the focus on family members and care organizations has increased considerably compared to the earlier meaning (Aumayr 2016a). Also included in the new meaning, is the idea of encouraging people to better adherence through these monitoring and potential alarming systems if an individual's behaviour is not supportive for the ageing related interventions. Even if not all current systems can provide such functions and potentials, a lot of elderly people fear that such systems would not be beneficial for their lives, the main fears include a loss of independence and self-control (because they feel they are being monitored and controlled) as well as a loss of or negative change in personal image (through seeing the results of the collected, objective data).

The EU runs a funding instrument named AAL Europe where the concept of AAL is described by six aims:

- extending the time people can live in their preferred environment by increasing their autonomy, self-confidence and mobility;

- supporting the preservation of health and functional capabilities of the elderly;

- promoting a better and healthier lifestyle for individuals at risk;

- enhancing security, preventing social isolation and supporting the preservation of the multifunctional network around the individual;

- supporting carers, families and care organisations;

- increasing the efficiency and productivity of used resources in the ageing societies (AAL - Active and Assisted Living Programme n.d.).

AHA

Active and Healthy Ageing (AHA) is a key phrase for a set of interventions that support the health status of people that are within vulnerable target groups or tend to be progressing towards a state of disability or negative ageing. AHA was described by the WHO: "Active ageing is the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age. It applies to both individuals and population groups" (World Health Organization n.d.). In this context, "active" focuses on integration and social inclusion, not just on physical activity. The interrelation between both is obvious. But to support just activity, would fail the concept. Activity can be considered to be an economic activity, a spiritual activity, a cultural and social activity as well as participating participation in civic affairs. Health aims at physical and mental wellbeing as well as social wellbeing. AHA is a concept of quality of life that is supported by intergenerational solidarity and interdependence.

From a practical perspective, this concept has the same basis as AAL. Whereas AAL is technology-based, AHA is open to solutions from a broad range of disciplines and is less focused on ICT support.

Mobile Health

Mobile health (mHealth) is a summary of technologies that are related to health behaviour and monitoring on the basis of a mobile device. The mobile device can be a mobile phone or smartphone, wearable or tablet. Any mobile communication device can be used as a health related device. mHealth is by definition of the Foundation for National Institutes of Health "the delivery of healthcare services via mobile communication" (Torgan 2009). The main benefit of this use of technology is in the lower cost compared to diagnostic machines. Also, the measurements can be taken more often and by the patient him- or herself. This is important for people living in rural areas, with chronic diseases or living in less economically developed countries where top diagnostic equipment may not be accessible to everyone. The WHO and Médicins Sans Frontieres use mobile applications for eye diagnostics in third world countries where the medical devices would be too expensive, and the application delivers a level of accuracy close to that of the more expensive medical devices. This data is maybe not suitable for the needs of a study but fulfils the objective of helping people.

Health Data

Health data, in a classical sense, describes data collected to provide information about the health status of a society. It deals with bigger populations and comparisons over one or more years to provide an insight in the health behaviour of nations or social groups. In recent years, personal health data was added to this concept by using health data on an individual level. By giving patients the chance to collect data by themselves, personalized data sets could be gathered and provided better insights in the individual health situation. The most prominent issue with the collection of such data was the self-measurement of blood pressure, mainly because the procedure with analogue devices requires proper implementation and most automatic devices have considerable inaccuracy so that the resulting data should be used with caution (keeping these inaccuracies in mind).

In 2015, Aumayr proposed categories for health data according to the use and processing of the available data:

- Basic data: heart rate, SpO2, blood sugar, breathing frequency, etc.

- Processed data: heartrate variability, HbA1C, stress level, etc.

- Interpreted data: diagnosis of disease

- Class of understanding data: therapy design (Aumayr 2015)

This allows a classification and relation between different data sets as well the hierarchical integration of data sets in software engineering. Data from questionnaires and assessment instruments (e.g. MMSE, GDS etc.) represent basic data at the questionnaire level. When evaluated and compared against thresholds, they become processed data. If a diagnosis is made based on these data, diagnosis is then considered interpreted data.

