Human Avatars, the Next Paradigm in Healthcare

Adrian M. Ionescu, EPFL, Switzerland @ SEMICON Europa 2019
Outline

• Technologies for Global Challenges
• Energy efficient technologies for Edge Artificial Intelligence & Verticals
• Health EU initiative: a Revolutionary Integrative Technological Platform for P3 Healthcare to shape future missions in Digital Healthcare
Global Challenges for Humanity in 21st Century

1. Climate Change

Greenhouse gas emissions must be drastically reduced within the next decades to stay within 1.5°C of warming above pre-industrial levels and avert the worst impacts of climate change.
Global Challenges for Humanity in 21st Century

2. Energy

We are at a crucial point on how we make and use sustainable energy:
Global Challenges for Humanity in 21st Century

3. Health
The 20th Century reactive healthcare model is unsustainable!

The median increase in health care spending has been 2% points above GDP for nearly 50 years in all OECD countries, with only minor fluctuations. Expectations:

- **30% of GDP in the United States by 2040** (up to 97% in 2100)
- **30% of the median OECD GDP by 2070**

We need a paradigm change: a P3 Digital Healthcare revolution.

We are not yet almost there!
How technology can help?

• Every day new evidence of our unsustainable impact on the environment is emerging.

• We have a critical window of opportunity to put in place commitments and actions to reverse the trend of nature loss.

• Digital Technology should play a crucial role in decoupling development and environmental degradation.
Nanoelectronics: ~10nm 3D transistors

Today: 14 nm:
- 40 millions transistors/mm²

2019-2020: 10 nm:
- 100 millions transistors/mm²

Virus

Negatively stained Influenza Virus, usually spherical or ovoid in shape, 80 to 150 nm.
Iphone & Guardian Angels

- First wireless computer with sensors

2007

- Edge technologies

2011
The Zettabyte Era

1985
Storage 21PB
Coms 59PB
Comp 0.74PIPS

2007
Storage 277EB
Coms 537EB1
Comp 195PIPS

2020
Storage 140 ZB
Coms 272 ZB
Comp 2'590 ZIPS
Edge IoT >50 ZB

The Future of AI Computing?

2020: 10% of the world’s data (Source: IDC).
What is **True AI**?
Stretching the truth!?

- Many companies claim highly sophisticated automation software with some AI elements, none so far established **True AI** to replace the humans.

- **What is True AI @ Edge?**
  - ability of software to analyze and interpret that data in order to automate processes in a human-like intelligent way (ML = just the current status);
    - **dedicated processing hardware**
    - **deep & valid data generator technology**
    - **Edge AI key attributes**: energy efficiency: computing, communication & sensing, data security, form factor, costs
The Internet-of-Things makes healthcare accessible to all

- IoT technology bridges the gap between digital and physical data sources of data, by monitoring patient behavior in real time.
- Gradual transitioning from institution-centric care delivery to patient-centric care delivery practices.
- Internet of Things (IoT) Healthcare Market to Reach $322.2 billion by 2025.

**Is IoT in healthcare the missing link in value-based care?**

improve outcomes, reduce costs and ultimately provide greater access to high-quality care for more people across the globe.
Autonomous sensor nodes for IoT

100 microWatt – 10 mW
/sensor node

Smart hub: 100mW – 10W
(tens of sensors /hub)

Source: IMEC
What else?
Today our technology can predict weather...

SENSORS → BIG DATA → MODELS → COMPUTING → WEATHER FORECAST
... but cannot predict health status

- Goal: turning a stream of information into predictions of outcomes
- Can a Wearable Fitness Device Predict Your Heart Attack? Value chain!

SENSORS → BIG DATA → MODELS → COMPUTING → HEALTH FORECAST
Biosensing as enabler of revolutionary smart sensing & computational systems

- **Wearable** biosensors: ECG, EEG, EMG, SpO2, blood pressure, pH, glucose, various analytes/biomarkers in biofluids, ...
- **Implantable** sensors and transducers
- **Organs on Chip** with embedded biosensors!

