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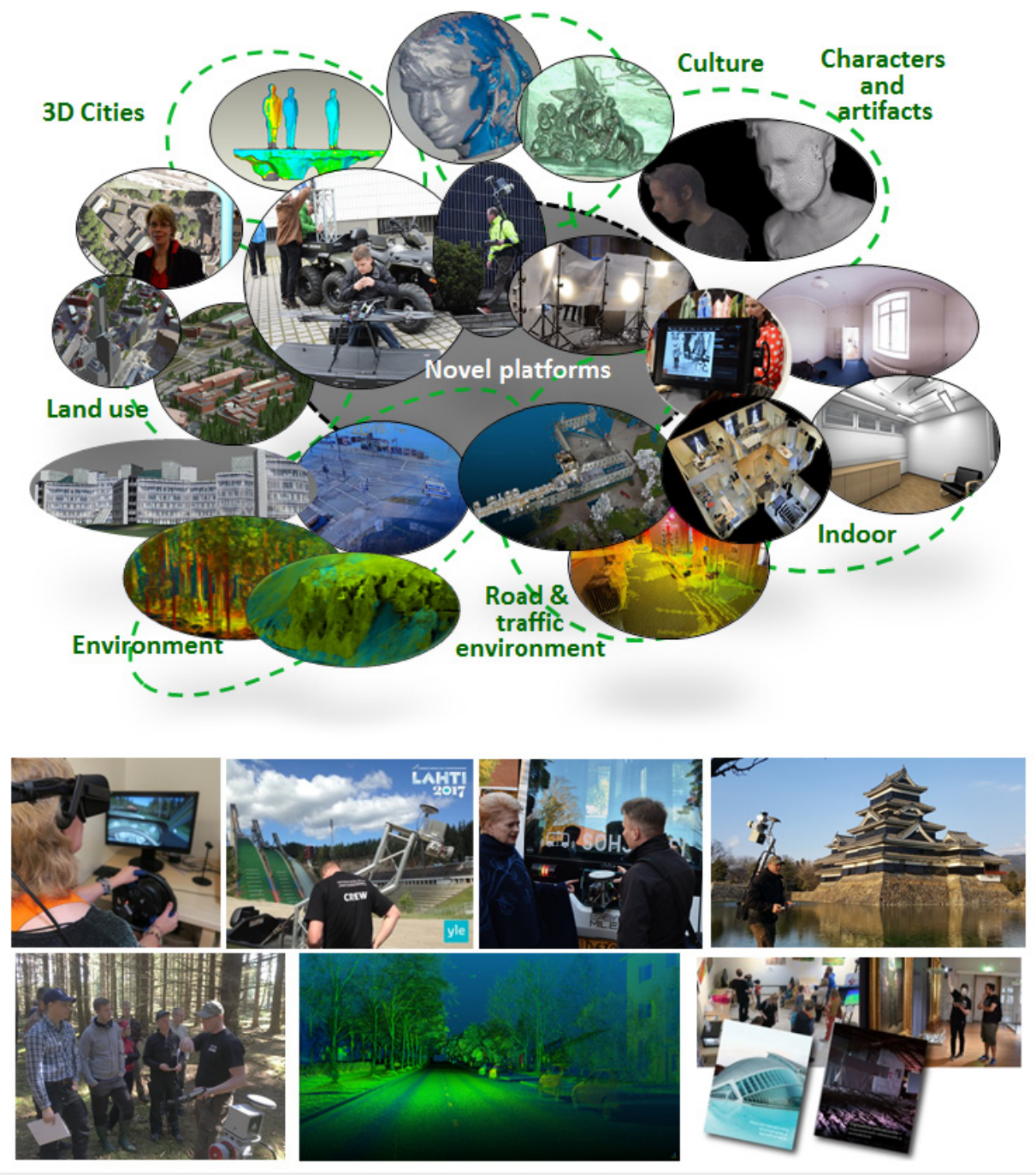

Smart Point Cloud Ecosystem—Solving the 3D, 4D, and Virtual Reality needs of Engineering, Society and Culture

Impact case study
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Field 3b: Engineering

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Smart Point Cloud Ecosystem—Solving the 3D, 4D, and Virtual Reality needs of Engineering, Society and Culture

1. Summary of the societal impact

Problem to solve: There is a global trend toward the convergence of physical and virtual worlds. Increasing need for information in future services and decision-making can be supported with 3D, 4D and mixed reality data and analysis. A large number of location-based services and consumer-grade applications will be based on this kind of 3D geospatial data. This information is fundamental in maps, 3D digital cities, concepts of Digital Twins, self-driving car technology (100m cars sold annually), to name but a few examples. Accurate 3D information is also increasingly applied in various engineering tasks, natural sciences, architecture and cultural heritage.

