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COMPREHENSIVE VISUALIZATION OF UNDERWATER VIDEO DATA

Uncertainty, Provenance, and
Multidimensional Analysis
in the Fish4Knowledge Project

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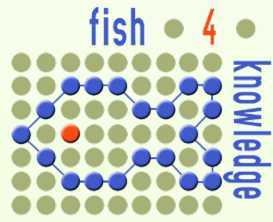
3. Multidimensional Analysis

Interaction principles
Live demo



But first, an introduction to Fish4Knowledge:

<http://www.youtube.com/watch?v=AFV-FiKUFyI>



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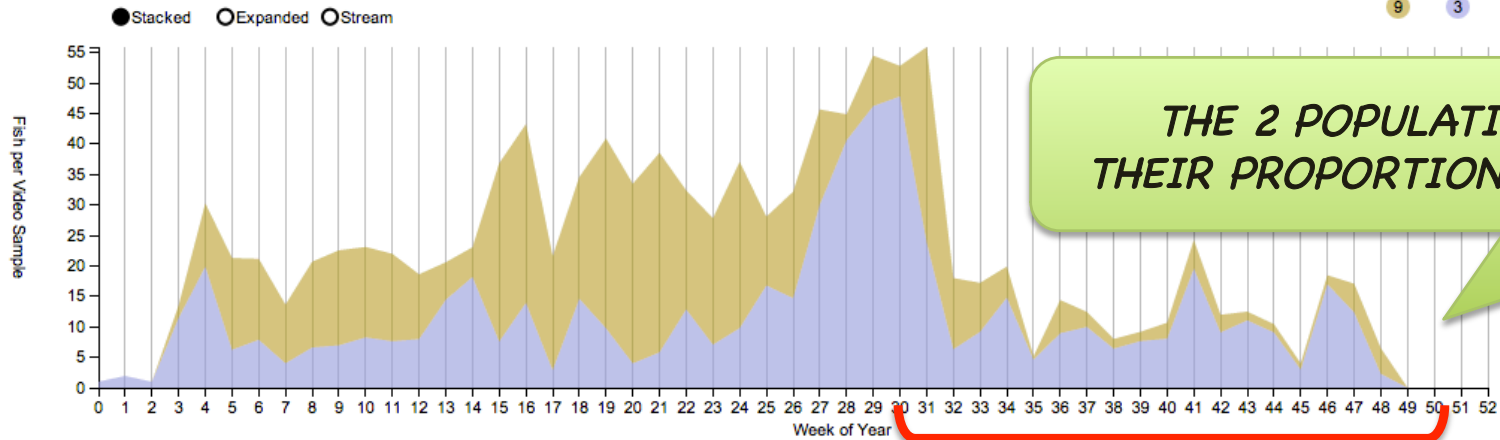
REPORTING THE UNCERTAINTY IN UNDERWATER VIDEO DATA

Conciliating practices from 2 domains:
Biology & Computer Vision

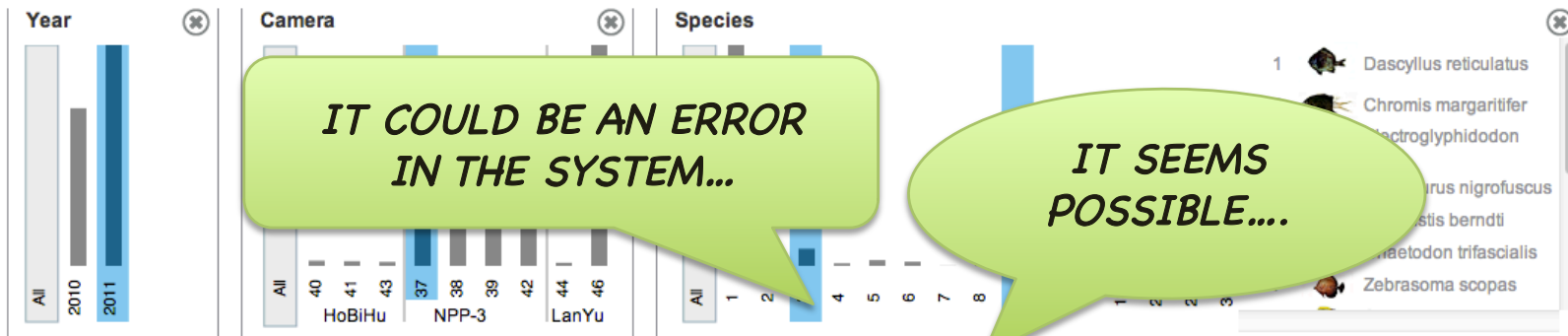
ARE THESE TRENDS SIGNIFICANT?