**Requirements**

- **High quality data** - multi-parameter sensing
- **Form factor** - frictionless
- **Autonomy** - low power, energy efficiency
- **User acceptance** - data security, privacy
- **Low cost systems** – 3D, on foil integration
Towards sensitive biostamps & tattoos

Electronic “skin” can monitor heart

An ultra-thin electronic device that attaches to the skin like a stick-on tattoo can measure electrical activity of the heart, brain waves, and other vital signs without the bulky electrodes used in current monitoring.

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Xsensio's Lab-on-Skin™

EXPLOITING THE DATA GOLDMINE IN A DROP OF BIOFLUID

- Ammonium for cramp prediction
- Sodium, Potassium for dehydration
- Chloride for cystic fibrosis
- Glucose for diabetes
- Urea for kidney failure
- Lactate for body exertion
- Cortisol for stress
- Cytokines for infection
- Neuropeptide for alertness
- Neuropeptide for depression
Real-time sweat analysis with Lab On Skin™

- Embeddable unique Xsensio’s Lab-On-Skin™ electronic stamp technology: minute by minute non-invasive multi-biomarker sensing

- Ultra-low power UTB SOI ISFETs: <50nWatts/sensor
- Near Nernst limit sensitivity
- Selective
- Zero energy microfluidics

F. Bellando et al., IEDM 2017.
Edge AI sensors: cross sensitive sensor arrays & dynamic signatures using Machine Learning

**Conventional chemical sensors**
- Chemical species
- Sensor array
- Interaction
- Transduction
- Response
- 1:1 interaction between analyte and sensor
- Value lies in each specific sensor element
- Challenge: Sensor element development, cope with interfering analytes

**Cross-sensitive sensor array**
- Chemical species
- Sensor array
- Interaction
- Transduction
- Response
- Analyte interacts with multiple sensor elements
- Value lies in the dynamic response to chemicals
- Challenge: Design and training of sensor array, pattern recognition / machine learning
The exposome: from concept to utility

- The exposome would require measurements of exposures over time across the life course of an individual.

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**Table 1** Some examples of approaches and tools to measure the exposome

<table>
<thead>
<tr>
<th>Approach</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomarkers (omics)</td>
<td>Genomics, transcriptomics, proteomics, metabolomics, epigenomics</td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Targeted</td>
<td>Adductomics, lipidomics, immunomics</td>
</tr>
<tr>
<td>Sensor technologies (including mobile phones)</td>
<td>Environmental pollutants, physical activity, stress, circadian rhythms, location [global positioning systems (GPS)]</td>
</tr>
<tr>
<td>Imaging (including mobile phones, video cameras)</td>
<td>Diet, environment, social interactions</td>
</tr>
<tr>
<td>Portable computerized devices (including palmtop computers)</td>
<td>Behaviour and experiences (ecological momentary assessment), stress, diet, physical activity</td>
</tr>
<tr>
<td>Improved conventional measurements (combined with environmental measures)</td>
<td>Job-exposure matrices; dietary recall (e.g. EPIC-Soft)</td>
</tr>
</tbody>
</table>

Human Exposome: bio and environmental co-monitoring for healthcare!

Environmental related diseases:

- **RESPIRATORY INFECTIONS**: more than 1.5 million deaths annually from respiratory infections due to environment.
- **CANCER**: environmental accounts for an estimated 31% of global lung cancer burden.
- **CARDIOVASCULAR DISEASES**: 2.5 million people die every year from cardiovascular disease attributable to chemical and air pollution.
- **DIARRHOEA**: about 1.5 million deaths per year from diarrhoeal diseases; 88% of all cases of diarrhoea attributable to water, sanitation and hygiene.
- **MALARIA, INTESTINAL NEMATODE INFECTIONS, HEPATITIS B and C, TUBERCULOSIS**, etc.
Thinking forward the healthcare...

