The light and the dark sides of the moon: possibilities of Industry 4.0 for early non-invasive diagnosis of pathology and health-risks

M V Vasilieva¹, V A Glukhova¹, E V Grednovskaya¹, A A Dydrov¹, I I Klebanov¹, I A Nikolaeva², K Yu Nikolskaya¹, R V Penner¹, V E Tseilikman¹

¹ South Ural State University (National Research University), Chelyabinsk, Russia, 76, Lenin prospekt, Chelyabinsk, Russia, 454080
² Kurgan State University, Kurgan, Russia, 63, Sovetskaya St., Kurgan, Russia, 640020

E-mail: tceilikmanve@susu.ru

Abstract. Industry 4.0 is an innovation infrastructure based on global digital connectivity to create smart plants and provide global automation in science and society. In Industry 4.0, the Internet of Things is used to collect big data from embedded sensors into live and inanimate objects. "The health calculator is positioned as a universal objective measure of human health, since it can be used not only in any disease, but also in preventive medicine, in particular, in examining astronauts and athletes and in life-risk occupations. However, even such a deeply thought-out software as health calculator requires its further development, that is, the transition to a second-generation device in which health is assessed from other methodological points of view. We have tried to summarize Industry 4.0 into medicine. We began to construct ‘Digital Twins’ with the psychological "twins organisms". In the future, this structure will serve as a bridge from psychology to psychopathology. To conclude, Industry 4.0 can bring to humanity unique opportunities in maintaining health and preventing diseases and at the same time engaging it in qualitatively new stressful situations. Therefore, now it is worthwhile to look for ways to increase human resistance to new versions of informational stress.

Introduction

Industry 4.0 is a global innovation phenomenon based on the ability to digitize large amounts of all sorts of data. Such global digitization makes measurable the most unexpected things in the most diverse areas of our life. Global digitization allows real-time measurements as well as past experience measurements. When we add real-time data analysis to the Internet of Things, a state of global communication or “Quantitative Planet” is created [1]. Medicine is based on the results of past experience more than any other field of activity and the ability to measure the huge accumulated knowledge of medicine opens up a completely new era for medicine. Here we discuss some of the positive and negative effects of Industry 4.0 with respect to medicine. Currently, there are great expectations for revolutionary changes in personalized medicine due to Digital Twins.

Personalized medicine uses ultra slim information in the deviations from the normal on individual persons [2]. Digital Twins in engineering provide a conceptual base for measurements in therapy and preventative care. Digital Twins stand for a specific engineering paradigm, where individual physical artifacts are paired with digital models that dynamically reflects the status of those artefacts. When
applied to humans, digital twins can be viewed as a fundamentally new technology based on human perceptions that dynamically reflect measurements of molecular status, physiological status, and lifestyle over time. Their use will allow an individual assessment of the long-term effects of experienced immediate events. In addition, the “twin organisms” will help doctors to develop personalized therapy for each specific case. It also seems possible to expand the software product by incorporating psychometric data, which, despite being “non-physical quantities”, closely correlates with changes in the level of neurotransmitters and hormones. If it is possible to reproduce these behavioural disorders in Digital Twins, then they can be used in experimental psychotherapy. In general, the use of twin organisms for this purpose in the future will dramatically reduce the use of laboratory animals and cell cultures and thereby reduce the time of preclinical and clinical trials of pharmacological preparations.

The main indicator of physiological health is the maintenance of homeostasis or constancy of the internal environment of the body. However, under the shell of visible health pathological processes may form that give rise to the development of the disease. They can flow for a long time in a latent form and make themselves known when it is too late to take any measures. There is no doubt that sooner these adverse factors will be identified, the more chances there are to stop the development of fatal diseases in the bud. In our opinion, the solution of this important biomedical problem requires a large-scale use of the capabilities of Digital Twins. The mechanistic use of global digitalization can give rise to “A Demon of the Second Kind” from the short story by Stanisław Lem, to something that was able to work at a speed of “three hundred million information per second” and have an efficiency factor of zero. Therefore, it is crucially important at the start to determine the methodological approaches. There are two types of models for Digital Twin. The first model is creating through analytical techniques. The second model is being creating through the machine learning and artificial intelligence techniques. Neuronal Networks, which are, represents the mathematical models, as well as their software or hardware implementations, built on the principle of organization and functioning of biological neural networks – networks of nerve cells of a living organism successfully used for created Digital Twins in the both types of models.

The Digital Twins in psychology
Currently, there have been a few attempts to use Digital Twins in cardiology and in oncology [3, 4]. However, there are no data on the use of this approach for psychiatry, although the psychosomatic diseases are widely presents in the world. Therefore, the psychological fragments are quite necessary in the Digital Twin of those diseases. Here we have tried to summarize the further prospects of translating Industry 4.0 into medicine. We have taken the first steps. We began to construct the Digital Twins of the human psychological profile. In future, this structure will serve as a bridge from psychology to psychopathology. A further perspective for the development of this approach is the use of artificial intelligence for psych diagnostics. The next step to translate art intelligence will be building a bridge from psychology to recognizing psychosomatic pathology. The axial structure for this approach may be Jung’s theory of psycho-types.

