Smart, Personalized and Adaptive ICT Solutions for Active, Healthy and Productive Ageing with enhanced Workability

Dimitrios Giakoumis[†]
Information Technologies Institute,
Thessaloniki 57001, Greece
dgiakoum@iti.gr

Konstantinos Votis
Information Technologies Institute,
Thessaloniki 57001, Greece
kvotis@iti.gr

Efthymios Altsitsiadis
KU Leuven
Leuven 3000, Belgium
efthymios.altsitsiadis@kuleuven.be

Sofia Segkouli
Information Technologies Institute,
Thessaloniki 57001, Greece
sofia@iti.gr

Ioannis Paliokas
Information Technologies Institute,
Thessaloniki 57001, Greece
ipaliokas@iti.gr

Dimitrios Tzovaras
Information Technologies Institute,
Thessaloniki 57001, Greece
dimitrios.tzovaras@iti.gr

ABSTRACT

Along with population ageing comes the increasingly intensified phenomenon of a shrinking and ageing workforce. Novel solutions are needed so as to help ageing workers maintain workability and productivity, along with a balance between work and personal life, which supports them into good quality of life, active and healthy ageing. In this line, the "Ageing@work" project, initiated by the European Union, develops a novel ICT-based, personalized system to support ageing workers (aged 50+) into designing fit for purpose work environments and managing flexibly their evolving needs. On top of personalized, dynamically adapted worker and workplace models, computational intelligence will assess user specificities and needs i.r.t. work conditions, both in terms of ergonomics, health and safety issues and task assignments. Recommendations will then be provided both to the worker and company, under strict privacy restrictions, on how the working conditions must adapt. The worker models will be populated by unobtrusive worker sensing, both at work, at home and on the move. To foster workability and productivity, personalized, intuitive, age-friendly productivity, co-design enhancement tools will be developed, including ones for AR/VR-based context-awareness and telepresence, lifelong learning and knowledge sharing. On top of these, a novel Ambient Virtual Coach (AVC) will encompass an empathic mirroring avatar for subtle notifications provision, an adaptive Visual Analytics – based personal dashboard, and a reward-based motivation system targeting positive and balanced worker behavior at work and personal life, towards a novel paradigm of ambient support into workability and well-being. The integrated system will be developed by user-centered design and will be evaluated at two pilot sites, related to core Industry 4.0 processes of mining and machines production.

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CCS CONCEPTS

Applied computing → Life and medical sciences → Health care information systems; **Human-centered computing → Collaborative and social computing →** Collaborative and social computing systems and tools;

KEYWORDS

Ageing workforce, workability, age-friendly workforce management, eHealth, Virtual User Models

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1 Introduction

The ratio of people of working age (15-65) to people aged over 65 is decreasing and is expected to decrease further in the coming years [1]; by 2030 workers aged 55-64 will make up 30% or more of the workforce in many countries [2]. Parallel to the ageing of the workforce, the phenomenon of workforce shrinkage is also evident [3]. According to the demographic projections of Eurostat, the EU working age population will be declining by 0.4% every year between now and 2040, a decline that has already started in 2010. These developments have led many EU governments to raise the official retirement age and restrict possibilities of early retirement resulting to longer working lives and longer exposure of workers to hazards and risks [4].

The effects of the ageing workforce can be felt also outside policy and are affecting companies [5]. Industry appears increasingly dependent on the knowledge, skills and experience of their older workers [6]. This pushes companies to explore ways to

keep older workers employed for a longer period of time and also to support them to maintain their work ability and increase their employability. Responding to this need for sustainable job longevity of ageing adult populations, however, is faced with both challenges and opportunities. Some of these reside within the natural changes that come together with the ageing process, some arise from the changing workplace conditions.

Ageing brings a multitude of changes to humans. Sensorimotor and cognitive capabilities tend to degrade [7,8] along with changes that appear in the aging person's psychology and social state [9]. Major health problems that ageing workers may face include musculoskeletal and mental disorders; depression is also currently one of the most common reasons for work disability and early retirement, while the decline of physical work capacity with age is further underlined by considering that cardiorespiratory capacity and muscular strength tend to fall by about 1–2% a year after the age of 30 [2]. The changes associated with ageing diminish the work ability and productivity of the aging persons. According to the WHO [2], about 30% of men and women in the age group 50–64 years are considered to need urgent adjustments at work due to health problems related e.g. to musculoskeletal and mental disorders, to prevent the risks of early retirement and work disability.