Health as a Construct

Health can be understood as a threefold situation of "social aspects", "cognitive and psychological aspects" as well as "physical aspects". This concept has been well known for a very long time and was already applied in traditional forms of constructions devoted to health like in an Asklepieion[1] in ancient Greece. There are also important spiritual aspects, but in literature, it is very rare to have RCT-like evidence for spiritual effects that are not considered as cognitive or psychological effects. Therefore, they are summarized under the cognitive and psychological aspects. All factors are interrelated in one way or another so they are hardly assessable without an understanding of the others.

Physical Aspects

The physical aspects of health are related to the metabolism, cardiac system, neurological system etc. These aspects include diagnostic processes with blood samples, tissue samples, MRT, EEG, ECG etc. Most of what we thought to know in the last years has changed because of a better understanding of genes, epigenetic, neurology, new medications for chronic diseases and improved surgery methods. Especially in the area of chronic disease management, the interrelation among health aspects becomes clearer. This implicates also neurodegenerative diseases as the decline over time is a chronic disease with no hope for improvement. This produces a special dynamic in the health system.

Cognitive and Psychological Aspects

The cognitive and psychological aspects are dealing with mild cognitive impairments (MCI) as well as with Alzheimer disease or depression. Within the project IMPETUS (2015-2016) the potential of ICT supported psychological intervention platforms for age related depression was analysed, the research team successfully evaluated the position of the diagnosis of depression in the health care system of Austria. It was interesting that depression was a standard diagnosis in senior care but rarely treated as such. But the impact on health and compliance is dramatic. The relation between the cognitive and physical aspect is very strong (Moussavi et al. 2007). Moussavi et al. showed that depression has an effect on comorbidities to a much larger extent than other comorbidities would. One explanation from the experience in Austria is that if a patient is suffering from a lack of motivation and has lost the personal meaning of life, then why should this person take any medication to prolong life? This extreme example shows the dynamic between the two aspects. A study by Ciechanowski et al. (2000) showed that people with depression have a lower compliance in dietary recommendation and medication intake for their diabetes treatment than people with low or no depression (Ciechanowski, Katon, and Russo 2000). Also, the positive effect of a collaborative care model (a model which includes psychological care) was shown in a study by Unützer et al. (2002). The study showed that the effectiveness of the Improving Mood-Promoting to Access to Collaborative Treatment (IMPACT) had significant impact on quality of life, depression and satisfaction with care (Unützer et al. 2002).

Social Aspects

The social aspects of health are related to inclusion of people in a working and positive social environment. Two main terms are related to the negative aspects of it: loneliness and isolation.

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[1] An asklepieion is a form of ancient hospital. The hospital followed the idea that the patients have to be healed in physical, psychological and spiritual conditions and each disease had an effect on all three aspects. As the psychological, spiritual and physical aspects built the foundation, a temple or church could be found at the top of each asklepieion.

Whereas loneliness is the perception of the individual and depends on the psychological state as well, isolation is something that is experienced as from outside of the patient (e.g. stigmatisation, avoidance, etc.). Both aspects focus on the loss of the social role and social bindings in a community. Loneliness and isolation are strongly related to worsening health problems. For depression see (Luanaigh and Lawlor 2008); for cardiovascular risk see (Hawkley et al. 2003). The interrelation between social aspects and cognitive as well as physical aspects was shown in 2009 by Cornwell and Waite. The effect was mainly visible in the self-perceived health status. They see social disconnectedness and perceived isolation as something working together and inflicting problems to health (Cornwell and Waite 2009).

House et al. showed that mortality risk is decreased if the social integration is high (House, Landis, and Umberson 1988). This shows that the social aspects are strongly related to mental and physical wellbeing and should therefore be considered more strongly as a vital part for maintaining a good quality of life by the health care sector.

