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Future Trends Forum

Artificial Inteligence:

Integration in the Physical World

Introduction

The latest edition of the Future Trends Forum (FTF), organized by the Bankinter Innovation Foundation, explored the impact of Artificial Intelligence on the physical world (hereinafter referred to as physical AI), a technology that combines advanced AI with adaptive physical systems capable of interacting with their environment in real time.

During the forum, experts from around the world discussed topics such as the integration of robotic systems in smart factories, the improvement of human-robot interfaces through multimodal algorithms, and the investment opportunities arising from this technological convergence. Ethical considerations and Europe's potential role as a leader in this technological revolution were also examined.

The Future Trends Forum set three main goals for its analysis of this emerging technology:

1. **To understand the current state of physical AI by analyzing recent advances in robotics, autonomous systems, and physical devices, as well as anticipating key trends for the next 5 to 10 years.**

2. **To identify opportunities and risks by examining the social, regulatory, and ethical impacts, along with new business opportunities in specific sectors.**

3. **To develop strategic recommendations by proposing guidelines to maximize the potential of these technologies, particularly in Europe.**

The interaction between the physical world and the advanced learning capabilities that characterize physical AI opens up new technological and social opportunities, but also raises profound philosophical and cognitive challenges.

This report has been translated by AI.

What is Physical AI?

Physical AI, often referred to as Embodied AI in English, represents a new era in the interaction between artificial intelligence and the physical world. It combines advanced learning capabilities with physical systems that can perceive and respond to their environment. Equipped with sensors and cameras, these technologies gather and process real-time data, enabling autonomous and adaptive actions in a physical context.

The Key: Human Intelligence and its Relationship with AI

Antonio Damasio, a renowned neuroscientist and Trustee of the Bankinter Innovation Foundation, emphasizes that artificial intelligence cannot fully replicate human intelligence due to the absence of biological life, homeostasis, and conscious feelings—essential elements for consciousness and environmental adaptation.

According to Damasio, consciousness arises from the interaction between homeostatic feelings, such as the regulation of vital functions, and reflective mental processes—something that current AI lacks. This limitation hinders AI's ability to emulate human minds.

A first step toward overcoming this limitation would be for AI to recognize human emotions and respond accordingly. Significant progress has been made recently in this area, with promising new developments announced.

Technological Advances and Challenges

Advances in AI are redefining how machines interact with their environment and with humans, driving greater adaptability through integrated models and highlighting the role of open-source development in robotics. However, this progress also presents challenges that require not only technical solutions but also ethical considerations regarding its social and economic implications.

Jeremy Kahn, AI editor at Fortune magazine and author of Mastering AI: A Survival Guide to Our Superpowered Future, highlights key advances in AI integration and adaptability:

New Unified World Models: Innovations such as Gaia by Wayve and developments from World Labs combine perception and decision-making into a single system, surpassing traditional approaches based on separate subcomponents. This integration enhances efficiency and the generalization of applications.
Foundational Models in Robotics: Companies like Physical Intelligence and Covariant are developing foundational models that allow robots to operate in diverse environments and perform various tasks without intensive retraining.
Autonomous Drones: Autonomous drones are achieving unprecedented levels of independence, with both commercial and military applications. Notably, they can operate without GPS and make autonomous decisions.
Humanoid Robots: Initiatives by Tesla, Agility Robotics, and Boston Dynamics are advancing the development of humanoid robots with potential industrial and domestic applications. However, significant technical and social challenges remain to be addressed. These advancements promise to transform our relationship with machines and broaden the possibilities for robotics.

Trust and Perception in Generative AI

Pilar Manchón, Director of AI Research Strategy at Google, emphasizes that public perception and trust are critical for the adoption of physical AI. In her analysis, she highlights three key points:

The Challenge of Trust: According to Edelman's Trust Barometer, scientists and companies inspire greater trust on AI-related topics, while governments and media tend to generate more skepticism. This underscores the need for transparent communication from technology developers.

Anthropomorphism and Acceptance: Manchón advocates leveraging people's natural tendency to anthropomorphize AI systems, as this facilitates more intuitive interactions and fosters empathy toward these technologies.

Social and Cultural Impact: Generative AI, when integrated into physical systems, can boost efficiency and creativity while addressing social issues such as loneliness by acting as artificial companions in isolated contexts.