What’s the real opportunity for future Edge AI technology for Healthcare?

The value of being sick!

What’s the value of NOT being sick = healthy?
Leading Causes of death...

“an error in judgment, skill or coordination of care; a diagnostic error; a system defect resulting in death or a failure to rescue a patient from death; or a preventable adverse event.”

Number of Deaths in the United States

<table>
<thead>
<tr>
<th>Cause</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart disease</td>
<td>614,348</td>
</tr>
<tr>
<td>Cancer</td>
<td>591,699</td>
</tr>
<tr>
<td>Medical Error</td>
<td>251,454</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td>147,101</td>
</tr>
<tr>
<td>Accidents</td>
<td>136,053</td>
</tr>
<tr>
<td>Stroke</td>
<td>133,103</td>
</tr>
<tr>
<td>Alzheimer's Disease</td>
<td>93,541</td>
</tr>
<tr>
<td>Diabetes</td>
<td>76,488</td>
</tr>
<tr>
<td>Influenza &amp; Pneumonia</td>
<td>55,227</td>
</tr>
<tr>
<td>Kidney disease</td>
<td>48,146</td>
</tr>
<tr>
<td>Suicide</td>
<td>42,773</td>
</tr>
</tbody>
</table>

Medical errors are the 3rd leading cause of death in the United States.

Sources: CDC. National Center for Health Statistics. Number of deaths for leading causes of death, 2014.
2030: From Object to Human Digital Twins

Digital Twins of All Objects

Digital Twins of All Humans

A Truly Personalized and Preventive Healthcare System: SUSTAINABLE
Imagine a revolutionary healthcare and disease management system in Europe, built on human avatars aiming at:

**Empowering every citizen with a Human Avatar enabling access to comprehensive personalized healthcare, healthy lifestyle and disease prevention**
Why Health EU is disruptive?

- The **missing link** of the 21st century for **breaking barriers** between Medical Knowledge Creation and Medical Knowledge Application

- Creates a P3 **Citizen – Human Avatar – Clinical Professional triangle**
Disease complexity in the 21st century with a focus on cancer and the role of a Human Avatar

Human Avatars — and not the patients! — calibrated on individuals will be the test vehicles, enabling all AI-assisted search processes for identifying the best drugs and therapies.
Health EU Integrative Technology Platform: much more than a Digital Twin...

Big Data
IoH
AI

Data Generator Technology
Body-On-Chip

© Health EU
Health EU expectations

- Delivering on the promises of personalised and preventive medicine in advancing towards affordable universal healthcare solutions
- Taking medical sciences and practice to the next level to promote well-being and improve life expectancy in good health
- Providing future tools and infrastructure to accelerate the generation of new data that can further enhance our knowledge to support prevention and personalised treatment of diseases
- Creating new business models, financing frameworks and incentive schemes

You, Your Human Avatar, Clinical Professional
- Up to 80% of the costs associated to NCDs preventable with Health EU Human Avatars:
  - Less chronic diseases (by prevention and monitored avatar-guide healthy living)
  - Better Quality of Life
  - Less adverse drug effects & medical errors (3rd leading cause of death)
  - Cheaper medication by personalized repurposing
  - Less need for organ transplantation by prevention
  - Less (severe) surgical interventions and less misguided therapies
  - Less need for animal testing by Organs on Chip
Conclusions

• High expectations from novel technologies to sustainably solve Human Great Challenges: Climate Change, Energy and Health!

• Sustainable energy efficient IoT & AI will enable citizen-centric applications for a new Quality of Life in the zettabyte era.

• A revolution in P3 Digital Healthcare possible by IoT & AI: Human Avatars for a Healthy YOU!

Health EU Manifesto
https://www.health-eu.eu/support/
Thank you!
Questions?