Evaluation of Proposed Standard Data Format and Compression Algorithms for 2D/3D Pavement Surface Image

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September 19, 2019

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ACKNOWLEDGEMENT

- The authors would like to thank the FHWA Contract DTFH6117P00139, the project manager (Andy Mergenmeier) and the committee panel (Dave Huft, Rick Miller, and Jianhua Li) for providing the input and guidance.
- The authors would like to thank the data provided by the Oklahoma State University (OSU).
- The authors would like to thank the input on the data format provided by the state DOTs, vendors, and Universities.
  - Ames Engineering, Mark Leichty and Ryan Emmerson
  - Apiroter, Sajid Mukhtar
  - Dynatest, Salil Gokhale
  - Furgo, Matthew Taylor
  - Georgia Department of Transportation, Eric Conklin

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ACKNOWLEDGEMENT (CONT'D)

- The authors would like to thank the input on the data format provided by the state DOTs, vendors, and Universities.
  - HyMIT LLC, Robin Huang
  - International Cybernetics Co., Michael Nieminen
  - Kansas Department of Transportation, Rick Miller
  - LMI Technologies, Glenn Hennin
  - Oklahoma State University and WayLink Systems Corp, Kelvin Wang
  - Pathway Services Inc., Scott Mathison
  - Pavemetrics, John Laurent
  - South Dakota Department of Transportation, Dave Huft
  - Texas Department of Transportation, Jenny Li
  - Vectra Geospatial, Shrikrishna Shastry
  - Virginia Tech, John Ferris from Virginia Tech
  - Washington State Department of Transportation, Jianhua Li

Outline

- Project objectives
- Need of standard data format
- GT enhancements
- Summary
- Recommendations

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Project objectives

- Objectives:
  - Independently evaluate the three reports and the proposed draft specification for the standard data format and compression algorithm for 2D/3D data, which were delivered under the previous FHWA contract, DTFH6115P00103 (carried out by OSU).
  - Verify the functionality and performance of the proposed standard data format and compression algorithm in terms of image fidelity processing speed, data storage requirements, and other important parameters.
  - Assess the suitability of the standard data format for use by state highway agencies and 2D/3D technology vendors.
  - Propose a set of rules by which a state highway agency can conform compliance with the standard data format.

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Need of Standard Data Format

As indicated in the RFQ HTSBAL1700000003PR, a standard data format will address the following needs:

- Reprocessing data when new analysis algorithms are developed.
- Analyzing 2D/3D digital images from different sources.
- Supporting the structure of the AASHTO standards separating data collection from analysis (similar to longitudinal profilers and falling weight deflectometers).
- Effectively exchanging data across users, software tools and platforms.
- Promoting the development of 2D/3D pavement data collection and analysis technology.
- Facilitates efficient certification and production verification processes

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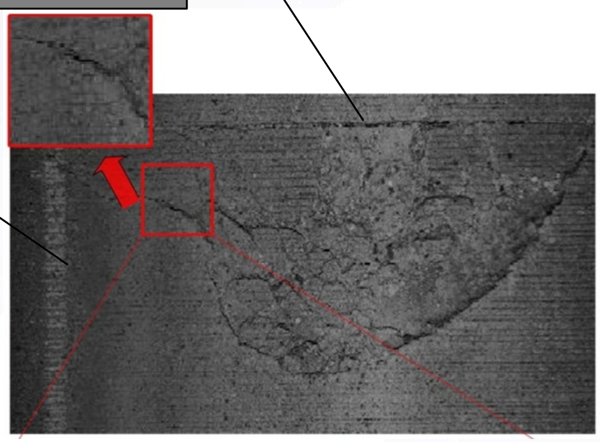
2D and 3D Pavement Image

- Definitions in AASHTO R86 -18
  - Pavement Image is a representation of the pavement that describes a characteristic (**gray scale**, color, temperature, **elevation**, etc.) of a matrix of points (pixels) on the pavement surface
  - In this project, 2D image indicates gray-scale image; 3D image indicates image storing elevation at each pixel.

