Smart Analyzer

Experiences and questions in an ongoing ISTA Validation Project

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1. *Cuscuta* sp. limited analysis

It is a purity analysis performed on forage legumes that:

- Is **not** a mandatory analysis under ISTA Rules
- Is **mandatory analysis under MERCOSUR** requirements to import forage legumes to Uruguay, under Uruguay's National Decree No. 380/995 (1995), which dictates that *Cuscuta* sp. is a prohibited weed seed by law
- Analysis must be done in sample sizes **10 times larger** than ISTA Rules establishes for Other Seed Determination (OSD) analysis, which means
    - 500 grams for *Medicago Sativa* (~ 6 person-hours)
    - 300 grams for Lotus sp. (~ 7 person-hours)
    - 200 grams for *Trifolium Repens* (~ 7 person-hours)

Cuscuta sp. on millimeter paper

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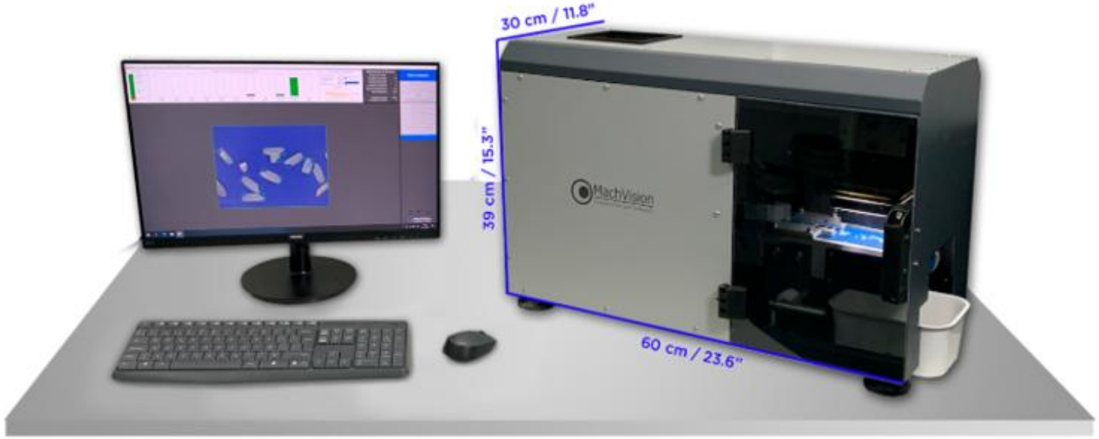
2. A brief introduction to the Smart Analyzer

An automated computer vision system designed to perform Cuscuta sp. limited analysis in forage legume seed samples. Combines image capturing and processing, feature extraction and deep learning for detecting the presence of *Cuscuta* sp. seeds. We aim to validate the Smart Analyzer in three forage legume species: Alfalfa, Lotus and White Clover