Offered solution: Photogrammetry, laser scanning (LS), and other 3D sensing technologies are the main methods for providing 3D, 4D and virtual reality from point clouds for our living environment, with varying scales, from local to global. Mobile laser scanning (MLS) is one of the main techniques applied today in autonomous driving and autonomous machines, creating virtual reality, street view mapping, corridor surveys (road, powerline, fluvial), and providing 3D geoinformation for decision-making, for culture production and even for entertainment. Capturing urban data with backpack LS was a novel innovation, using various technologies: GNSS/IMU (Global Navigation Satellite System)/IMU (Inertial Measurement Unit) positioning, LS, digital photography and data-driven algorithms for improving the positioning in often GNSS denied urban space. Personal laser scanning (PLS) allows rapid data collection of a complex environment without compromising the data coverage, precision and accuracy of the data. The research aims to develop modern surveying practices, investigate alternative system and sensor layouts and performance related issues, as well as formulate automated data processes for 3D modelling, and seeks methods for improving geometric quality of data and data fusion. With the emergence of consumer-grade 3D sensing, highly automated digital photogrammetry, and novel visualization methods (mixed reality, game engines, browser-based 3D), these technologies have matured to a degree where they can contribute to actions outside the traditional professional domain.

Impact: Research of Aalto/MeMo (joint institute with the Finnish Geospatial Research Institute, FGI) has brought significant societal impact by 1) developing the concept of national elevation modelling with airborne laser scanning (ALS), which is now open data. Today four-fifths of Finland is covered by this dataset. Current model is 50% cheaper to produce than the older product, accuracy is 10 times higher, and it requires only one-third the personnel. The Finnish process has been transferred to Sweden and Estonia, annually saving tens of millions euros. 2) Standwise forest inventory in Finland is based on ALS, research begun by Prof. J. Hyyppä and Prof. H. Hyyppä. The saving for society is about €20-30m per year. We have initiated precision forestry based on individual trees obtained from LS. By 2030, it will be the main global technology to derive forest information for industry. 3) We have been the forerunner in the world in developing new measuring platforms, for example MLS, unmanned aerial systems (UAS), and PLS equipped with various mapping sensors. Our technology has led to new startups in Finland, as well as in the USA and Japan.

2. Underpinning research/artistic activity related to Aalto activities

Multidisciplinary research approach: With these initiatives, we contribute to society in a significant way by enhancing digital transformation in engineering, culture and arts as well as providing economic savings in society. We operate with 4 professors at Aalto and about 30 personnel. The group consists of engineers of different backgrounds (civil, survey, electronic, IT), designers, culture producers, geographers and 3D artists.

Internal and external networking: The group is active nationally and worldwide. With the Finnish export industry, end-user organisations, and decision-making bodies, we have formed a leading

point cloud research ecosystem and entity focusing on LS, especially on MLS. We collaborate with more than 150 organisations. We interact with Finnish decision-makers, national strategies, Transport Code actors, land use, infrastructure and city planning, the export industry (sensor, software, vehicles, services), international top researchers, startup founders, national leading visionaries, citizen business angels and venture capital to identify opportunities provided by technology disruptions and to maximize the benefits for Finland.

Strategic focusing: The research is related to two of Aalto University's key research areas: *Human-centered living* and *Digitalisation*. Our Institute is a world-leading research environment in the field of LS. Aalto/MeMo and FGI together are ranked #1 in the Web of Science in the field of (mobile) LS. The point cloud ecosystem started in 2012 with developed multiplatform MLS solutions, such as vehicle- and trolley-operated urban area data acquisition, and boat-mounted equipment for fluvial environments. The Centre of Excellence in Laser Scanning Research (2014-2019) brought insight into topics of PLS and UAS. The Academy of Finland's Strategic Research Funding *Pointcloud* project (2015-2021) focuses on the utilization of point clouds for 3D modelling and commercial potential in mapping forests, cities and routes, such as roads, power lines and rivers.

World-class research infrastructures: Our 3D studio with self-built mapping systems serves as an outstanding learning environment for our students and researchers, making it possible to showcase our field with concrete examples. In this way, we have combined teaching and research to support one another.

3. References to research

Selected references in building new platforms and applications on flood mapping, national land mapping, road environments, powerline corridor surveys, forest inventory, and autonomous driving.