According to the theory of C G Jung [5], all people can be divided into eight groups, depending on their psychological attitude and basic psychological function, which together determine the psychological type of the individual. Thus, this typology is a multiparameter value and can serve both as a method for arranging the diverse psychological experience, and as a psychologist-practice tool for selecting a specific approach to each patient. Also, each psycho type has its own markers of stress. The selection of such markers on the video will allow you to make a more detailed picture of the patient’s disease. The task of recognizing a psych type is the classification problem, which may be solved with a large amount of machine learning tools, e.g. neural networks. Neural network are able to extract high-level properties of abstraction from input data, therefore the range of problems solved by different typed of neural networks covers tasks from the definition of handwritten symbols [6] to human gait recognition [7], where theses how significant results.

The neural network, trained on bright, indisputable representatives of every type, will allow a combination of experience of many psychologists that leads to exact and impartial typing. At the
moment, a data preprocessing model has been developed. Here the module preprocessing the source data. A video length of up to 10 seconds is used as the system input data. На вход подаются исходное видео и параметры, позволяющие регулировать размер видеофрагмента, порог бинаризации, а также размеры эрозии, наращивания и масштабирования. The video features interviews with people of various psycho-types. These videos are created by professional psychologists, so the accuracy of the types presented in the video is an absolute variable. The pre-processing of this video consists of several stages. Below is a description of each stage, as well as algorithms for their implementation.

1. Fragment extraction. If you need to use a video clip shorter than the original, you need to cut it to a specified duration. Using shorter fragments will speed up the work of the program, and longer ones will increase the recognition accuracy.

2. Binarization. To determine the moving areas in the video, background subtraction algorithms are used, which consist in the threshold binarization of the image sequence. In this case, the first frame of the sequence is memorized, which is then subtracted from the following, thus coloring all the pixels in one of two colors, signaling its movement or static state.

In this work we use the ViBe background subtraction algorithm, which is as follows. Denote by \( \nu(p) \) the value of the attribute, for example, the RGB component of a pixel located in the image, and \( \nu_i \) is the background sign with the subscript \( i \). Then each pixel of the background in \( p \) is modeled by a set of \( N \) background segments:

\[
\mu(p) = \{\nu_1, \nu_2, ..., \nu_N\}
\]

(1)

taken from previous frames. To classify the pixel characteristic \( \nu(p) \), it is compared with all values contained in the \( \mu(p) \) model relative to the distance function (a metric that is usually specified as Euclidean) and the distance threshold.

3. Framing (dividing into frames). Since the neural network processes the image sequence, the binarized video fragment needs to be divided into frames.

4. Erosion (cleaning noise). After binarization, noises in the form of single pixels may remain on the frames. Simple cleaning can be performed using morphological transformation – erosion. The erosion algorithm consists in applying a certain structural element to each pixel. If at any position every single pixel of a structural element coincides with a single pixel of a binary image, then a logical addition of the central pixel of the structural element with the corresponding pixel of the output image is performed. As a result of applying the erosion operation, all objects smaller than the structural element are erased, and the objects connected by thin lines are separated, and the sizes of all objects are reduced.

Erosion of the binary image \( A \) by the structure element \( B \) is denoted by \( A \ominus B \) and is given by the expression:

\[
A \ominus B = \{z \in A | Bz \subseteq A\}
\]

(2)

5. Dilation (capacity). Since erosion can separate thinly connected parts of a single object, after erosion it is necessary to conduct a build-up operation that will increase the size of the moving areas and connect these parts. The transformation algorithm also consists in applying to each pixel an image of a certain structural element, but logical addition is performed over the entire structural element and provided that any single pixel coincides with the origin of its coordinates.

Erosion of the binary image \( A \) by the structural element \( B \) is denoted by \( A \oplus B \) and is given by the expression:

\[
A \oplus B = U \ b \in B \ A
\]

(3)

6. Skeleton building. The skeleton building method is an erosion of the image until its thickness is equal to one pixel. In the Zong-Sun algorithm used, a 3x3 matrix is introduced. This algorithm summarized at the figure 1.
**Figure 1.** Transition from input measurement of video recording data to output Jung’s Psychological Types Scale via binarization, framing and skeletonization.

This algorithm allows to obtain a set of specific data an image with a set of specific points and with skeletonization of the human body, for example. These data will be transmitted to the input of another neural network, which will allow to create the measurement model of the psycho-type of person, according to Jung.