These advancements are blurring the boundaries between the physical and digital worlds, opening up new opportunities while raising ethical and regulatory challenges.

Technical and Conceptual Challenges

Physical AI faces significant technical and conceptual challenges, particularly in learning, simulation, and physical interaction:

Limitations in Learning and Understanding
Ramón López de Mántaras, Emeritus Researcher at the Artificial Intelligence Research Institute (IIIA) of the CSIC, points out that current AI systems lack a deep model of the world, which limits their reasoning and real understanding capabilities. According to López de Mántaras, while current generative language models can answer questions based on textual patterns, they do not genuinely understand context or cause-effect relationships. To advance, he suggests equipping AI systems with multisensory bodies that enable interaction with their environment, following approaches such as DeepMind's PLATO project, which is inspired by Jean Piaget's developmental psychology.

Scarcity of Realistic Simulations and Models
Dario Floreano, Professor of Intelligent Systems at EPFL, highlights the lack of adequate simulators for training complex robots, such as bio-inspired drones or soft medical robots. He proposes the development of neural simulators based on physics to model dynamic movements and more realistic environments, along with new learning architectures that better integrate the morphology and environmental dynamics of robots.

Human-Robot Interaction and Ethical Use
Leila Takayama, an expert in human-robot interaction and Vice President of Design at Robust.AI, emphasizes the importance of developing AI systems that interact intuitively with humans. One of the main challenges, according to Takayama, is striking a balance between robot autonomy and human supervision, particularly in critical applications such as environmental monitoring or combating illegal fishing. A notable example is the use of autonomous drones in the Bahamas to fight illegal fishing, demonstrating how physical AI can address global problems while overcoming technical challenges, such as ensuring robustness in complex environments.

Challenges in Skill Generation and Contextual Understanding
Current models, such as those developed by Google, integrate vision, language, and action, but they merely reuse learned patterns without generating new skills or adapting to unknown contexts. This highlights the need for multidisciplinary approaches that drive progress in simulation, autonomous learning, and human-robot interface design, opening up immense opportunities to transform both technology and society.

Applications in Strategic Sectors

The adoption of physical AI in the industrial sector is transforming how machines interact with their environment and with humans. Following an analysis of technical and conceptual challenges, attention turns to how innovations in advanced robotics are directly impacting productivity, safety, and sustainability in key sectors:

Industry and Robotics

Advanced Robotics in Industrial Applications
Francesco Ferro, CEO of PAL Robotics, highlights how advanced robotics is addressing increasingly complex tasks, ranging from logistics to assisted manufacturing. Ferro identifies three key trends in industrial robotics:

Growth of Collaborative Robots: Although their market share is still smaller compared to traditional industrial robots, collaborative robots (cobots) are growing rapidly due to their ability to work alongside humans without requiring extreme safety measures.

Development of Humanoid Robots: While humanoid robots are not yet ready for widespread adoption, their technological advancements are driving improvements in other areas. PAL Robotics has been a leader in this field, notably through its collaboration in the OpenDR project, which focuses on applying deep learning to robotics.

Ethics and Safety: Safety is crucial in dynamic industrial environments. Ferro underscores the importance of ensuring that robots can operate without cloud connectivity to protect data integrity and reduce cybersecurity risks.

Practical Cases of Industrial Implementation
Javier del Ser, Chief Scientist of AI at Tecnalia, highlights the practical application of physical AI in sectors such as automotive and logistics. The integration of robotic systems with advanced sensors is optimizing processes like quality inspection, reducing operational time and costs. A notable example is the use of mobile robots in automotive assembly lines, where advanced perception technologies process real-time data, enabling precise adjustments and greater efficiency in dynamic environments.

Autonomous Mobility

Pablo Castellanos, Vice President of Engineering at Wayve, details how this startup is transforming autonomous mobility by developing vehicles capable of generalizing their learning to adapt to different environments and vehicle types. Wayve's approach focuses on end-to-end AI that mimics human learning, distinguishing itself from traditional methods that separate perception, planning, and execution.

Key Technological Advances

1. Generalized World Models:
Tools like Gaia, a "dreamer" model that predicts and generates complex scenarios in simulations, accelerate development and enhance safety.