Each disease can be analysed in its impact to health by identifying potential effects on each aspect of health. The most promising way to analyse these interrelations is a systematic approach which combines health, behaviour and the personal evaluation of the patient with regards to the situation. This should be done following the three aspects of health as mentioned above.

Systematic Approach for Mapping Behaviour Changes to Health Situation

A system is an interdepending group of actuators that are interacting in terms of autopoiesis and increasing the self-referential elements. The complexity of the interaction and the interrelation grows with time and stimuli from its environment. For these kinds of systems, called autopoietic systems (Maturana and Valera 1982), a determination would be that the environment can stimulate the system but not really interfere with it.

When considering health, there are some aspects that can be clearly influenced by the environment, e.g. accidents. It is therefore necessary to accept health as a system that is para-autopoietic. As long as the stimuli are not as strong as the system elements, environment may stimulate the system but not interfere. But if the stimulus is stronger than at least one main element of the system, the system will be damaged. One example would be the death of a close relative. This is a disrupting act towards the social and psychological aspects and can lead to severe effects like depression. Another example would be a car accident. The physical disruption by the impact of the car accident is directly affecting the physical element and bringing severe damage to the system. Another aspect is that constant stimulation of a factor can lead to exhaustion or structural decompensation and result in the breakdown of a structural element. This can lead to a system failure.
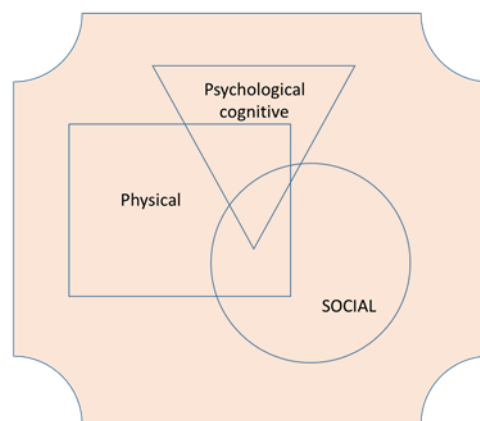
Figure 2. Individual's health system by systematic approach.

Burnout syndrome can be pointed out as an example of how a multifactorial permanent stress to the system can lead to a serious disease. This idea of a health SYSTEM at the individual level can support the ways in which we analyse how diseases and comorbidity can affect the patient (see Figure 2). There is a chance that, by increasing our understanding on an individual level, we

can further support such individuals when they have to cope with critical life events. Following the idea of Salutogenesis (Antonovsky 1997), health is a state of being which can move between two poles, life and death. The tendency towards one of these poles defines the outcome. Antonovsky wanted to find factors that keep people healthy under extreme situations. in order to do this, he developed the concept of the SOC - sense of coherence (Antonovsky 1993). The three main features of the SOC are Comprehensibility, Manageability and Meaningfulness. The most powerful feature is the Meaningfulness as it is similar to a drive for motivation. Compared to the model of the individual's health system, each aspect can be related to one feature. Physical aspects are part of the manageability and the comprehensibility is connected to psychological and cognitive aspects. The meaningfulness relates to the social aspect of health. This is plausible when taking into account that the search for the social role and position is considered a basic drive of human nature. Maslow (1954) described this as the three upper levels in the hierarchy of needs whereas love and belonging is below esteem and self-actualization is ranked highest of all (Maslow 1954). All three elements need a social environment.

The theoretical approach discussed here can be found in some of the recent projects that the authors are involved in. Each aspect of health is covered and interrelated. As a proof of concept, three projects are described to show the practical implication of a systematic approach on health following the idea of an individual's health system.