There is systematic evidence, however, that sustainable job longevity can be associated with positive health outcomes. Work can have a positive effect on physical and mental health and well-being for all workers if working conditions are appropriate [10]. For example, keeping an employee integrated in a social environment such as work, can provide health benefits [11] e.g. as social interaction helps preventing the decline of cognitive functions [12]. According to EU-OSHA, workers who return to work can recover from a long-term illness if working conditions are adapted to the workers' needs and the process of reintegration is properly managed.

Nevertheless, the average worker can often face daunting challenges in fast-evolving labour conditions. Age-friendly, flexible work arrangements in the work environment are necessary to help the older person to cope with their intrinsic and extrinsic body and life changes as years go by. Novel work paradigms, such as those introduced by the gig economy (e.g. short-terms jobs, freelancers etc.) have shown that, once the working **arrangements** and **conditions** are flexible enough and controlled by the worker, even those who have already retired, can be fond of remaining at work for longer, even if they need to this end to sometimes **learn how to use a new technology**. A core challenge nowadays concerns how this tendency of older workers to remain active at jobs of the gig economy, can as well be migrated to further workplaces, such as industrial ones, allowing workers to indulge similar benefits, while at the same time their skills and experience accumulated over time remain valuable assets to the growth of diverse productive sectors, in the context of Industry 4.0 developments.

Companies have been trying to meet the challenges posed by an ageing workforce by adopting established occupational safety and health (OSH) practices that promote sustainable working lives. Such practices include life-course approaches to workplace health, workplace health promotion, introducing return-to-work measures, adapting work to the individual, and providing structures for lifelong learning [4]. There are many successful cases that involve at least to a certain extent the use of digital technologies (e.g. GPS-based personal emergency response systems, basic IT systems); many of these practices, however efficient, remain predominantly manual/offline.

In the same time, technological advances in the work environment have been seismic. Technology has been remarkable in collecting, storing and processing work and private life data. Factory-of-the-future and other industry 4.0 technologies have shown considerable potential in augmenting job quality and satisfaction through an improvement on working conditions [13, 14]. Progress has been notable: user-centric, responsive, active systems employ state-of-the-art technologies spanning from AI to advanced collaboration tools, visual analytics and big data to make work life easier for workers in the office and factory. These systems, however surprising, are rarely applied in combination [15] and remain remote from OSH and ageing territory.

2 A vision for future AI-based tools to support workability and QoL

In the context of the Ageing@Work project, we envision a holistic approach for supporting the ageing workers through the fusion of smart working and living environments, enabled through a series of highly adaptive, personalized ICT tools that will help the effective establishment of key measures to counteract for crucial issues hindering the ageing workers' workability and well-being. This can eventually allow ageing workers to remain healthy, active and productive for longer. As shown in Figure 1, our vision has at its core, the basic principles of the workability house [16] endorsed by OSHA and the EC.

Specifically, we consider that the key to effective promotion of workability in the older workers, is to provide support to **all of those layered factors**, both at work and at home, while in parallel, emphasizing on tools that help the worker **(a) to connect** more easily to the one place while s/he is physically at the other (i.e. connect to work from home and vice-versa) and **(b) to maintain a balance** between work and personal life, that fosters both productivity, workability and overall well-being.

In this line, focusing then at each layer of the workability house separately, first of all it becomes evident that effective solutions should support the ageing worker maintain, to the extent possible, her/his **health and functional capacities**. A key to such support can be tools to help into the ***proper, physical design of the workplace, so as to improve its ergonomics*** and overall, workplace aspects that can affect the workers' health and safety.