2. Simulation with Synthetic Data:
Tools like Prism recreate diverse driving situations, which are essential for training and validating models.

3. Decision Explainability:
The Lingo model provides explainability for vehicle decisions, helping users understand the vehicle's responses and building trust.

Current and Future Challenges

The deployment of autonomous vehicles fa ces significant challenges beyond technology:

Regulation and Public Perception:
Although current autonomous systems may be safer than human drivers on average, the lack of regulatory standards and public distrust is hindering widespread adoption.

Scalability:
According to Castellanos, achieving fully autonomous level 4 or higher vehicles remains a distant goal. For now, the company is focusing on advanced driver assistance systems (ADAS) as an intermediate step toward full autonomy.

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Health and Well-being

Physical AI is also transforming the healthcare sector, with applications that combine advanced robotics and personalization to improve the quality of life for the elderly and other vulnerable groups. This field integrates cutting-edge technology with a human-centered approach, targeting both patients and caregivers to address challenges such as loneliness, personalized care, and efficiency in caregiving environments.

Assistive Robotics and Personalized Care

Dor Skuler, founder and CEO of Intuition Robotics, introduced EllieQ, an assistive robot designed to enhance the quality of life for older adults. This robot acts as a social companion that proactively interacts with users to reduce loneliness and promote healthy habits. EllieQ features:

Multimodal Interactions:
It combines language, lights, movement, and sound to create an empathetic connection with users.

Proactivity and Personalization:
The robot initiates conversations and activities based on users' needs and preferences. For example, it can proactively suggest reminders for medication depending on the context.

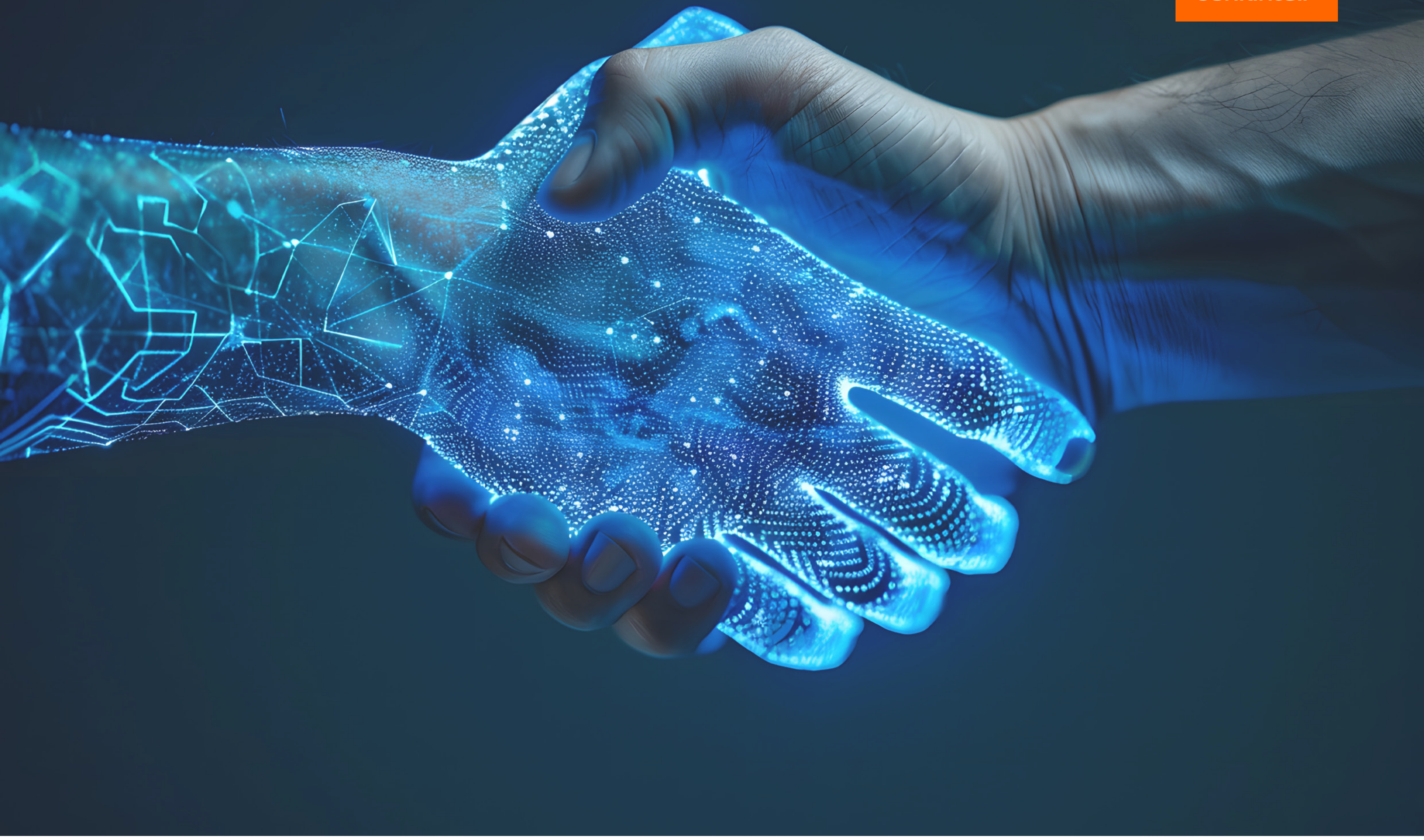
Measurable Outcomes:
Studies conducted in collaboration with Cornell and Duke Universities report a 90% improvement in quality of life and a significant reduction in loneliness.