Behaviour as Key Data Source

In many studies it was announced that behaviour monitoring can support in analysing the activities of daily life and make changes in this pattern obvious for care givers (Aran et al. 2016; Chetouani, Cohn, and Salah 2016; Werner et al. 2013; Zagler, Panek, and Rauhala 2008). This should increase the efficiency of care in terms of early detection. Especially for Alzheimer disease, recording changes in behaviour would be both interesting and valuable for further research.
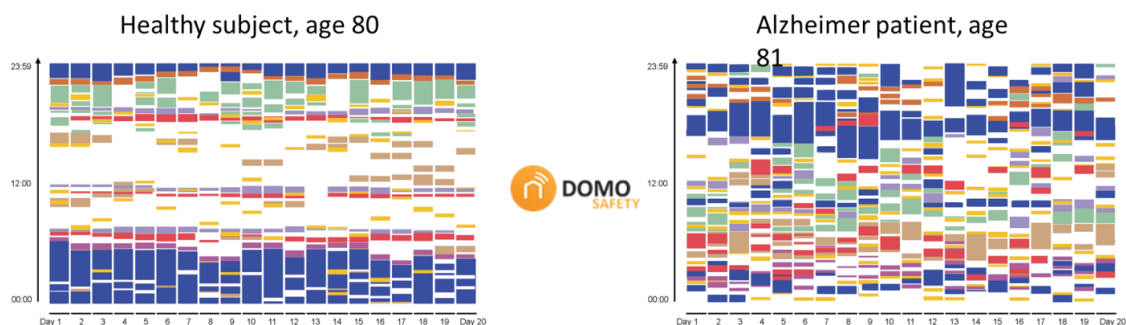
Figure 3. Structure of a day by ADL. Image provided by DOMO-Safety System, http://www.domo-safety.com

The structure of daily life can be organized in sleeping phases, activity phases, relaxation and daily routines. A normal day is therefore rather structured with little variation. When monitoring a patient suffering from Alzheimer, the structure becomes disrupted. With the DOMO Safety system, a visualization of this structure is possible and impressively shows the effect of a disease on behaviour as well as highlighting the potential of behaviour monitoring for early detection (see Figure 3).

To achieve a high quality in mapping behaviour and diagnosis, a standardized model for this transition is needed. Reference (Aumayr 2016b) suggested *transponding* as a process model for relating diseases with the potential of sensor based behaviour monitoring (Aumayr 2016b). This 8-step concept follows the basic idea of formalizing development and innovation including all legal requirements from the beginning onwards.

With working systems for monitoring behaviour and a systematic approach to link diagnoses and behaviour, the proof of concept is the next step. This is done within several projects on international and national scale (see Table 1).

Examples of Running Projects (2017)

SOCIALCARE

SocialCare (AAL - Active and Assisted Living Programme 2016) is an AAL-Project running from 2015 to 2017 which aims at providing a digital networking platform for volunteers, neighbours, family members as well as professional caregivers on a local scale. The platform will enable older people (65+) to:

- Access professional and voluntary care and wellbeing services, the main focus being on integrating environmental sensors such as motion sensors or microphones for the home as well as bio-sensors such as blood pressure or blood sugar in order to monitor physical health parameters (= care component, IoT component);

- Stay in contact with their peers and other members of the community by allowing people within the community to create activities and associations (= social component);

- Learn from the extensive database which will provide support and information for frail older people. Trainings will also be provided on demand, allowing caregivers to stay up to date with current first aid and care/nursing practices (= learning component);

- And therefore live longer independently at home.

The project aims to support and promote such social innovation processes by bringing together both stakeholders and citizens. Pilot testing will ensure that the application meets the required needs in providing the care, social and learning components and thereby improving the lives of the elderly within the set trial communities.

WAALTeR

The nationally funded AAL-Project WAALTeR, "Wiener [Viennese] AAL Test Region" running from 2016 to 2019 focusses on social integration, security, health and mobility for elderly people who wish to live autonomously for as long as possible.[2] Based on previous AAL Projects, WAALTeR aims to develop individual service packages for elderly people based on the following themes:

- Social integration: a social calendar allows users to network, creating events or get-togethers. Through an interest-based database, users can search for people with similar interests as well as people looking for assistance or simply just companionship for accomplishing routine tasks such as grocery shopping.