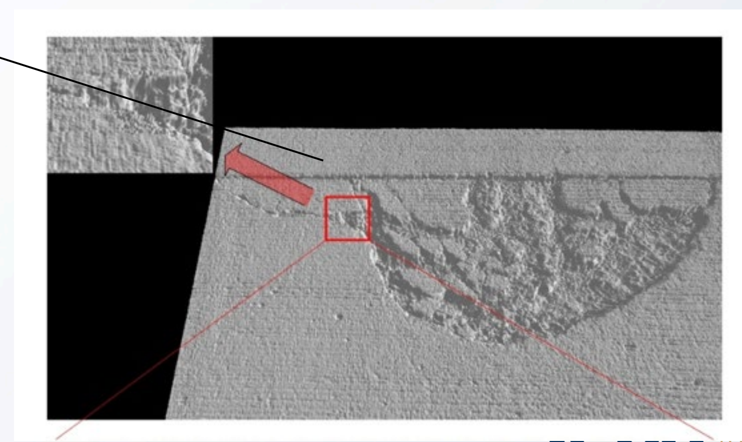
- Grey-scale value (0 to 255)

Pixel, typically 1 mm x 1 mm

X,Y



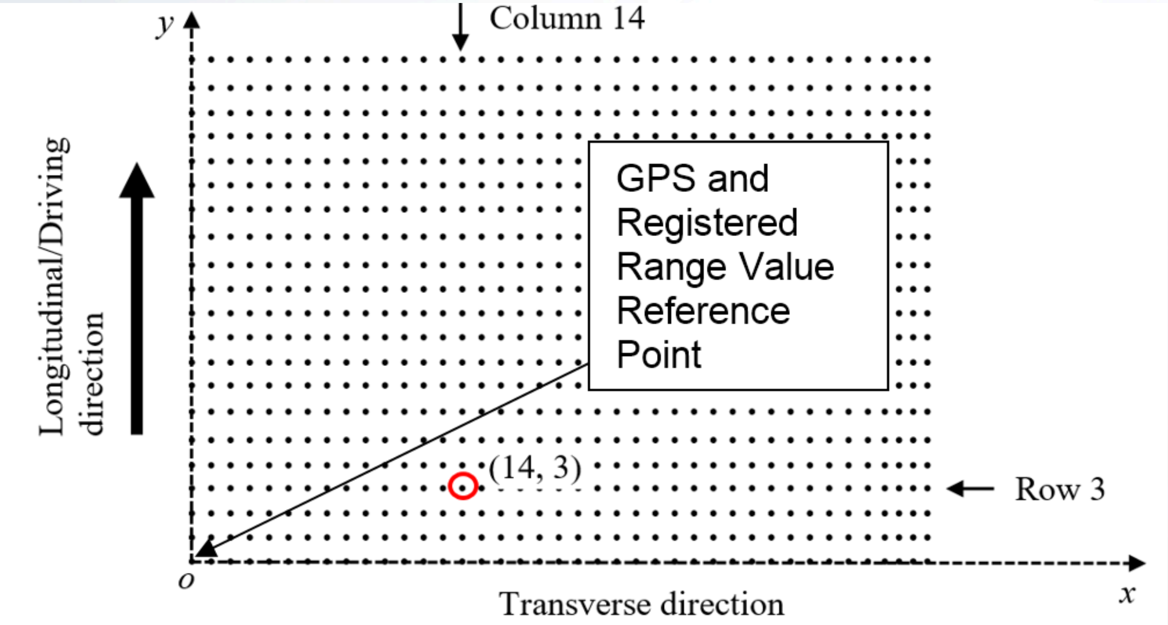
- Range (registered or unregistered)
  - A 2D matrix, too



Picture from: OSU Task 2 Report

Enhancement: Image Representation

- A defined image coordinate system
- A defined method of pixel storage



Variable Name	Data Type	Data Details
Pixel Storage	Uint8	R – Row-first storage; C – Column-first storage