In any case, as years go by, the ageing worker's functional capacities will change and as such, solutions to support also the *better workplace design, in terms of process orchestration, task assignments and scheduling* that respect the ageing worker needs, seem also of major importance. Moving our focus from the first level, more to the second, that of competence, it is evident that in this case, ergonomics and task assignment optimization can be

further complemented by *productivity enhancement tools*, i.e. tools that can support the ageing worker perform target tasks more easily, learn new tasks, collaborate with colleagues, share knowledge, etc.; tools adequately personalized to the individual ageing worker, while at the same time properly tailored to the needs of the workplace, be it at a factory on the move, or at home.

Nevertheless, no matter how well a workplace is shaped and how many tools are there to support the job that needs to be done, one of the most crucial factors that can affect the older person's workability concern her/his values, attitude towards work and motivation. Taking this into account, it becomes clear that a holistic ageing worker support solution must pay also due attention on improving job satisfaction and help, to the extent possible into motivating the ageing worker to remain productive, possibly through some *reward system and a personalized, highly unobtrusive, proactive and at the same time discreet virtual assistant* that will emphasize on providing jointly, incentives for both work–related and life aspects of the individual.

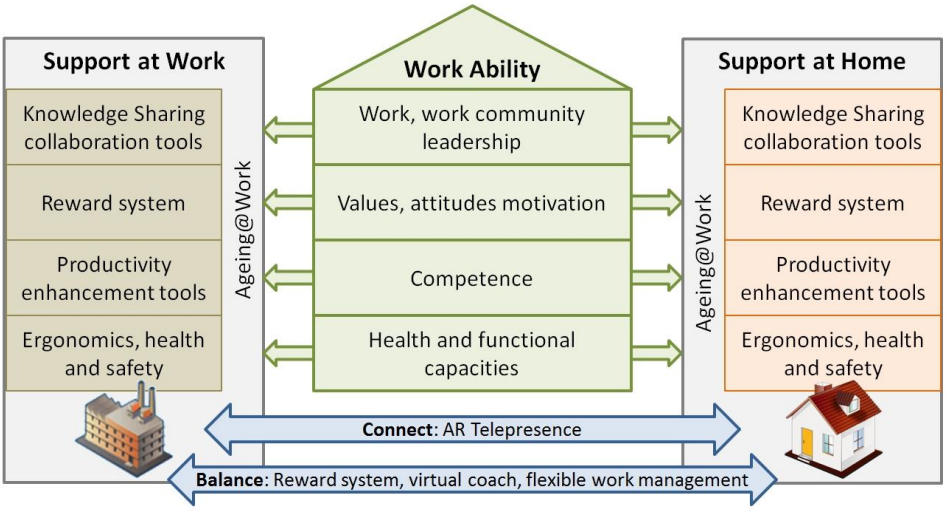

Figure 1: The Ageing@work vision of AI-enabled, ICT solutions to support ageing workers into the key factors of workability

Finally, when moving up to the upper layer of the workability house, it becomes clear that tools to also support the ageing worker's work and leadership characteristics within the workplace community, allowing the work site to capitalize on her/his expertise are necessary, such as indicatively, *knowledge sharing and collaboration tools*, which, following what has been described above, should among others, focus on one hand on telepresence and on the other, on solutions that will help parts of the older worker's experience and knowledge gained through the years, remain valuable assets of the company, even after the worker's retirement.

3 Conceptual Architecture of the proposed toolkit

At the AI core of the overall Ageing@Work concept lie **(A) novel, highly advanced Virtual User Models** of the ageing workers (wVUMs). Among others, the models will encode user behavior information derived from unobtrusive user activity monitoring, as well as user affect recognition. User activity monitoring will be based on unobtrusive sensing approaches; indicatively, action recognition based on the accelerometers of the user's smart-watch [17], audio signals processing [18], as well as further sources, related e.g. to biosignals processing for user emotion recognition [19,20,21]. The VUMs then will be used to represent users in automatic simulations to support decision making processes [22].

Apart from the typical profiling capabilities, based on unobtrusive worker behaviour monitoring both at work and at home, the Ageing@Work wVUMs hold a further, highly important novel element, of advanced computational intelligence, endorsed through machine learning methods that summarize worker behavioural and physical factors of interest, respective to the work and life context, into workability and wellbeing indexes relevant to active and healthy ageing. The indexes will be assessed herein on the basis of occupational and ageing health knowledge, driving personalized, simulations-based system decisions on both preventive and reactive measures that can help the worker, either in the short-term or in the longer term.