- Safety: a sensor placed within the house is able to recognise falls and call for assistance accordingly. A mobile emergency call button can be used to recognise falls that occur outside the home.

- Health: a tablet-based fitness programme encourages people to stay fit by providing fitness courses, keeping track of daily activities (for example by coupling a pedometer to the AAL-system). People with chronic illnesses can additionally add or synchronise their personal data (for example blood sugar levels, blood pressure levels) to the system, which in turn can greatly help the physician in adjusting further treatment strategies.

Mobility will be addressed within all three aforementioned topics with the overall aim being an improvement in quality of life by encouraging individual activity, social integration, societal participation and greater autonomy.

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[2] http://www.waalter.wien/Startseite

My-AHA

My-AHA[3] is a 4 year H2020 Project which started in 2016 and aims toward reducing and preventing frailty. Factors impacting frailty have been classified into three groups that can be monitored through several wearable devices, a smart phone (various apps), and ambient assisted living based sensor devices:

- Cognitive factors which include all cognitive senses and will be monitored and improved through cognitive games and exergames;

- Physical factors which will be monitored by vital data, as well as data on gait speed, quality of sleep and fall risk as well as movements and activities in general;

- Social factors will be monitored by analysing emotions and the quality of speech of the users.

Conditions of the users will be assessed in detail through various cognitive, physical, psychological and social tests at several intervals during the first smaller (3-month) and second larger (18-month) test period. During these trials:

- VitaDock (a cloud-based solution) will collect vital data;[4]

- VitalinQ is a platform that supports a healthy lifestyle;[5]

- The iStoppFalls (an ICT-based system) collects data on falls, the risk of falls and encourages activities that lower the risk of falls;[6]

- And finally the Smart Companion Application offers an android customisation designed to address the specific goals and needs of elderly users, such as medication reminders, geofencing, turn-by-turn navigation, fall detection as well as allowing for easy communication with caregivers to provide an additional sense of safety and protection.[7]

By improving the ability to detect an increase in risk for frailty, intervention tools and strategies can be put in place to prevent or reduce frailty accordingly.

Table 1. Overview of projects.

Overview	SOCIALCARE	WAALTeR	My-AHA
Main focus	Social network and neighbourhoods	Testing region for technology focused on ageing	Frailty prevention
Method	Fieldtrial	RCT	RCT
Number of Participants	50-60 individuals	83 households (about 100-130 individuals)	600 individuals
Length of trial	8 weeks	18 months	18 months
Number of participating countries	2	1	7

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[3] http://www.activeageing.unito.it/
[4] https://cloud.vitadock.com/
[5] http://www.vitalinq.nl/
[6] http://www.istoppfalls.eu/cms/front_content.php
[7] http://smartcompanion.projects.fraunhofer.pt/

Behaviour Health Sensors as Support for Increasing Effectiveness in Health Care

Following the results of the ongoing projects, behaviour and health are closely related and measurable with sensors. Indicators of behavioural changes can be logged and linked towards potential diseases. There are also positive effects on the self-efficacy of the users and increased motivation. By this promising result, the following assumptions may be made and discussed:

If diseases can be monitored and analysed with a variety of sensors that map behavioural aspects to health developments, it will be possible to:

1. Identify early signs of frailty;

2. Identify risky behaviours;

3. Increase self-awareness of patients;

4. Increase feeling of self-efficacy of patients;

5. Increase therapeutic effects;

6. Decrease general costs in care of each individual;

7. Deliver personalized health care with higher quality (in effectivity and adherence).

In a next step, the idea will be supported by developments in the area of artificial intelligence and increase the practical aspects in order to support the early detection and pattern recognition semi-automatically.

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