Carme Torras, Research Professor at the Institute of Robotics and Industrial Informatics in Barcelona, shared her work on developing robots for healthcare environments, presenting two innovative applications:

Assisted Feeding:
A robot equipped with sensors and cameras that helps patients feed themselves safely and autonomously. It has proven to ease the burden on caregivers and improve the patient experience.

Alzheimer's Care:
An interactive robotic system designed to cognitively stimulate patients in day centers by engaging them in activities such as memory games and personalized tasks. This has enhanced social interaction and attention in patients.

Both experts emphasize the importance of co-creation, involving end users, caregivers, and healthcare professionals to ensure that these technologies meet real-world needs. They also highlight critical ethical challenges related to privacy, autonomy, and emotional interaction, stressing the need for clear standards in the design and deployment of such systems.



Finance and Services

Physical AI is transforming the financial sector by optimizing processes such as risk management, decision-making, and service personalization. Sergio Gago, Managing Director of AI and Quantum Computing at Moody's, describes a system with a "swarm of agents," where multiple AI models collaborate as virtual analysts to offer recommendations based on historical data, real-time analysis, and advanced simulations.

Among the applications, credit risk analysis stands out, where AI agents evaluate the risks of companies that often fall outside the reach of human analysts, and the creation of optimized investment portfolios using historical data and market trends. Gago emphasizes the need to integrate these systems with traditional financial models approved by regulators, ensuring interpretable and transparent results in a strictly regulated environment.

As an example, a prototype was presented where these AI agents collaborate to respond to complex financial queries in real time, demonstrating the potential of physical AI to support more informed financial decisions.

Modelos Cuantitativos a Gran Escala (LQMs)

Large-Scale Quantitative Models (LQMs) are revolutionizing artificial intelligence by integrating physics, biology, and natural sciences to generate knowledge based on scientific laws and simulations, surpassing the limitations of Large Language Models (LLMs). According to Fernando Domínguez, Vice President of SandboxAQ, this technology is transforming key sectors such as healthcare, materials, and navigation.

Advances in quantitative models: LQMs, unlike LLMs that rely on textual data, generate precise data through scientific simulations, improving the applicability of their solutions.

Disruptive applications of LQMs

> **Health and Life Sciences:** In collaboration with Stanley Prusiner, SandboxAQ has used LQMs to simulate key molecules for Alzheimer's treatments, reducing costs by $1.3 billion and accelerating drug development by 6 years.
>
> **Development of materials** by optimizing processes that previously required years of experimental research.
>
> **Quantum sensors** that detect magnetic irregularities in human tissues, enabling precise diagnoses in hospitals like Mayo Clinic and Mt. Sinai, UCSF. Additionally, these devices are portable and cost-effective, revolutionizing access compared to traditional equipment.
>
> **GPS-free navigation:** In collaboration with the U.S. Air Force, magnetic sensors have been developed for navigation in adverse conditions, essential for military operations and commercial aviation where GPS interference is common.