A second important aspect of the Ageing@Work modelling and AI core concerns **(B) Virtual Workplace Models (VWMs)**,

which will encode the main relevant topological and resource –oriented characteristics of the ageing worker's working context, be it in-place, at the factory/worksite, or at home.

The above models will be the basis for the Ageing@Work **work co-design tools**, which will comprise: **(C) A Personalized Ergonomics Design tool**; following a simulations-based optimization approach, this will output suggestions on parameters of the user's workplace VWMs, which once changed, could help the worker work in an environment that fosters productivity, health and safety, both in a preventive or reactive way according to the person's evolving specificities. Alongside, **(D) an Age-friendly Work Management assistant tool**, will help both the

worker, as well as their supervisor, take optimal decisions as concerns the orchestration of the tasks of the worker themselves or the overall factory, respectively. Notably, a key challenge and novelty of our approach concerns the fact that on one hand, the personalized system will derive work arrangement suggestions at a personal level to the worker (e.g. tasks scheduling, suggested working place or working hours), while in parallel, without disclosing to the manager information further to the minimal one accepted by the worker, will try to suggest overall factory process arrangements in respect of the worker needs.

In parallel to the above, the virtual worker and workplace models will drive the provision of highly advanced and personalized workability enhancement tools, based on cutting-edge technologies, including AI, VR and AR interfaces formulating an ensemble of intuitive interfaces for HCI and remote collaboration. More specifically, the aim will be to provide in-place and remote productivity and collaboration support through: **(E) Lifelong learning, training and productivity enhancement tools** and **(F) Bi-directional AR and VR based telepresence**. Notably, a key aim will be to help the factory capitalize on the advanced older worker experience and skills in the best and easiest way possible, both when the older worker is on-site (e.g. by using AR so as to provide important indications that need attention) and when is working from home (e.g. from AR-based teleconference through to AR and VR-based remote collaboration to guide a younger worker, help resolve a production problem etc.).

(affected by and affecting), personal life aspects. A core novelty will concern the provision of highlights on crucial parts of information related to the worker's behaviour which are sometimes missed by the workers themselves (e.g. too many hours at work, adverse environmental conditions, possibly increased stress or fatigue), through an empathic, mirroring user avatar. The avatar will run at the user's smartphone and its form will be adaptive, user-selected; the core concept of worker mirroring will concern providing indications to the worker on possibly important information, initially through a respective subtle change in the avatar's appearance and behaviour, while if remained un-noticed and untreated, the notification will become increasingly more intense. The Ageing@Work AVC will be both proactive and discreet, avoiding attention theft, and will be developed on the basis of cutting-edge persuasive technologies so as to not only provide suggestions and further information deemed necessary, but also be *effective* when doing so. Notably, advanced AI, VR and Visual Analytics will be fused with psychology and behavioural research, so as to eventually realize a personalized effective work and personal life coach.

A further key novelty to this end will concern an integrated personalized reward system that will further promote positive behaviours both at work and daily life, as well as the major goal of personalized balance between those two. Indicatively, positive rewards will both be provided upon the worker's achievement of some set productivity goal, as well as good physical activity or dietary habits at work or at home, while in parallel, positive