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Do they represent the real fish community?



Stacked chart | Number of Fish per Video Sample | over Week of Year | stacked over Species
 Open a filter | for Species 3,9 * in 2011 * at Camera 37 * analyzed by D50-R52 *



FACTORS OF UNCERTAINTY

Many reasons could make the above trend insignificant



Image Processing Errors

Varying Sampling Size

Varying Videos Quality



Sampling "with Replacement"

Varying Camera's Field of View

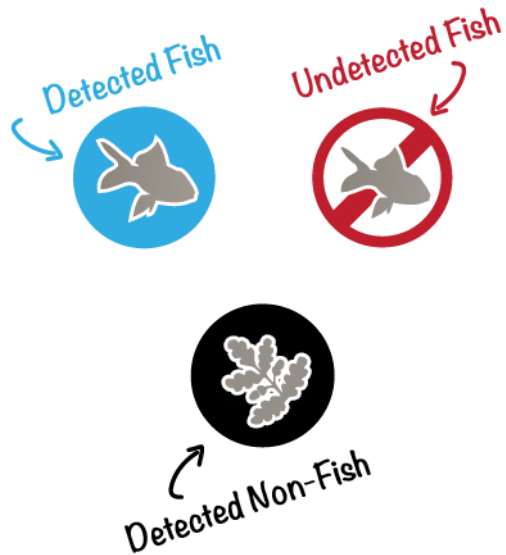
...unknown factors?

FACTORS OF UNCERTAINTY



Let's focus on potential failures of the video analysis software

Image Processing Errors



Video analysis is not perfect

- Some fish are not detected
- Some species are not recognized



Commonly measured with:

- ROC evaluations
- TP, FP, FN, TN
- False Alarm Rates, Detection Rates...

EVALUATION OF IMAGE PROCESSING

The ROC curves explained

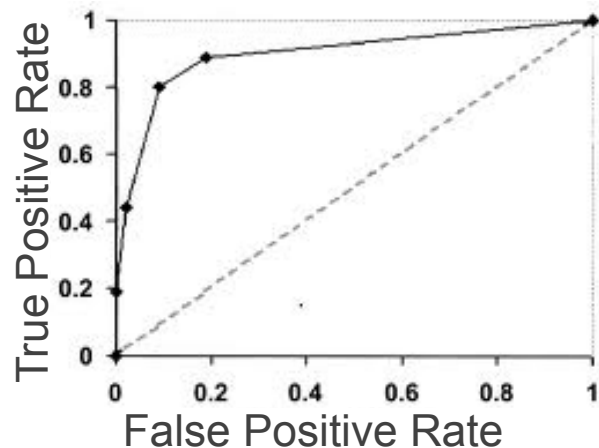
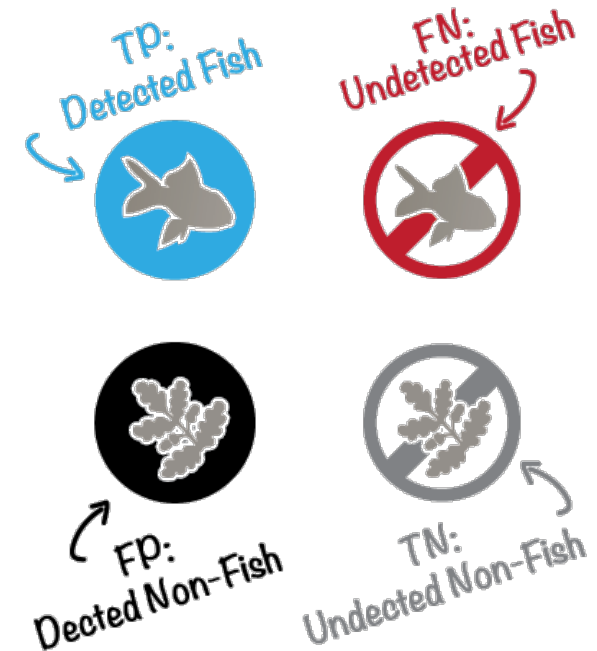