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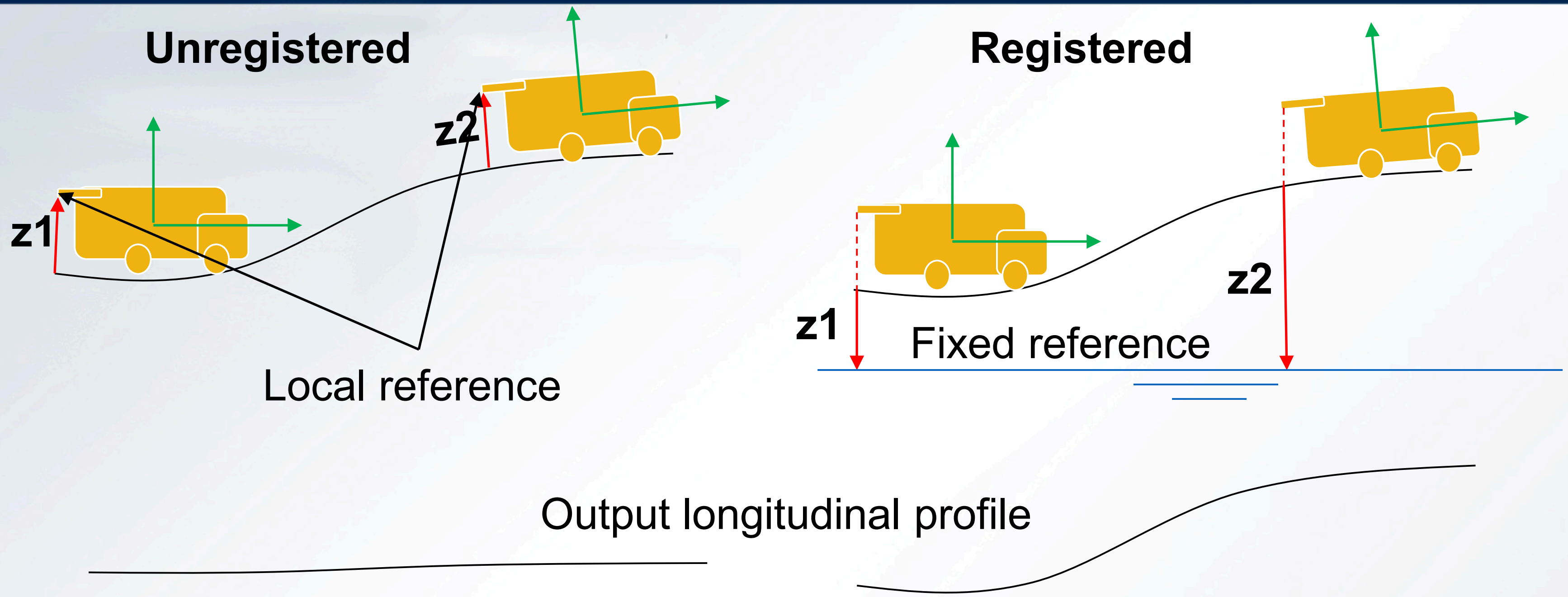
Enhancement: Registration of Range Data



Variable Name	Data Type	Data Details
3D Registration	Uint8	R – Registered; U – Unregistered
Reference Range Value	Float 32bit	Range value of the reference point. 0 when "3D Registration" is "U."