Connection Between the Digital and Physical Worlds: Domínguez highlights the synergy between LQMs and LLMs, where these act as interfaces that connect physical simulations with real applications, creating an innovative bridge between the digital and physical worlds.

Challenges and future perspectives: although LQMs must overcome challenges such as hardware scalability and integration into broader systems, they present transformative potential, opening new frontiers for AI in areas where generating reliable data is critical.

Ethical, Social, and Economic Challenges

The expansion of physical AI brings a series of ethical, social, and economic challenges that cannot be ignored. As these technologies deeply integrate into our lives and systems, they have the potential to transform how we work and interact, as well as the values and principles that guide our decisions. This section addresses the most critical aspects of ethics, regulation, and security associated with physical AI, highlighting expert contributions on the topic.

Ethics and Regulation

La regulación de la IA física requiere un enfoque ético y responsable que garantice seguridad, transparencia y equidad. Desde la interacción humano-máquina hasta la gestión de riesgos globales, los expertos del Future Trends Forum subrayan la importancia de establecer marcos normativos que aborden estos desafíos de manera integral:

Iyad Rahwan, Director of the Center for Humans and Machines at the Max Planck Institute for Human Development, emphasizes the importance of understanding machine behavior as a cultural and social phenomenon. He proposes using behavioral science methods to analyze the norms emerging from human-machine interactions. Initiatives such as the "Moral Machine" experiment have revealed ethical dilemmas that vary across cultures, such as the prioritization of human lives in accidents involving autonomous vehicles, highlighting the need for global regulatory frameworks that adapt to local contexts.

Ginevra Castellano, Director of the Social Robotics Lab at Uppsala University, stresses that transparency and trust are essential for developing responsible social robots. In projects such as SimAware, which uses participatory design to understand user expectations in autonomous vehicles and robots applied to education and healthcare, Caste llano demonstrates how public perception affects the adoption of these technologies. This underscores the need to incorporate ethical values from the earliest stages of design.

Gadi Evron, CEO of Knostic, analyzes the risks of privacy and security in the integration of AI into corporate and social systems. He highlights how tools like language models can be exploited for security breaches and data manipulation. Examples include "jailbreaking" in AI systems and growing concerns about knowledge privacy, especially in corporate environments where data leaks can have severe consequences.

Shahar Avin, Researcher at the Center for the Study of Existential Risk at the University of Cambridge, points out the catastrophic risks associated with physical AI, particularly due to the integration of digital and physical systems, which increases vulnerability. He stresses the need for international regulation to prevent the misuse of this technology in critical infrastructure or weapon systems, warning that the lack of global collaboration poses a significant obstacle to ensuring its safe development.

Labor Impact and Training

The transformation that physical AI is generating in the labor market is profound, affecting both the skills required and employment opportunities across various sectors. As technology advances, it presents both risks and opportunities for workers and organizations. Experts from the FTF have analyzed how automation and training can reshape the dynamics of work.

