smAvo: A Transcontinental Odyssey by Land and Sea

18 August 2021 | Road Pavements Forum

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Overview

- Introduction & Research Objectives
- smAvo/smaTo Instrumentation
- The odyssey



- Packhouse environments (short duration, high impact)
- Road transportation (2-day journey, moderate impact, low impact environment)
- Ship transportation (2.5-week journey, low impact environment)
- So-what?
- Future development & research
- Conclusions
- Questions & Discussion



The Great Odyssey

- End-to-end transportation chain
- Transportation engineering in action



Research Objectives

- Quantify potential damage of avocadoes and tomatoes in transportation environments
- Development of custom, low-cost, programmable sensor platforms / instrumentation
- "Big Data" processing requirements
- Data-driven recommendations / guidelines for improving processing & packing (packhouses, transportation by road and sea)
- Various stakeholders/projects: SAAGA, PHI, ZZ2, Halls, FleetMon and planet.com



smAvo Instrumentation

- Originally developed 3 smAvo prototype units
- Suited to initial field trials (March 2019)
- Moisture penetration during the first packhouse trial → optimize design





smAvo Instrumentation

- Improved waterproof design with simplified operation
- Smaller, more representative volume
- **Density** lower than water \rightarrow flotation
- Softer PETG filament used for exoskeleton
- smaTo: identical electronics, different shell
- Primary sensors considered for study
 - 3-axis MEMS accelerometer (100 Hz)
 - 3-axis MEMS gyroscope (100 Hz)
 - Easy quantification of produce response on transportation infrastructure



smAvo Instrumentation



- Detailed development process published in HardwareX
- Open access journal: article link



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Data Processing Pipeline

- Data stored on non-volatile SD cards
- Automatic **post-processing** using software developed in Python
- Aggregate representative statistics to establish trends, insights, conclusions and recommendations



Python[™]



Packhouse Processing (SAAGA)

- Short duration high-intensity
- 20 packhouses instrumented (possible 37 packhouses) over a 7-month period
- Wide geographic spread (Limpopo, KwaZulu-Natal, Mpumalanga)
- Different loading methods (bins & crates)
- Various levels of mechanization & packline capacities encountered
- Field testing conducted whilst observing all Covid-19 regulations & safety protocols



Packhouse Classification Model

 All statistics combined; choose three candidates (optimized, average & unoptimized packhouse)





Packhouse Acceleration History

- Large differences in duration and amplitude experienced by smAvos
- Large amplitude accelerations → roller elements



Acceleration Vector Distribution

• Largest intensity about section with smallest second moment of area, i.e. large flat face tends to align with rollers



Average packhouse

1.0

0.0

0.5.8

0.0.3

-0.5

-1.0



Unoptimized packhouse



- Farm-to-packhouse route (short sections, high variability)
- Differences between tractor and truck transportation (paved and unpaved)



 Excessive vibrations lead to lenticel damage → shorter shelf life → poor quality and low value





- Substituted the smAvo for smaTo devices (identical electronics)
- ZZ2 packhouse (Tzaneen) → Pretoria market → Cape Town market (1800 km)





- Acceleration history representative of both the box confinement and road conditions (paved / unpaved)
- Lack of geolocation data (GPS signal) compensated for using barometric air pressure measurements (smaTo is not completely waterproof)



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Unexpected resonance / high-intensity vibration phenomena



- Unexpected resonance / high-intensity vibration phenomena
- Link back to geolocation and road information for impact on produce





Transportation by Sea (Halls)

 Avocadoes are exported from Cape Town harbor to Rotterdam in the Netherlands (13 500 km, ~2.5-week journey)

Instrumentation installation (2021/05/11)



Akadimos container vessel (9500 TEU) in port of Cape Town (2021/05/13 12h00)

Akadimos arrives in Rotterdam (2021/06/01 14h19); live webcam



Transportation by Sea (Halls)

- Real-time tracking using in-house data platform (Innovation Africa)
- Incorporation of satellite positioning and maritime weather models (FleetMon)



Transportation by Sea (Halls)

- Majority of the 8× instruments operated as expected
- Successfully measured movement of the vessel and barometric effects associated with quality control measures
- Battery technology remains primary limitation (for refrigerated environments)
- Post-processing of data and results in progress with follow-up studies already underway

Instruments in Rotterdam Gerard de Jong – Quality Manager



Conclusions



- Custom designed instrumentation (smAvo and smaTo) works as designed
- New insight into packhouse dynamics, road transportation network, logistic operations, cold chain management and condition monitoring at sea
- Monitor not only produce, but also operating conditions pertaining to machinery (packhouses) and roads (with localization)
- Industry (15 500 km in total) stands to benefit from new sensor technology for risk identification and mitigation
- Identify areas for investment to reduce variability and nonconformant links leading to damaged produce



Future Research Endeavors

- Continuous instrumentation of export / international shipping routes that remains the least understood → LoRaWAN deployment at UP
- Discrete Element Modelling (DEM) of physical environments
- Blockchain technology → non-fungible digital twin captures origin, quality, eCO₂ footprint and risk to products



Acknowledgements



- SAAGA (South African Avocado Growers Association) for providing research funding & links with industry support
- PHI (Post Harvest Initiative) for funding related to smaTo/tomato work conducted in parallel to smAvo/avocado projects
- ZZ2 for their assistance in instrumenting vehicles (tomato shipments)
- Halls for their assistance in instrumenting containers (shipping to the Netherlands)
- planet.com for satellite imagery and FleetMon for satellite derived geolocation and associated weather data



Questions & Discussion



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