Ground-Truth dataset

- Contains expert-made detections
- To be compared with software-made detections

4 main measures

- **TP**: Detected by experts & software
- **FN**: Detected by experts, not detected by the software
- **FP**: Not detected by expert, detected by the software
- **TN**: Not detected by experts & software



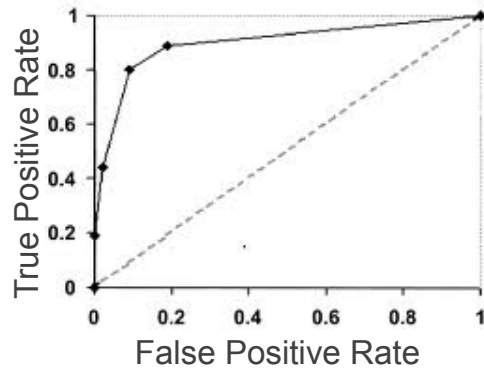
Other derived measures

- Rates: of TP, FP, Precision, Accuracy
- Calculated over different variable thresholds

VISUALIZING IMAGE PROCESSING ERRORS



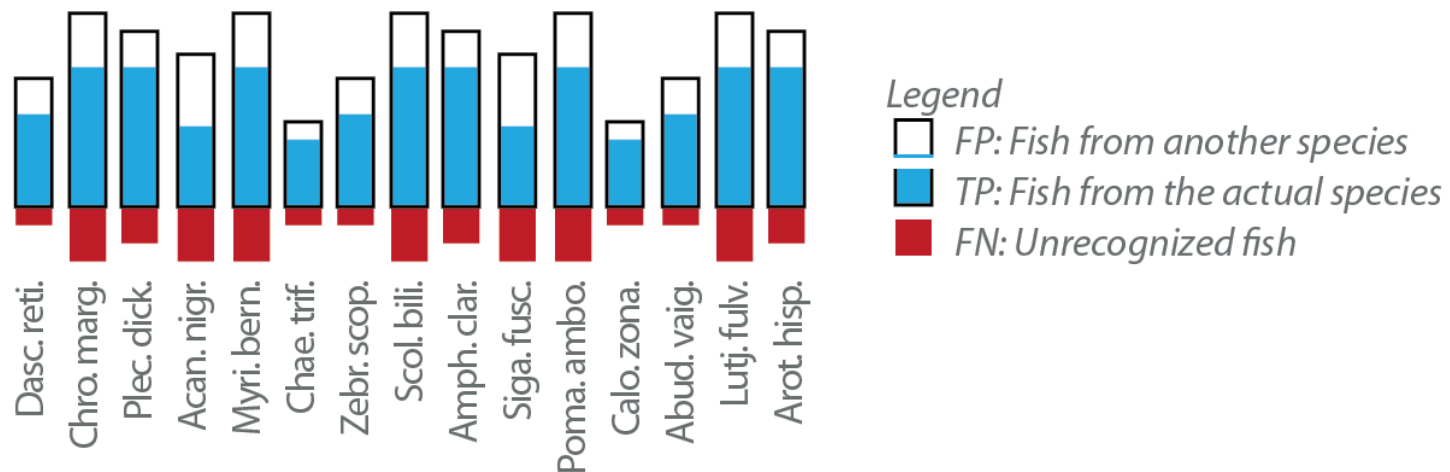
We simplified the ROC evaluation



Traditional “ROC” evaluations are over-complicated for non-technical experts.