Labor Market Transformations

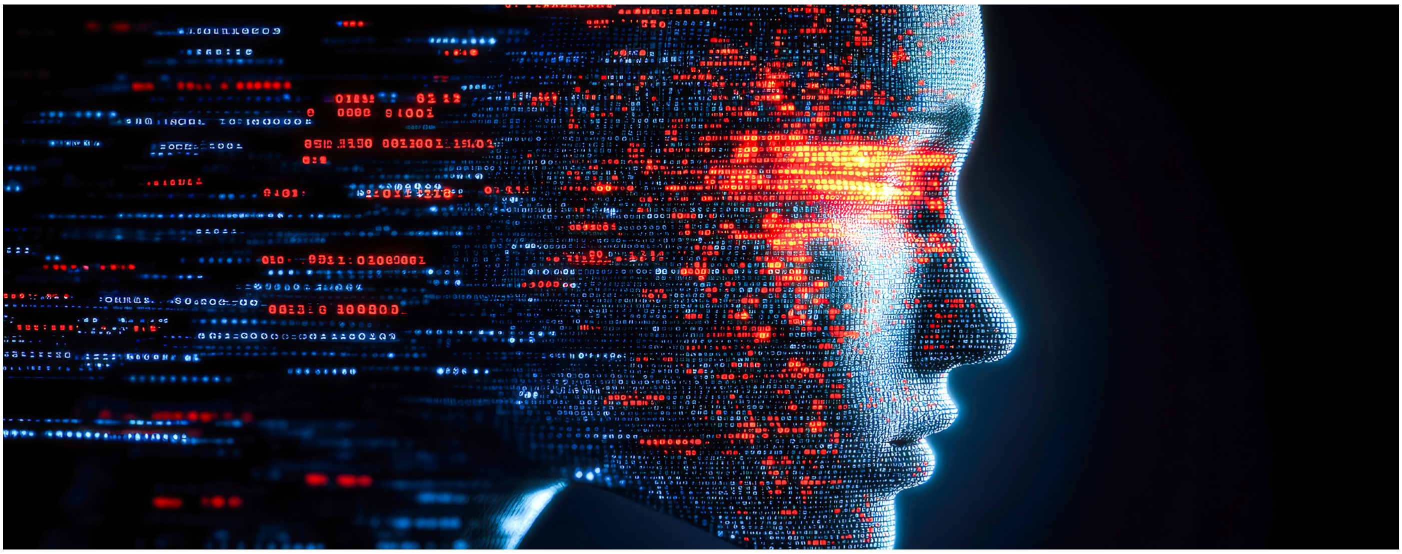
David Dorn, Professor of Economics at the University of Zurich, analyzes the impact of adopting physical AI in the labor market, highlighting that it primarily affects middle-income occupations, such as factory operators and administrative staff, where tasks are structured and well-defined. However, recent advancements are also impacting low-income jobs, which have traditionally been difficult to automate due to skills like visual recognition and verbal communication.

Dorn outlines three key scenarios to understand the impact of physical AI on work:

Task-Specific Automation:
Instead of replacing entire jobs, physical AI eliminates individual tasks, forcing workers to adapt to new roles. An example is the introduction of ATMs, which allowed bank employees to focus on personalized services.

Technological Complement:
AI enhances human productivity and enables companies to redirect resources toward innovation, especially benefiting highly skilled jobs.

Economic Redistribution:
The increased productivity driven by AI generates resources to create new roles in emerging sectors. However, the speed of change could destabilize society if not accompanied by appropriate public policies.



Thomas Hurd, founder of Zeki Data, highlights the critical role of major tech players in attracting and retaining global talent. According to his data, Europe faces unique challenges in scaling emerging technologies due to less consolidation in its industrial ecosystems. However, it has an advantage in the close collaboration between universities and deep tech startups.

Strategies for Talent Training

Sonia Chernova, Professor at Georgia Tech, emphasizes the importance of tailored training strategies for a diverse workforce. She underscores that personalization will be key in future training, highlighting examples such as:

Specific Retraining Programs:
Relocating workers to roles closely aligned with their current skills is more efficient and less costly than complete reskilling.

AI-Driven Continuous Education:
AI-based tools enable less experienced employees to learn from data generated by more experienced colleagues, reducing inequalities and improving access to skilled jobs.

Chernova also advocates for inclusive design from the outset of AI projects, promoting multidisciplinary teams to ensure that technologies are aligned with the real needs of end users.

Biases, Human Representations, and the Cultural Impact of AI

Artificial intelligence applied in generative and social tools is revealing biases that perpetuate inequalities and affect cultural values. Nuria Oliver, co-founder of ELLIS Alicante, highlights how technologies such as MidJourney reinforce social role stereotypes by generating biased images, such as associating “CEO” with men and “nurse” with female figures from the 1950s. These representations consolidate cultural and gender prejudices.

Beauty filters also amplify significant social issues:

Reduction of Diversity: They homogenize facial features, erasing individual characteristics.

Racial Biases: They associate beauty with European traits, reinforcing cultural prejudices.

Halo Effect: They increase perceptions of intelligence and trustworthiness based on appearance, negatively influencing job and social opportunities.

These technologies, while innovative, pose ethical and psychological challenges that require attention to prevent the reproduction of existing inequalities.

Investment and Competitiveness

Physical AI is attracting massive investment due to its potential to transform key sectors such as robotics and healthcare. Advances in generative models, hardware, and specific applications are driving global competition, with key players like the United States and China leading the way, while Europe lags behind in terms of investment and the number of initiatives.