SMART ANALYZER

Fully autonomous system, with CPU integrated

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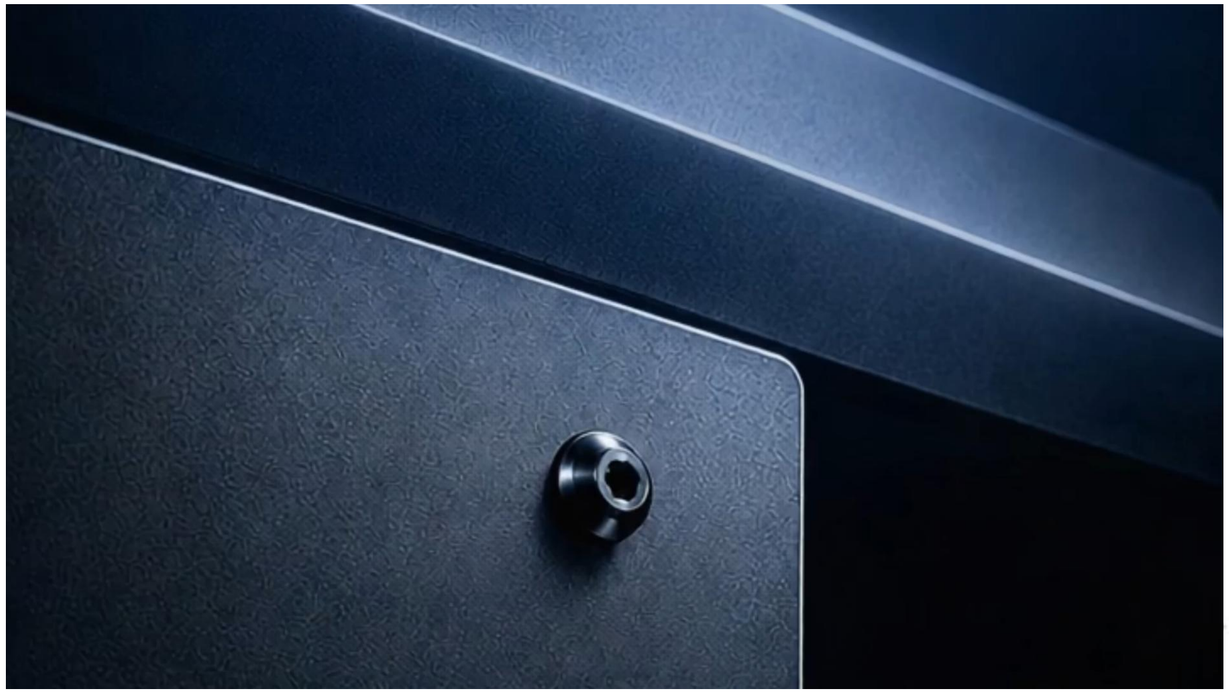
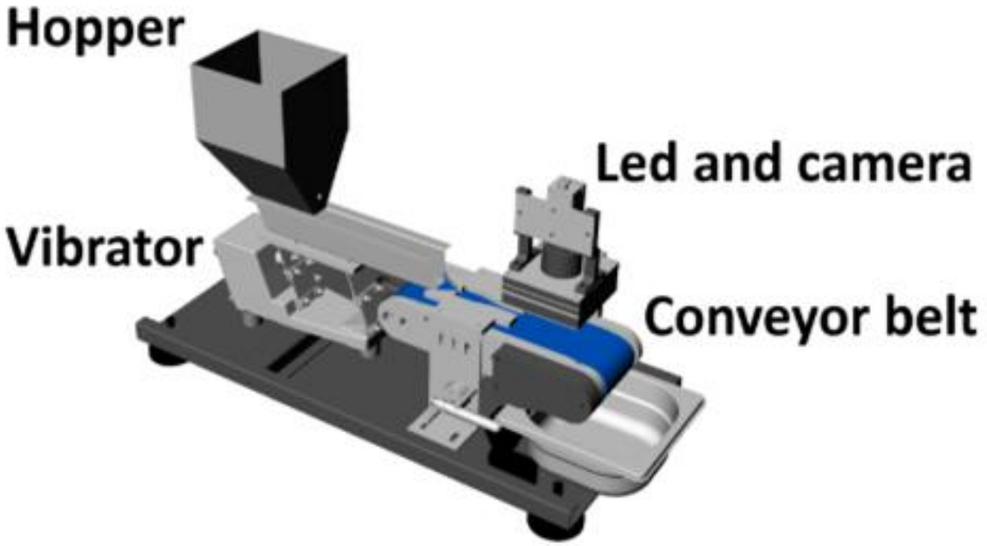
2. A brief introduction to the Smart Analyzer





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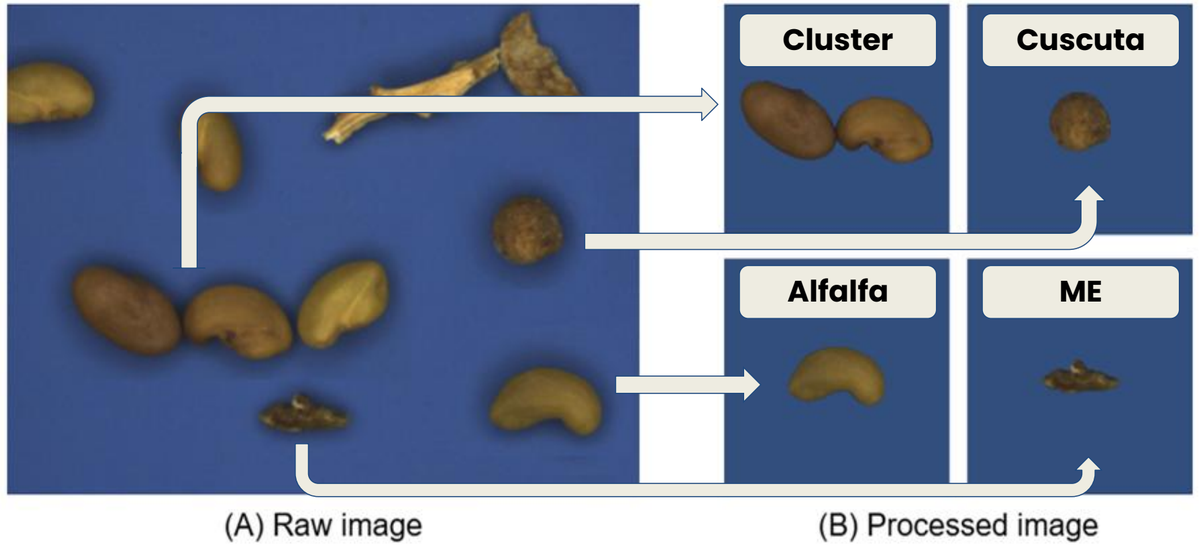
3. Images and classification model