We propose a new design:

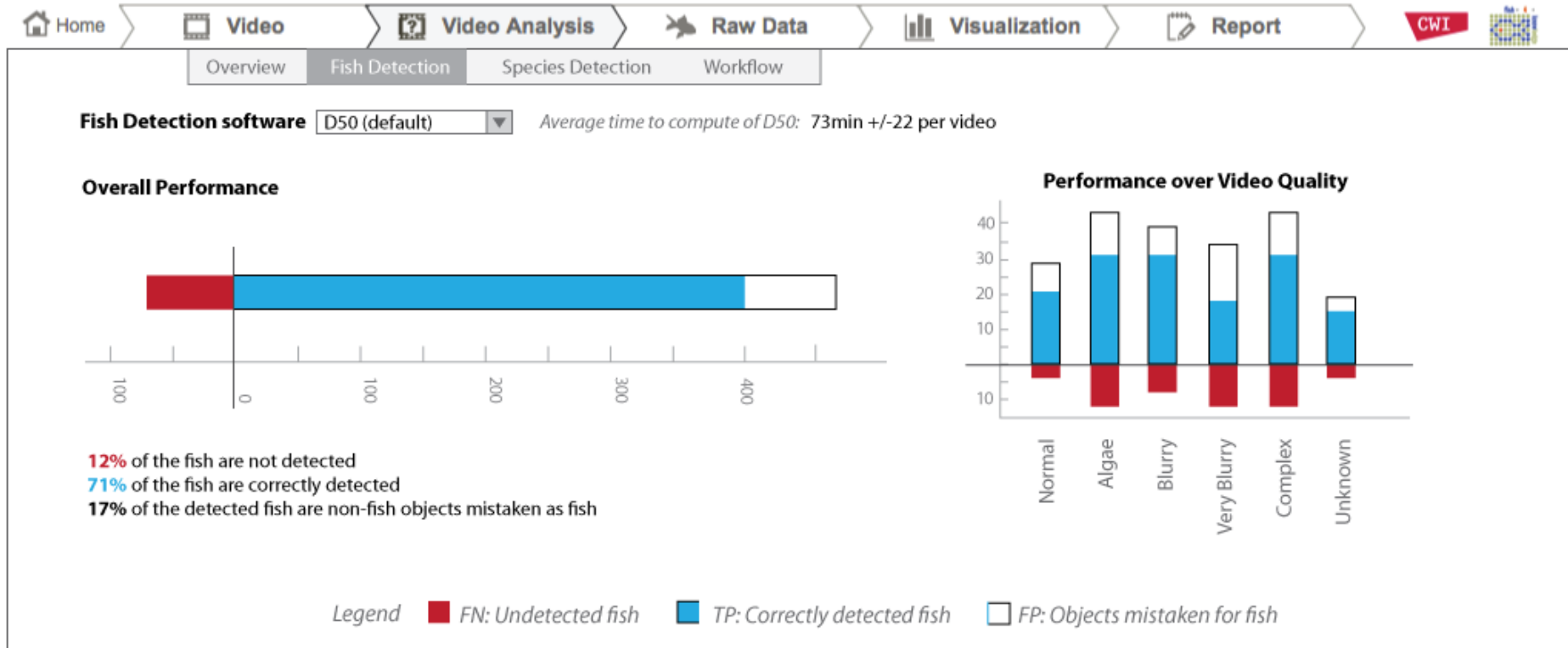
- Focused on fish counts: man-made or machine-made
- True Negatives are excluded, so as rates (FAR, DR, TPR, FPR...)



EXAMPLE OF APPLICATION



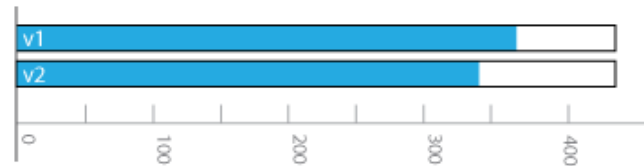
How we plan to implement the visualization of uncertainty





There are 2 versions of the software that can detect fish species. The version v1 can detect 15 species, and the version v2 can detect 23 species.