Trends in AI Investment

Eden Shochat, Partner at Aleph and trustee of the Foundation, explains how AI has become a strategic priority for investors, with a third of technology deals focused on AI. Shochat emphasizes that companies failing to adopt AI significantly tend to lose competitiveness.

Key trends highlighted include:

Scarcity of Technological Resources:
The shortage of talent, data, and GPUs limits AI growth. Shochat compares Nvidia's performance with Bitcoin, illustrating how the demand for specialized hardware is driving adjacent markets.

Advances in Generative Models:
Shochat points to an example of a model learning the rules of the game Minecraft by watching videos, demonstrating AI's potential to learn and generalize like a human. However, he acknowledges legal and commercial barriers to bringing such models to market.

Geopolitical Impact:
Strict regulation in Europe is hindering growth compared to the United States and China, where investment in AI is significantly higher.

Opportunities and Challenges in Robotics

Jordan Sun offers a complementary perspective based on his experience at SoftBank Robotics, highlighting how investment in robotics is shifting toward a problem-solving focus. Sun identifies three phases of investment in robotics:

Traditional Phase:
Dominated by players like FANUC and ABB, focused on industrial robots for highly centralized factories.

Resurgence of Investment in 2020:
Driven by advances in generative models, reduced component costs, and increased interest in specific applications such as logistics and agriculture.

New Business Models:
Sun highlights concepts like Robots as a Service (RaaS), where robots are rented to reduce adoption barriers and make them more accessible to smaller companies.

Political Perspectives and AI Sovereignty

The control of artificial intelligence is essential for ensuring the competitiveness and technological independence of nations. AI sovereignty requires both the development of homegrown technologies and policies that balance control, innovation, and international collaboration. David Shrier, Professor at Imperial College London, and Jordan Sun, previously mentioned expert, offer key approaches to these challenges.

Collaborative Models and Technological Sovereignty: David Shrier proposes the creation of a pan-European open-source software infrastructure, similar to the Airbus model, to enable cross-country collaboration, foster regional innovation, and reduce reliance on external companies. He emphasizes the importance of public-private partnerships to fund these initiatives, highlighting examples from Denmark and Switzerland, where governments collaborate with the private sector through tax incentives and support for AI infrastructure.

AI as a Geopolitical Weapon: Jordan Sun compares the strategic importance of AI to past arms races, stressing the leadership of China and the United States due to their dominance in foundational models, cloud services, and specialized talent. He underscores that technological sovereignty not only means possessing advanced technology but also avoiding critical dependencies on other countries. Sun advocates for ecosystems that enable local adaptation and development of AI systems to mitigate historical vulnerabilities.

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Reflections and Recommendations

The Future Trends Forum on physical AI provided a platform to explore advancements and applications and served as a space for reflecting on the future and generating concrete proposals. In early 2025, the Bankinter Innovation Foundation will publish the report on physical AI, which will contain the final recommendations developed in collaboration with the experts who participated in this edition.

Key Reflections

1. The Importance of the Human Factor:
Physical AI systems must be designed with a focus on human needs and values. Acceptance and trust are key to adoption. Integration should avoid dehumanization in key interactions, especially in sectors like healthcare and caregiving.

2. Balanced Innovation and Regulation:
Achieving a balance between regulation and innovation is essential. Regulation should not stifle development; it must ensure safety and fairness.

3. Interdisciplinary Collaboration:
The successful application of physical AI depends on cooperation between engineers, psychologists, regulators, and designers.

Strategic Recommendations

1. For Technology Developers:
Design systems that prioritize transparency and accessibility, ensuring that AI complements rather than replaces human skills.
Adopt modular models that facilitate the adaptation of technologies to different contexts.

2. For Regulators and Governments:
Establish harmonized international regulatory frameworks to foster innovation and ensure ethical and safety standards.
Promote training programs for regulators to better understand emerging technologies and their implications.

3. For Education and Society:
Redesign educational models to incorporate interconnected disciplines, preparing future generations to interact with physical AI.
Create continuous training programs to update the skills of the existing workforce.

4. For Companies and Industry:
Invest in R&D that prioritizes positive social impact.
Collaborate with startups and universities to accelerate knowledge transfer and the practical implementation of solutions.

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