HuMaIN: Human- and Machine-Intelligent Network of Software Elements

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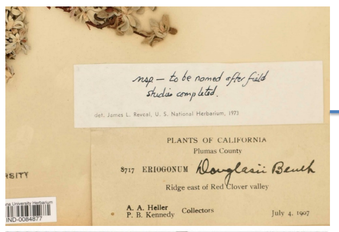
ACIS ADVANCED COMPUTING & INFORMATION SYSTEMS

Abstract

Biodiversity information extraction (IE) from imaged text in digitized museum specimen records is a challenging task due to both the large number of labels and the complexity of the characters and information to be extracted.

The HuMaIN project investigates software-enabled solutions that support the combination of machine and human intelligence to accelerate IE from specimen labels.

Among other contributions, the project proposed the use of self-aware workflows to orchestrate machines and human tasks (the SELFIE model), Optical Character Recognition (OCR) ensembles and Natural Language Processing (NLP) methods to increase confidence in extracted text, named-entity recognition (NER) techniques for Darwin Core (DC) terms extraction, and a simulator for the study of these workflows with real-world data. The software has been tested and applied on large datasets from museums in the USA and Australia.



Darwin Core terms:
Collected By: A. A. Heller, P. B. Kennedy
State: California
County: Plumas
Identified By: James L. Reveal
. . .

Darwin Core terms:
Collected By: J. R. Powers
State: California
County: Alameda
Event Date: 1960-06-04
. . .

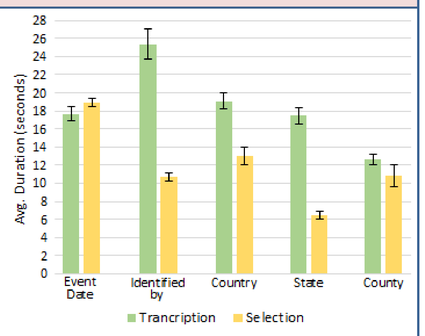
Task Design and Crowd Sentiment in IE from Biocollections

Problem: Volunteers are a scarce resource. How do interface's characteristics affect crowdsourcing result and crowd sentiment?

Results:

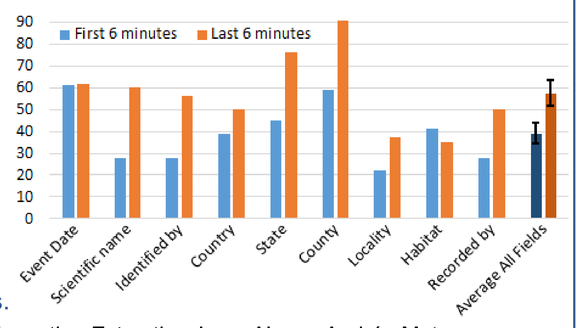
Transcription vs. Selection:

- Selection-based tasks generate results of 7.7% higher **quality** than transcription-based tasks.
- Users take 35% less **time** completing selection-based tasks than transcription-based tasks.
- Selection-based tasks are perceived as 15% more **boring** than the equivalent transcription-based tasks.



Granularity: Twelve 1-field tasks vs. 12-fields task:

- Twelve 1-field tasks improved the result's quality by 7.25% but required twice the time than a single 12-fields task.
- Users found 1-field tasks easier to complete than multi-fields tasks.



Users' Learning Process: First vs. Last 6 minutes.

- No difference found in the quality of the output.
- 1.5x more values are extracted in the last 6 minutes.

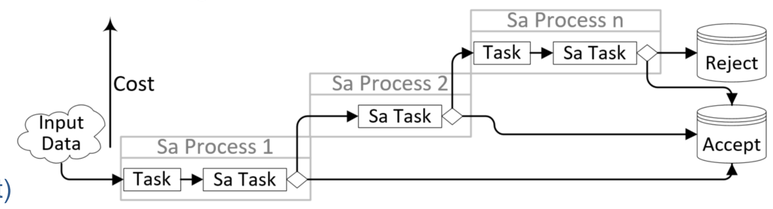
Paper: *Task Design and Crowd Sentiment in Biocollections Information Extraction*. Icaro Alzuru, Andréa Matsunaga, Maurício Tsugawa, and José A.B. Fortes. 3rd IEEE Collaboration and Internet Computing, 2017.