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2. **Vaaja, M, Kukko, A,** Kaartinen, H, **Kurkela, M**, Kasvi, E, Flener, C, **Hyyppä, H, Hyyppä**, J, Järvelä, J & **Alho, P** 2013, 'Data Processing and Quality Evaluation of a Boat-Based Mobile Laser Scanning System' *Sensors*, 13, 9, pp. 12497-12515. DOI: 10.3390/s130912497
3. Matikainen, L, Lehtomäki, M, Ahokas, E, **Hyyppä, J**, Karjalainen, M, Jaakkola, **A, Kukko**, A & Heinonen, T 2016, 'Remote sensing methods for power line corridor surveys' *ISPRS Journal of Photogrammetry and Remote Sensing*, 119, pp. 10-31. DOI: 10.1016/j.isprsjprs.2016.04.011
4. **Virtanen, JP, Kukko, A**, Kaartinen, H, Jaakkola, A, Turppa, T, **Hyyppä, H & Hyyppä, J**. 2017, 'Nationwide point cloud-The future topographic core data' *ISPRS International Journal of Geo-Information*, 6, 8, 243. DOI: 10.3390/ijgi6080243
5. **Hyyppä, J, Virtanen, J-P**, Jaakkola, A, Yu, X, **Hyyppä, H** & Liang, X 2017, 'Feasibility of Google Tango and Kinect for Crowdsourcing Forestry Information' *Forests*, 9, 1, 6. DOI: 10.3390/f9010006
6. Jaakkola, A, **Hyyppä, J**, Yu, X, **Kukko, A,** Kaartinen, H, Liang, X, **Hyyppä, H** & Wang, Y 2017, 'Autonomous Collection of Forest Field Reference-The Outlook and a First Step with UAV Laser Scanning' *Remote Sensing*, 9, 8, 785. DOI: 10.3390/rs9080785

4. Societal Impact, activities and roadmap for the case

Our collaborations, training of future experts, technology transfer and spinoffs have been successful: We have collaborated with Yle (Finland's national public service broadcasting company) in several virtual reality productions [1] [2] [3] (see Section 5) to create new media and novel visualization methods with virtual reality. The technology is expected to provide large savings and possibilities for organisations related to culture [4][8].

Since 2015, we have educated Japanese experts in LS of forests. This education has been missing in Japan. [7] In addition, European forest companies, such as Stora Enso, UPM and MetsäGroup are now (2014-2017) accepting the concept of precision forestry. [11] In addition, technology has been transferred to more than 20 companies in Finland, one of the closest collaborators has been Terrasolid, leading the LS preprocessing software business globally. [6]

Our mini-UAV laser scanner technology was spun off to Sharper Shape Oy in 2013 and later to Sharper Shape Group Ltd (North Dakota, USA), and was listed among 50 most potential Finnish startups in 2016 for corridor mapping. In a similar way, autonomous driving companies ArcticRed Oy and Gaze Inc (San Francisco, USA) have been founded. MLS has been spun off to Solid Potato Oy and real-time point cloud acquisition to Ladimo Oy. Forerunners in the world of developing new measuring platforms, for

example MLS, UAS, and PLS equipped with various mapping sensors. [5]

Finally, our students won the innovative Sick-competence 2017 award. Also, some of our researchers have won several prizes in hackathons and design competitions. [10]

5. Sources to support the impact case

Our innovations are often featured in Finnish and international media: Yle Svenska, Yle, Yle Puhe, *Tekniikan maailma*, *Tekniikka ja Talous*, *Kauppalehti*, *Tietoviikko*, *GIM Magazine*, *CNN Money*, *Xinhua News*, *The Guardian*, *Die Zeit Online* and others. For more detail, the following selection of links demonstrate the impact of the point cloud ecosystem:

1. World's first 3D virtual radio play (Helsinki Festival)
2. Lahti Ski Championships 2017– 3D ski tracks
3. Interactive 3D model of Puhos project, more than 50 000 visitors
4. Aalto Excellence Recognition 2016-2017
5. Laser Scanner in a Backpack - *GIM Magazine*
6. *Pointcloud* project
7. The Centre of Excellence in Laser Scanning Research
8. Virtual models come culture and art events – Tekniikka ja Talous
9. Sharper Shape closes 3 million in funding
10. SICK 25 v innovation competition
11. Wood supply digitalisation in Finland

6. Future goals

Our point cloud vision is 'Laser scanning will be omnipresent and affect the life of every citizen in the modern information society by the early 2020s'. We foster activities toward achieving a dynamic 3D Finland with point clouds. We pursue several breakthroughs, such as new multi-spectral and hyperspectral single photon LSs with our spinoffs. Such instruments could revolutionize surveying, urban planning, construction, industrial engineering, autonomous driving and robotics by providing active colour vision instead of grey scale of single wavelengths. We propose to use multispectral lasers for improved perception in different weather conditions, more accurate positioning of autonomous cars and classification of road, urban and forest data more reliably and faster. We are turning Finland into a continuously updated multi-temporal point cloud country-wise, and regionally on-demand LS directed change detection–we introduced the first in the world. From 2020 onward, we will start to scan the whole of Finland at 5-year intervals. The data is open, and it provides about €200m annual possible value added potential. We are and will educate experts mastering complicated processing, such as technologies mixing remote sensing, surveying, robotics and computer science for meeting the needs of society where more and more problems are solved with point clouds and virtual reality.