Overall Performance of Versions v1 and v2



Version v1

85% of the fish species are correctly detected
15% of the fish species are misidentified

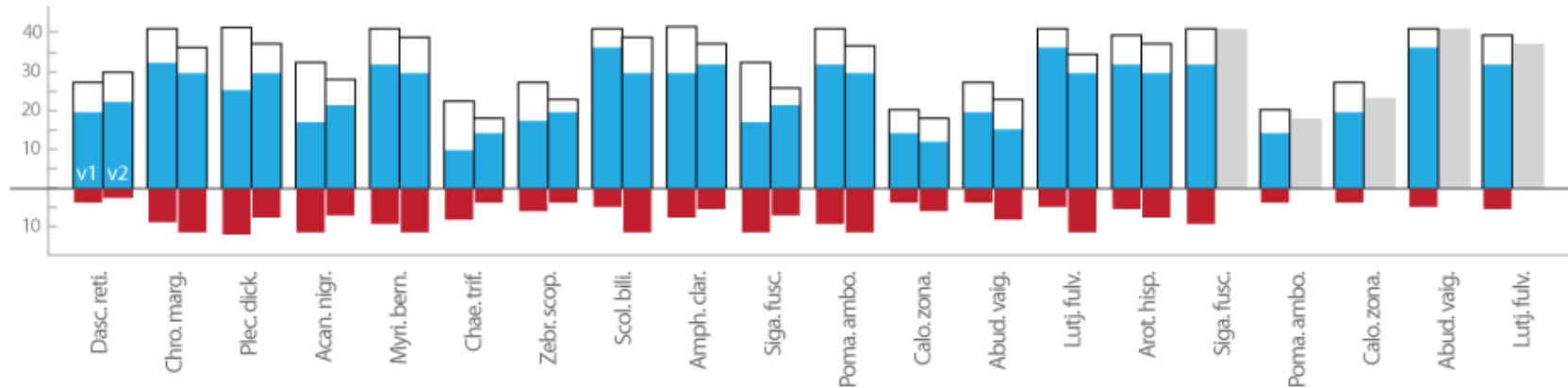
Version v2

79% of the fish species are correctly detected
21% of the fish species are misidentified

Legend

- FP: Fish from another species
- TP: Fish from the actual species
- FN: Unrecognized fish
- The species can not be detected

Performance of Versions v1 and v2 over Species



Detail for each Species

- Dascyllus reticulatus
- Chromis margaritifer
- Plectrogliphidodon dickii
- Acanthurus nigrofuscus
- Myripristis berndti
- Chaetodon trifascialis
- Zebrasoma scopas
- Scolopsis bilineata
- Amphiprion clarkii

Dascillus reticulatus

Error Risk

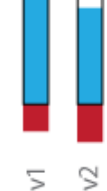


Confusion Risk

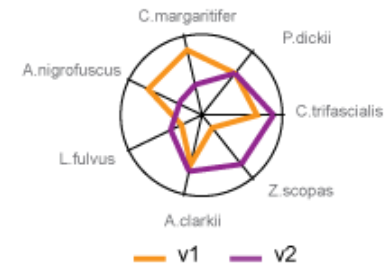


Myripristis berndti

Error Risk



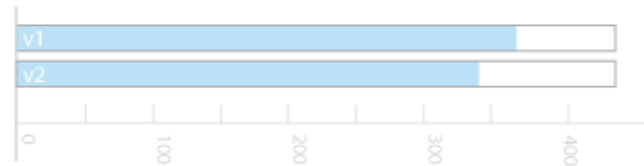
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Performance of Versions v1 and v2 over Species



IS IT RANDOM?

ARE THESE SYSTEMATIC BIASES?

Detail for each Species

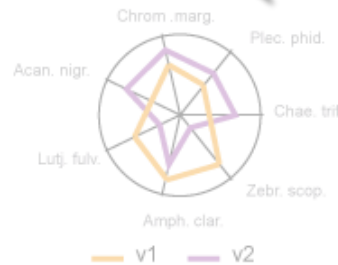
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Dascyllus reticulatus