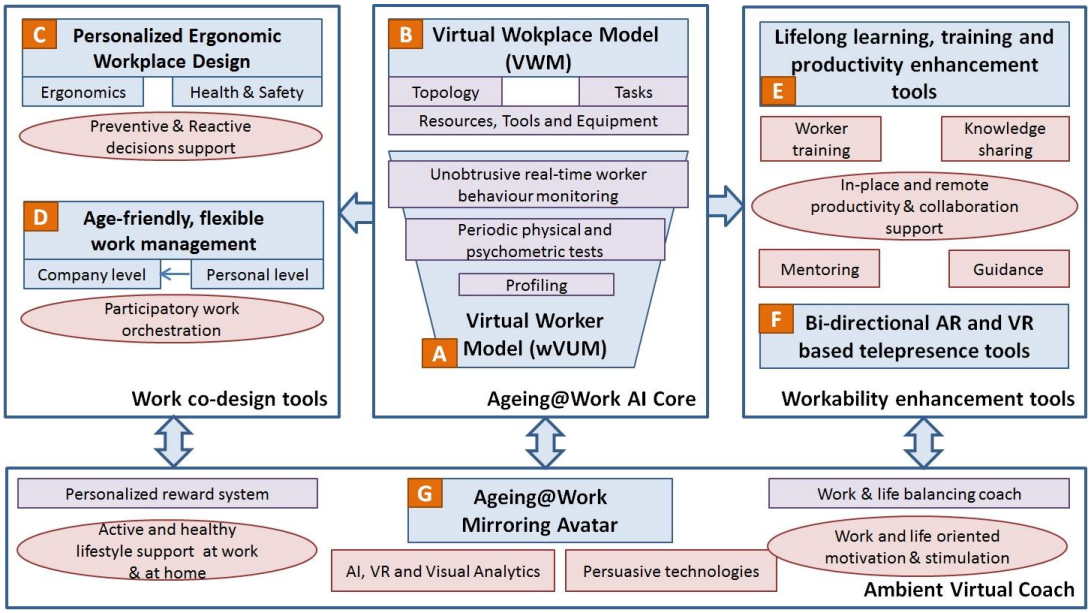

Figure 2: Conceptual Architecture of the Ageing@work toolkit

All of the above tools are eventually fused so as to provide an integrated, personalized supportive platform to the ageing worker, by means of the Ageing@Work Ambient Virtual Coach (AVC).

In this respect, Ageing@Work will introduce a novel **(G) Empathic "Mirroring Avatar"**, as an advanced paradigm of effective personalized support, both at work and in inter-related

rewards will be provided upon detection of positive, physical activity and socialization behaviours, let these concern e.g. some walk, some visit to a relative or friend, picking-up grandchildren from school etc. Accordingly, upon negative outcomes from the reward system, stimulating coach behaviour based on the mirroring avatar, as well as more extensive notifications provided

based on visual analytics will serve to the core aim of work and life motivation and stimulation of behaviours that foster productivity, along with active and healthy ageing.

4 Conclusions

4.1 Ageing@Work innovations

Ageing@Work introduces the integration of different digital tools in core industry 4.0 and the factory paradigms to ensure satisfactory conditions in work environments and provide meaningful incentives (e.g. rewards etc.) towards highly motivated and engaged ageing workers in positive behaviors and perceptions about work. In this scope, a wide variety of cutting-edge technologies are introduced as the AR, VR technologies and also the visual analytics along with the context-aware Avatar in order to provide highly personalized support and enhance workplaces' adaptation and productivity. To cater in depth for workers' needs, Virtual User Models target to adapt users' behavior at workplaces. Among the main objectives of the project is to combine different digital tools through effective methods and incorporate in these advanced technologies, valuable knowledge from psychology and behavioral research, in order to enable an active ageing workforce. To achieve these goals, Ageing@Work introduces a holistic, interdisciplinary approach integrated to appropriate technologies to design the most engaging technologies for seniors in worklplaces both from the perspective of health and wellbeing. Moreover, taking into account the importance of OSH legislation and general culture, Ageing@Work is aligned with these guidelines to ensure safety in workplaces.

4.2 Future challenges and concerns

A constantly increasing ageing workforce in parallel with technology advances is expected to generate a number of challenges for technologically supported work environments. Also Industry 4.0 evolution due to its main attributes of digitation and interconnection inherently presents major opportunities. However, apart from productivity optimization supported by the advances of ICT, also quality improvement in production process is a critical component that has to be enhanced by exploiting individuals' key capabilities to tailored –made tasks. Moreover due to the involvement of multiple technologies and tools, needs could be emerged for interactivity enhancement and functions' updating which bring also concerns about increased cost and time.

Furthermore, despite the huge business and benefits in industrial environments through digitization, industry standards and policies have to be redefined according to data protection concerns. Data visualization tools from one hand could enable the effective management of potential risks at workplaces but also have to be filtered properly, in order to be aligned with the proper ethical and legal requirements.

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