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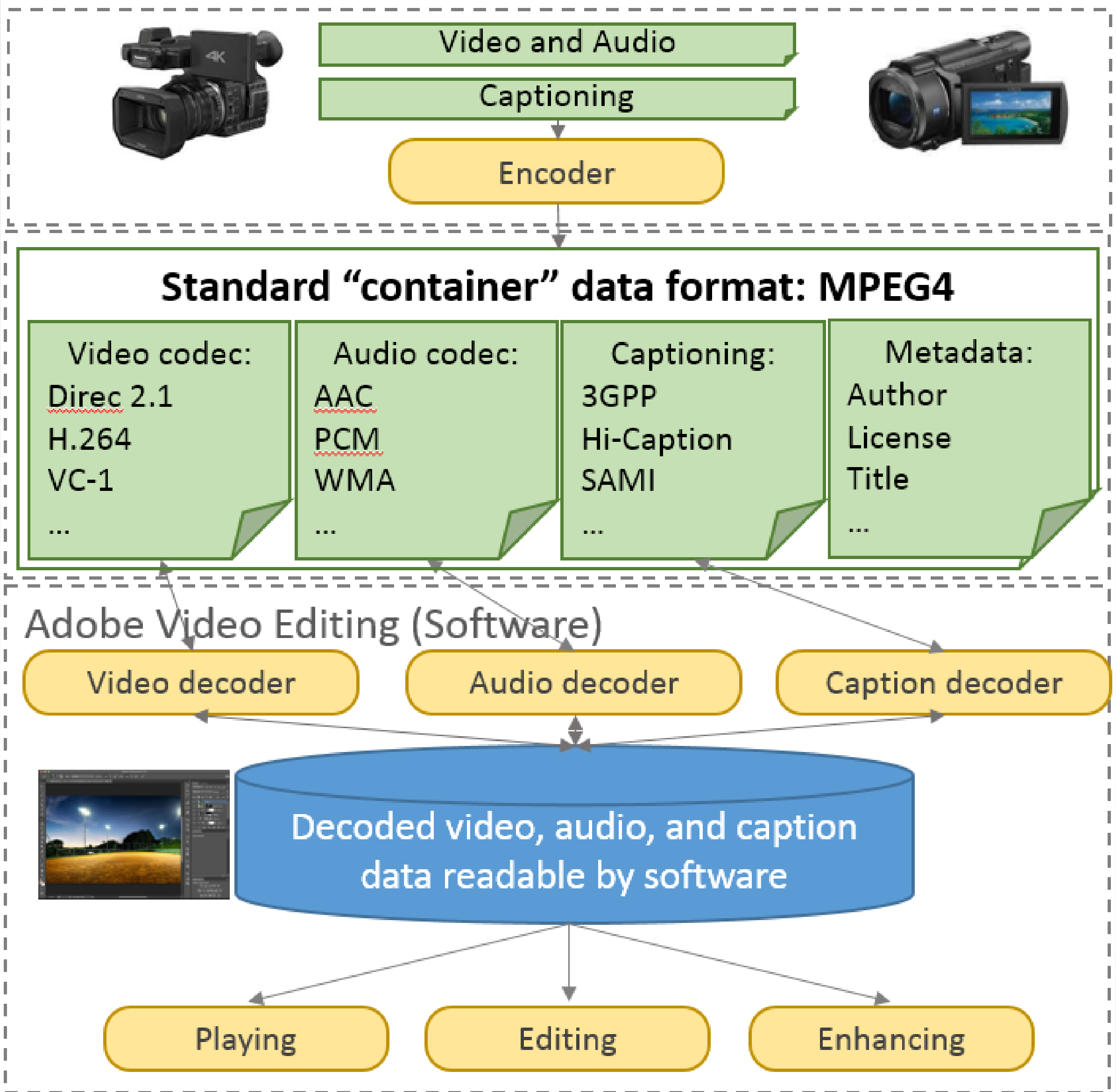
Enhancement: Other File Headers and Input from Industry and Users

- Header fields are added to record the information for System Sensor and Organization Name
  - Sensor System Number was added to provide sensor level tracking information
  - Organization Name was added to provide the information of the organization that the operator is affiliated to.
- The original four reserved data fields were merged as one data block that can be used for storing customized information
- Input from industry and users (Examples)
  - Use better naming convention for the data types, suffix s and u to the type name to explicitly indicate whether it is signed variable (Int32 ->Int32s).
  - Choose 16 bits as the required bit depth for 3D range image.
  - Combine and leave more space for the reserved data field; let the user determine how this field should be interpreted.
  - Add an ISO compliant file signature at the beginning of the .psi file.
  - For String types, make them "Null" terminated (from variable length)
  - Use type double 64-bit for better GPS Latitude and Longitude resolution.

Video Format Analogy– Separation of Data Collection from Data Analysis



codec: a device or computer program for encoding or decoding a digital data stream or signal.