Self-aware Information Extraction (SELFIE) from Biocollections

Problem: Data generated by automated methods for biocollections IE are not accepted because they contain many errors, only crowdsourcing is used.

Proposed Solution: Self-aware IE workflows. A **SELFIE workflow** is a sequence of self-aware human-machine processes (**SaPs**) organized in **incremental-cost order**. The cost is a function of performance variables defined by the workflow designer. Elements of a workflow:

- Input (e.g., specimens' images)
- Self-aware Processes (SaPs)
- Data processing Tasks and Self-aware Tasks (SaTs)
- Output: DC terms (Accept), Unknown images' terms (Reject)



SaTs extract and **evaluate** candidate values, taking the most appropriate **action**: accepting the own result or requesting processing by the next (more costly) SaP.

Results (SELFIE Experiments):

- Event date: Alphanumeric with defined patterns. NLP: Regular expressions.
- Scientific name: Textual known field. NLP: Suffixes (patterns), Sequential search.
- Recorded by: Textual unknown field. NLP: Dynamically created dictionary + search.

Table I. Results' improvement obtained by SELFIE, when compared to the Human-only IE approach.

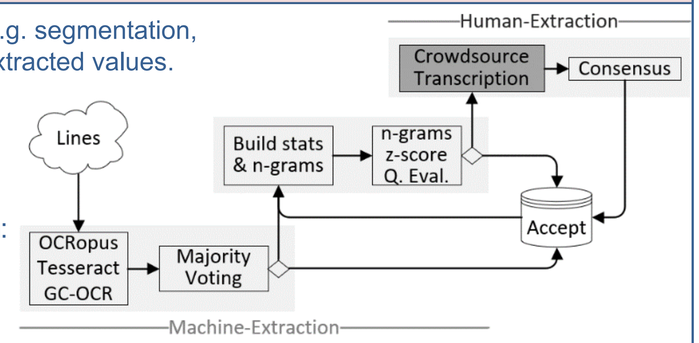
	Event date	Scientific name	Recorded by	Avg.
Quality Improvement	-1.9%	1.6%	-0.6%	**-0.3%**
Duration Reduction	45.8%	15.3%	20.4%	**27.2%**
Crowdsourcing Reduction	48.0%	25.0%	23.5%	**32.2%**

Paper: *SELFIE: Self-aware Information Extraction from Digitized Biocollections.* Icaro Alzuru, Andréa Matsunaga, Maurício Tsugawa, and José Fortes. IEEE 13th eScience, 2017.

OCR Ensembles for Text Extraction & Confidence Estimation

Problem: OCR engines generate errors (e.g. segmentation, recognition errors) that may propagate to extracted values.

Proposed Solution: An ensemble of three OCR engines (OCRopus, Tesseract, and the Google Cloud OCR) is used to estimate confidence in the extracted data.



Characteristics of the Implementation:

- Ensemble in a SELFIE workflow.
- Two hybrid human-machine approaches for crowdsourcing were tested.
- Dataset: representative group of 6 biocollections and ~ 3,000 images.

Results:

The ensemble labeled about **57.5%** of the automatically extracted sentences as high-confidence transcriptions.

The two hybrid crowdsourcing techniques saved, on average, an additional **18.5%** of crowdsourcing tasks, for total average saving of **76%** in the crowdsourcing tasks.

Table 4-5: Savings in the number of crowdsourcing tasks when the Ensemble of OCRs and two types of crowdsourcing are applied.

	Tasks required	Ensemble savings	Hybrid crowd. savings	Total savings
Dynamic Human-Machine Consensus	3 x nL	57.55%	15.801%	73.35%
Hybrid Transcriber /Reviewer	2 x nL	57.55%	21.225%	78.78%

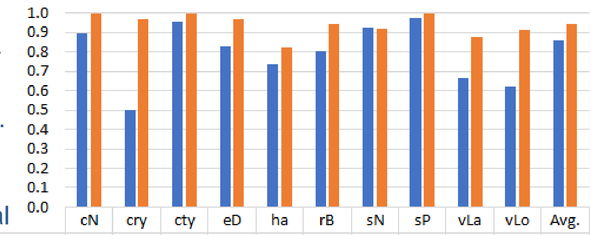
Paper: *Quality-aware Human-Machine Text Extraction for Biocollections using Ensembles of OCRs.* Icaro Alzuru, Rhiannon Stephens, Andréa Matsunaga, Maurício Tsugawa, Paul Flemons, and José Fortes. IEEE 15th eScience, 2019.