Next part of the work is neural network topology adjustment a recognition task solution. Recurrent LSTM, convolutional networks will be applied to preprocessed video frames. Training set granted by experts and preprocessed with implemented utility will be used to adjust weights of network. Our next steps will be related to the formation of a biological passport for each psychological type which will include their physiological, metabolic and genetic features, as well as their susceptibility to stress what will allow in the future to prevent the stress-related diseases. In this study, we created a “Digital Twin” of in healthy people. Based on the obtained results conventional reference scale of Jung’s Psychological Types (JPTS) was to construct. Exploratory factor analysis found three significant measurand pairs: extraversion-introversion (E-I), thinking-feeling (T-F), and sensation-intuition (S-N). The result showed that the three factors of E-I, T-F, and S-N corresponded to Extraversion, Agreeableness, and Openness. In the healthy people the references value for each measurand pairs were obtained. In the future, we plan to study the characteristics of the manifestation of psychosomatic diseases in individuals with different psychological types based on the reference values of this scale. In particular, we began to model the “Digital Twin” of an autoimmune psychosomatic psoriasis disease. We trace the features of the course of psoriasis in individuals with different psychotic types according to Jung.

**Hypothetical risks of Industry 4.0 for human health**

Despite the obvious benefits of Industry 4.0, it carries some dangers to human health. First of all, this is due to the fact that the activity of an employee at the enterprises of Industry 4.0 requires unlimited plasticity and readiness for change. Meanwhile, with age the majority of people become more and more conservative and any changes lead to violations in the psychological zone of comfort, which is fraught with the development of severe psycho-emotional stress. In addition, Industry 4.0 implies an increase in the importance of artificial intelligence, which leads to the development of information stress associated with the replacement of workers by automated control systems [8]. The indicated problems require complex measures of solution at the physiological levels. Countering information stress and disorientation in the context of high-speed technological progress is one of the priority transdisciplinary tasks. Obviously, it must be solved both with the help of medicine and with the help of other humanitarian technologies. These technologies fit organically into the strategy of futurization (including futurization of continuing education), which implies purposeful preparation of a person for the adoption
and introduction of technical-technological and other innovations [9]. Futurization is associated with the expansion of contextual knowledge of employees, informing about new and, including, hypothetical technologies, as well as systematic participation in forecasting seminars and trainings. With proper implementation of the strategy, the employee will not be distracted from production and will adapt more effectively to change.

Accordingly, employees will be engaged in tasks that require responsible decisions in the interaction between human and machine and which may expose them to health risks as well as to the dangers associated with automated tools and greater psychosocial stress. Psychosocial stress can trigger the development of comorbidity, the nature of which remains a mystery.

Conclusion
Industry 4.0 can bring to humanity unique opportunities in maintaining health and preventing diseases and at the same time engaging it in qualitatively new stressful situations for which there are no recipes for adaptation. Therefore, now it is worthwhile to look for ways to increase human resistance to new versions of informational stress. With a successful solution to this problem, Industry 4.0 will undoubtedly revolutionize medicine.

Acknowledgments
The study was supported by the Russian Science Foundation (grant#17-15-013418) and by the Government of the Russian Federation according to Act 211 (contract 02.A03.21.0011).

References
[1] Özdemir V 2018 The Dark Side of the Moon: The Internet of Things, Industry 4.0, and the quantified planet Omics 22(10) pp 637-641
[2] Bruynseels K, Santoni de Sio F, van den Hoven J 2018 Digital twins in health care: ethical implications of an emerging engineering paradigm Front. Genet. Feb 13 doi: 10.3389/fgen.2018.00031. eCollection 2018
[3] Miller W and Jaffe A 2016 Biomarkers in heart failure: the importance of inconvenient details ESC Heart Fail. 3(1) pp 3–10 doi: 10.1002/ehf2.12071
[4] Kummar S, Williams P, Lih C-J, Polley E, Chen A P, Rubinstein L V, Zhao Y, Simon R M, Conley B A, Doroshow J H 2015 Application of molecular profiling in clinical trials for advanced metastatic cancers. J. Natl. Cancer Inst. 107(4) doi: 10.1093/jnci/djv003
[5] Jung 1921 Psychological Types [Psychologische Typen] (Zurich: Rascher Verlag) (in German)
[6] Le Cun Y, Bottou L, Bengio Y and Haffner P 1998 Gradient-based learning applied to document recognition Proc. IEEE 86(11) pp 2278-324
[7] Phung S L and Bouzerdoum A 2007 A Pyramidal Neural Network for Visual Pattern Recognition IEEE Transactions on Neural Networks 18(2) pp 329-343
[8] Leso V, Fontana L and Iavicoli I 2018 The occupational health and safety dimension of Industry 4.0 Med. Lav. 110(5) pp 327-338
[9] Ursul A D and Ursul T A 2017 Vectors of achieving sustainable future Philosophical Sciences 7 pp 139-149 (In Russian)