Error Risk



Confusion Risk

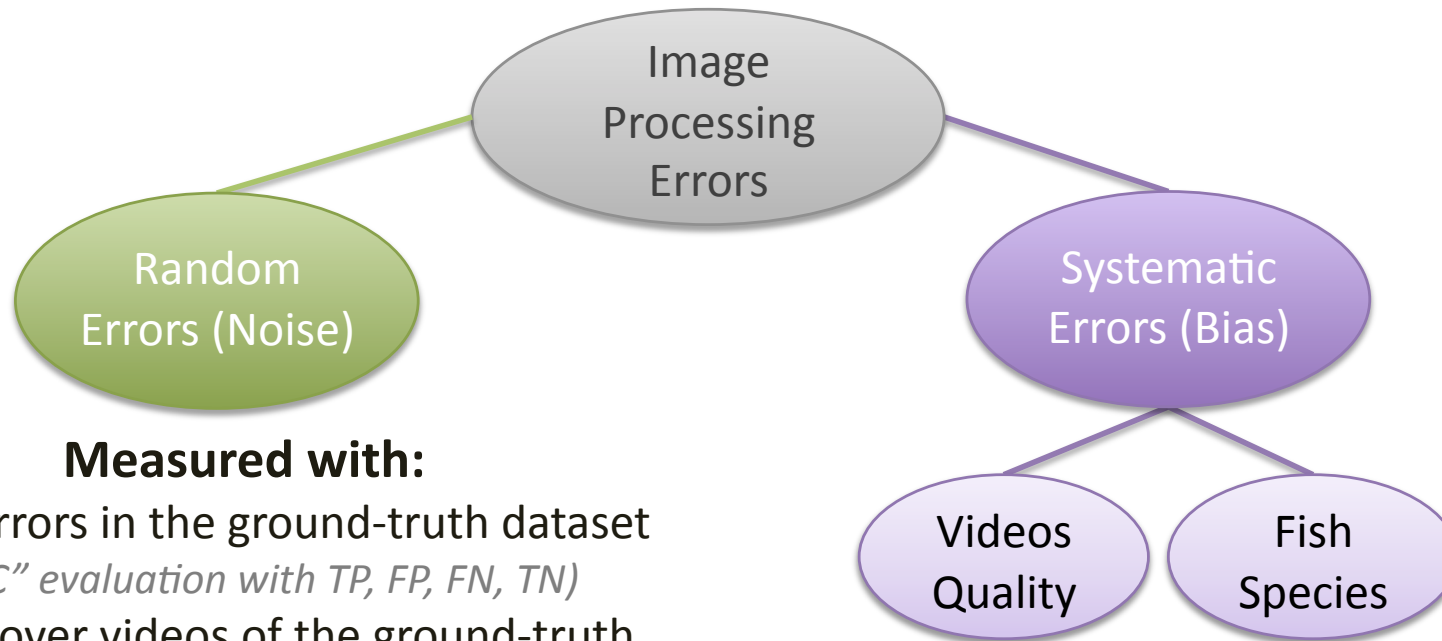


Error Risk



DIFFERENTIATING NOISE & BIASES

More than new visualizations, we also need new data.



Measured with:

- Average errors in the ground-truth dataset
(using "ROC" evaluation with TP, FP, FN, TN)
- Deviation over videos of the ground-truth

Measured with:

- Ground-truth datasets for species & video qualities
- Comparing levels of noise over ground-truth datasets
(average errors and deviations)

REPORTING THE PROVENANCE OF UNDERWATER VIDEO DATA

How to deal with complexity,
and improve trust and acceptance?

STRUCTURING PROVENANCE INFORMATION

Using tabs to deal with complexity

Level of Interpretation	Derived Information	UI tab	Uncertainty issues	UI features
5. Overall Study	Aggregated visualizations	"Report"	Validity of correlations	Group, comment and share visualizations.
4. Visualization	Aggregated counts	"Visualization"	Statistical variability. Validity of correlations.	Overview available data. Specify of adhoc visualizations.
3. Fish Species	Fish counts per species. Species counts.	"Video Analysis"	Image processing errors	Control video analysis processes and ROC evaluations.
2. Fish Detection	Fish counts			
1. Video images	Video clips	"Video"	Missing samples. Images quality. Camera changes.	Control sampled locations & periods. Check camera settings. Watch videos.