Problem: Proposed IE and confidence estimation methods rely on specific term's characteristics (e.g., suffixes, regular form). Can general IE and confidence estimation methods be created?

Proposed Solution: Reusing previously transcribed data to train general machine learning and statistical methods for the extraction and confidence estimation of DC terms.

Implementation:

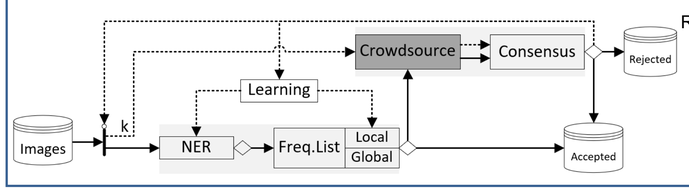
1) A named-entity recognition model was trained, by using 30% of the transcribed DC terms from 23,523 images of 29 biocollections, to extract ten DC terms. The remaining 70% of previously transcribed data were used for testing.



	cN	cry	cty	eD	ha	rB	sN	sP	vLa	vLo	Avg.
Recall	0.896	0.502	0.957	0.826	0.734	0.805	0.925	0.974	0.665	0.620	0.859
Similarity	0.999	0.968	0.995	0.969	0.822	0.944	0.918	0.998	0.879	0.914	0.941

2) By using local (dynamic - biocollection) and global (static - iDigBio) per-term frequency lists, high-confidence is assigned to automatically extracted values that exist in the local (crowdsourced) list or are found in the global (iDigBio) list 5 or more times.

Results: The NER model and the frequency lists were integrated in a Human-in-the-loop workflow for IE extraction. In every iteration, the transcription of the term in 50 images is crowdsourced, the NER model and the local (per-biocollection) frequency list are trained/improved with the new data.



Results of the extraction of the recordedBy term through the HITL SELFIE workflow for the wbd_ferns biocollection.

wdb_ferns	Iter. 1	Iter. 2	Iter. 3	Iter. 4
Number of images	1207	121	70	20
Mean Quality	0.830	0.853	0.953	1.000
Quality Std. Dev.	0.266	0.290	0.198	0.000

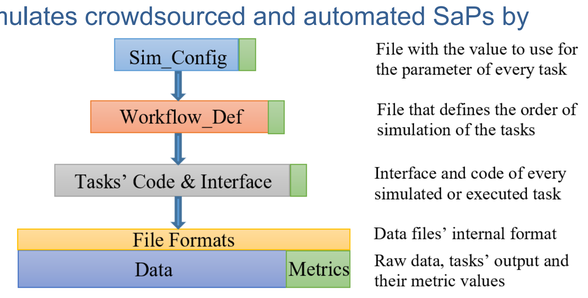
HuMaIN Simulator

Problem: Human-Machine IE requires images, crowdsourcing interfaces, volunteers, ground-truth values, scripts to process data, etc. Researchers invest a lot of time and resources validating an idea.

Proposed Solution: The HuMaIN Simulator. It emulates crowdsourced and automated SaPs by reusing previously extracted data.

Characteristics:

- Simulation engine and visualization capabilities.
- Hybrid workflows for the extraction of DC terms.
- Crowdsourcing and Automated IE Tasks' output
- Human-in-the-loop (iteration) support



Results: github.com/acislab/HuMaIN_Simulator

Paper: *Human-Machine Information Extraction Simulator for Biological Collections.* Icaro Alzuru, Aditi Malladi, Andréa Matsunaga, Maurício Tsugawa, and José Fortes. IEEE 3rd HMData Workshop, 2019.

Conclusions

- HuMaIN allowed the development of human-machine methods and software workflows for the extraction of DC terms from specimens' images. **https://github.com/acislab/HuMaIN**
- The hybrid method (SELFIE) and IE workflows were applied to real biocollections from iDigBio, the University of Australia, and WeDigBio FL Plants.
- SELFIE provides an approach to use automatically generated data, reducing the number of crowdsourcing sessions required while keeping a human-equivalent output quality.
- OCR Ensembles can be used to estimate confidence in the automatically extracted text.
- The data collected in biodiversity repositories can be used to generate automated extraction methods and creating confidence estimation methods for newly extracted data.
- The data and methods generated in this study can be tried and extended in the openly available HuMaIN Simulator.

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