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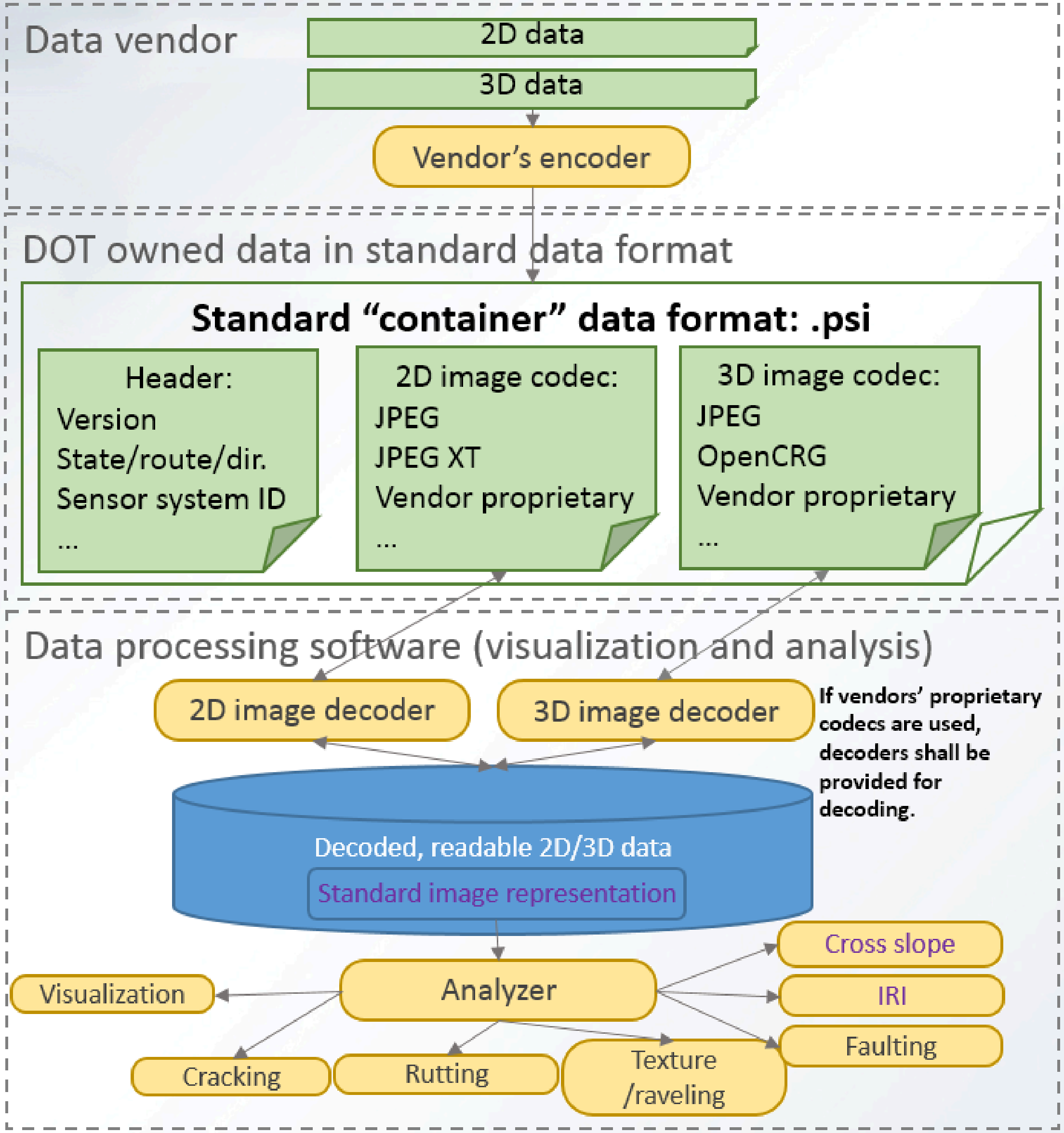
Proposed Standard Data Format: Pavement Surface Image (.psi)