Three independent classification models were developed, one for each target forage legume specie. Each model was trained on a dataset of **100,000 images**, evenly distributed across four output categories:

1. **Alfalfa/Lotus/White Clover:** Seeds belonging to the target forage legume species being analyzed (*Medicago sativa*, *Lotus* sp. or *Trifolium repens*)
2. **Cuscuta:** Seeds identified as *Cuscuta* sp.
3. **ME** (Foreign Matter): Extraneous material,
   - Other seed species
   - Inert matter
   - Broken seeds or debris
4. **Cluster:** Images where software was not able to segmentate grouped seeds due to overlapping or touching seeds.



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3. Images and classification model

A Convolutional Neural Network (CNN) with a customized architecture was used. After splitting the data into 80% training and 20% test sets, the classification results on the test set were as follows:

	Accuracy	Cuscuta Recall	F1-score	κ Cohen	AUC
Medicago Sativa (Alfalfa)	0.983	0.988	0.983	0.977	0.999
Lotus sp. (Lotus)	0.985	0.984	0.985	0.980	0.999
Trifolium repens (White clover)	0.995	0.992	0.995	0.993	0.999

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4. List of required documents

ISTA		Rayen Laboratorios + MachVision		
Guideline (TCOM-P-12*)	**Standard****	**Code**	**Title**	**Process description**
Process description (p. 4 to 15)	Environment, equipment, calibration and verification (5.2.7)	PTD04	Control and maintenance of critical equipment	Equipment and software identification
				Equipment and software maintenance
				Manufacturer's manual
				Equipment location
				Corrective maintenance
		PPU10	SOP for Cuscuta sp. limited analysis using the Smart Analyzer	Verification reports and calibration certificates
		PRH04	Staff training, evaluation and responsibilities	Equipment plus analyst monitoring
Maintenance, verification and monitoring (p. 8 to 15)	Quality control procedures (10.3)	PRH04	Staff training, evaluation and responsibilities	Maintenance and verification. Post-verification monitoring. Trends.

**** Advanced Technology Applications for Seed Testing Computer vision*** **;** ***** ISTA Accreditation Standard***

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4. List of required documents

ISTA		Rayen Laboratorios + MachVision		
Guideline (TCOM-P-12*)	**Standard****	**Code**	**Title**	**Process description**
Accreditation standard requirements (p. 8 to 15)	3.18	ODI	Organization cart	Human resources
	3.18, 4.3 and 4.5	PRH02	Preparation of job descriptions	
	3.18, 4.4 and 4.6	PRH04	Staff training, evaluation and accountability	
	4.4 and 4.6	PRH05	Training and annual evaluation of new MERCOSUR purity analysts	
	8.1	PPU10	SOP for Cuscuta sp. limited analysis using the Smart Analyzer	Environment, equipment, calibration, verification. Methods and procedures. Change control. Analysis report and certificates.
	9.1	PRH01	Requesting and granting vacations and leaves of absence	Staff identification and training

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5. Validation proposal

The TCOM-P-12 establishes that "*In cases where the seed quality characteristic is known, the impure seeds are spiked into the **30 samples** at levels that represent a **reasonable range in terms of impurity levels** and types (i.e. species). The species and impurity levels in samples are unknown (blind) to the lab staff that oversee the computer vision tool measurements. The 30 blind samples are run with computer vision tool and **should achieve 90% or better accuracy** (correct classification for the tool scope) in the 30 samples scored.*"

We propose: 30 samples with the weight established by the standard, samples made with seeds from different varieties and regions, 12 different levels of *Cuscuta* sp. contamination and randomized and completely blind trials for lab staff, for each species.

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6. Questions and next steps

- Is the proposed validation approach appropriate? Is this validation sufficient to fulfill the requirements of Annex 2 of TCOM-P-12?
- Would you recommend conducting three separate validations (one for each species) or a single validation including all species?
- Regarding the accuracy assessment, should the validation focus on whether the sample is correctly accepted or rejected, or on whether the model correctly detects and quantifies the number of *Cuscuta* sp. seeds?
- Which classification metric(s) would be most appropriate for this type of project? Is accuracy a relevant metric in this context?

Next steps: **work with ATC and STA Committees on the final validation.**

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Thank you!

Questions?

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