Bring the concept of **Standard "container" data format**

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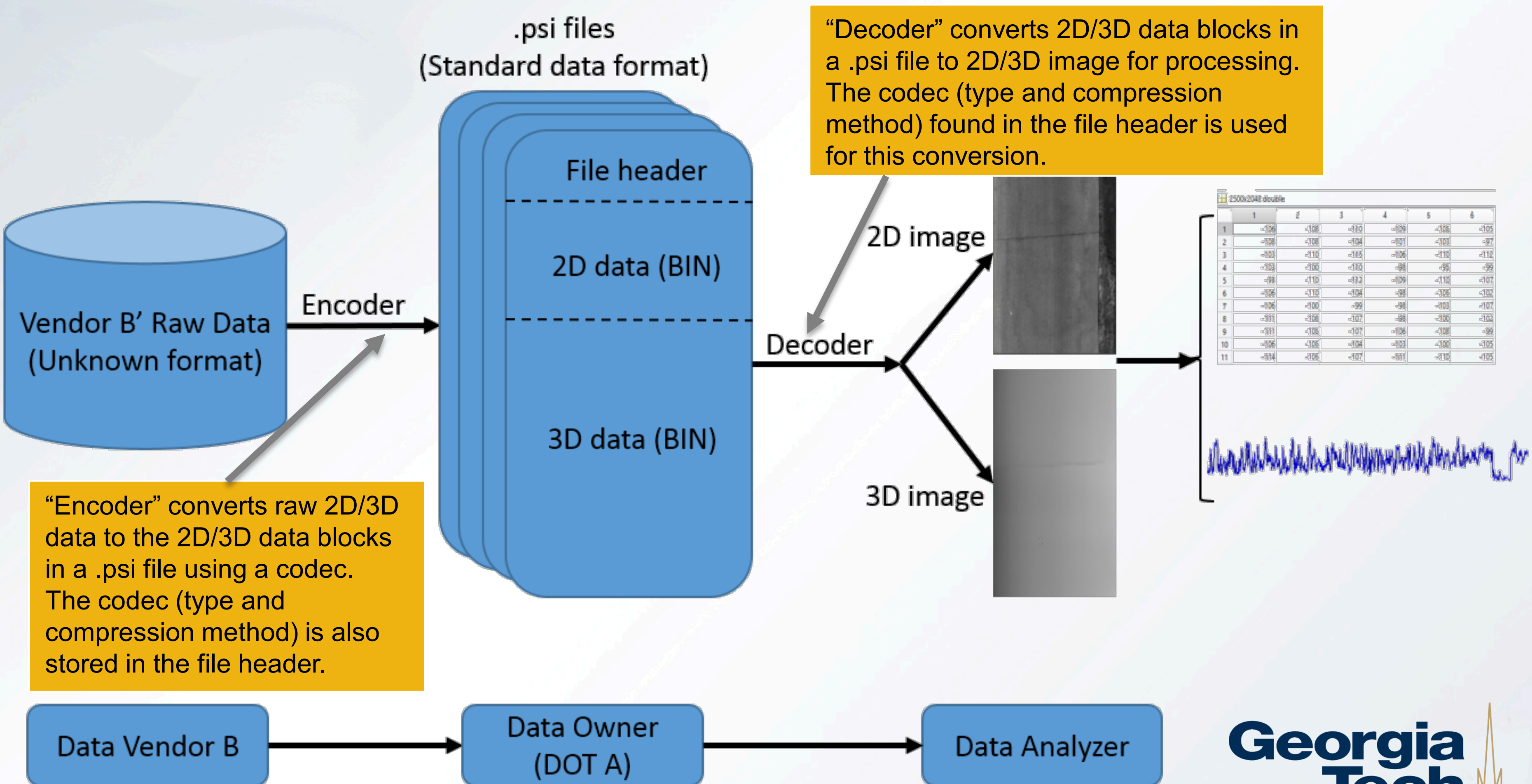
Preliminary Test with DOT A and Vendor B

For this test the data set was small so Vendor B did not compress the data (ZIP will used for compression for large data set) – Demonstrates success in no reliance on vendor for analysis.



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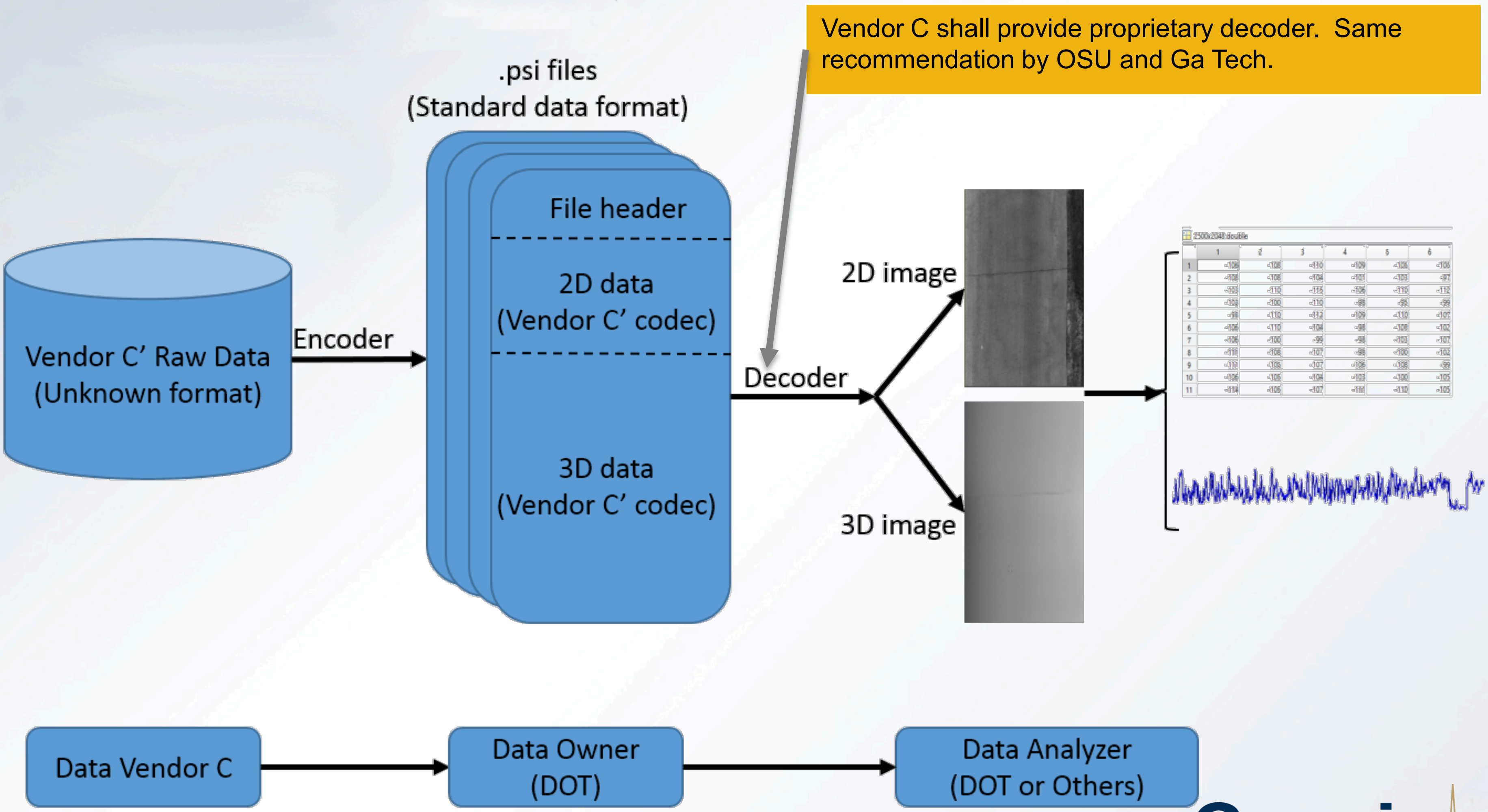
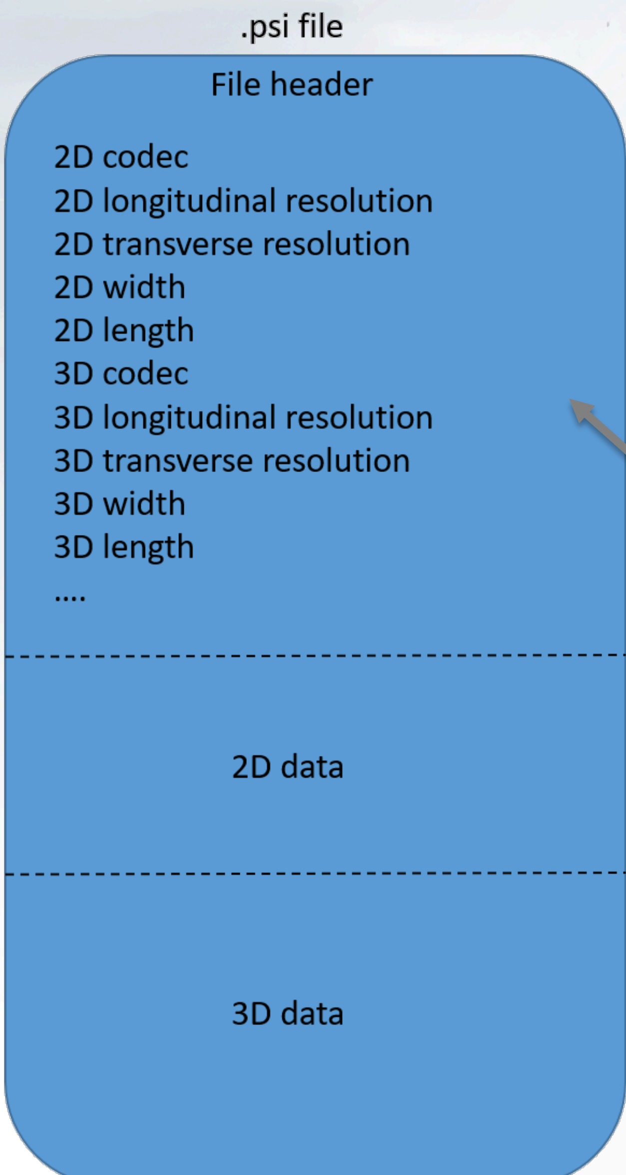
A Proprietary Codec from Vendor C Is Used



Data Format is Flexible



The fields in .psi file header define the 2D/3D image specification.

The specifier/DOT can allow the vendor to select the specifics or the specifier/DOT can specify/require certain specifics.

Such as pixel spacing, image size, codec, etc.

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Recommended Rules for Confirming Data Compliance

A list of minimal set of rules recommended for checking and ensuring the data compliance

Example of Minimal Rules and Validation Procedures

Boarder Properties	Sub-rules	Validation Procedure
File Integrity	The file signature is present	Check if the last four bytes of the file is "PSI"
	The file trailer is present	Check if the last four bytes of the file is "@@@@"
	The file's checksum equals to the given one	If a checksum is given, calculate the checksum based on the file content and check if it equals to the given checksum.
Header Correctness	The values in the required header fields are valid	For each value in required fields, if the field takes only assigned value, check if the value is in the "assigned values list". For example, version must follow the format "X.YY" where X and YY are numbers.
	The size of the 2D/3D data is correct	If the data is not compressed, check if the following condition holds: "datasize = bitdepth * width * length"
Data Correctness	The data in 2D and 3D section can be extracted using header information	Extract and decode the 2D and 3D data using header provided information. Check if the extracted data can be fit into a width * length matrix of that given data type.

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Summary

- The contributions of our work include
  - Critical assessment of the original reports and standard data format
  - Apply the “container-codec” concept widely used for multimedia data format
  - Development of a refined 2D/3D standard data format
  - Incorporation of the input from state highway agencies, 3D sensing technology vendors, and service providers
- A refined 2D/3D standard data format was recommended by adding the standard image representation, image coordinate system, range data registration, etc.
- A verification of various compression algorithms was performed and compared with the ones in the original report. Most of verification results match the ones in the original evaluation while some deviation exists due to the lack of complete parameter settings information.
- A test was performed with the help from a state highway agency and a 3D technology vendor. The results showed that a data transfer to the standard data format can be successfully performed without the loss of information.
- A set of rules and further works was recommended for a state highway agency to verify the data compliance of the standard data format

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Recommendations

- To facilitate the implementation of the 2D/3D standard data format, a standard library should be developed for vendors and data users to convert 2D/3D image data to the standard data format and extract 2D/3D image data from the files in standard data format. The library should be developed as early as possible to avoid duplicate effort and/or conflict implementations by different vendors and/or state highway agencies.
- Based on the recommended rules for verifying data compliance, a software tool should be developed for use by all state highway agencies. Meanwhile, the software tool should also include the functions for image visualization, pixel value identification, profile data extraction, and other interactive functions for measuring major types of pavement distresses, e.g., rutting, cracking, macrotexture, faulting, IRI, etc.
- Although 2D/3D standard data format has been developed, a clear definition and explanation of the standard data format is essential for successful implementation. A case study on utilizing 2D/3D standard data format should be developed to showcase the use of the standard data format for pavement image data collection, storage, management, processing, analysis, and applications for the success of the full-scope implementation of the standard data format.

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Questions