Incremental levels of interpretation

- From real fish to video images, and finally to high-level scientific studies
- Each level of interpretation uses information from the lower level

Specific provenance information

- Each level of interpretation deals with specific factors of uncertainty
- Specific provenance information is needed at each level

STRUCTURING PROVENANCE INFORMATION

Handling the uncertainties at the right level

L2,3: Image Processing Errors

L1,4 : Varying Sampling Size

Level of Interpretation	Derived Information	UI tab
5. Overall Study	Aggregated visualizations	"Report"
4. Visualization	Aggregated counts	"Visualization"
3. Fish Species	Fish counts per species. Species counts.	"Video Analysis"
2. Fish Detection	Fish counts	
1. Video images	Video clips	"Video"

L1,2,4: Varying Videos Quality

Sampling "with Replacement"

L1,4: Varying Camera's Field of View

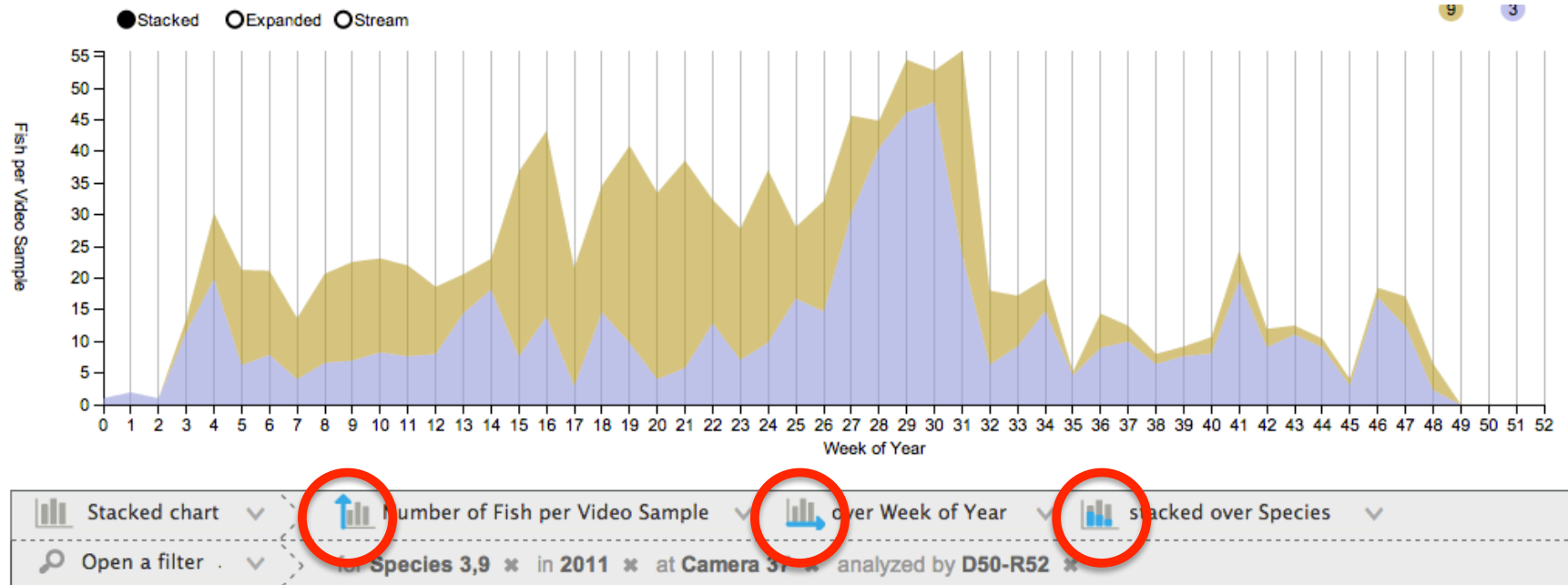
INTERACTION DESIGN FOR MULTIDIMENSIONAL ANALYSIS

There are many potential studies of our data,
and there is no one-fit-all visualization.

But we can support preliminary data exploration.

FLEXIBLE VISUALIZATION

User can define what the graph axes represent
e.g., what dimensions are plotted

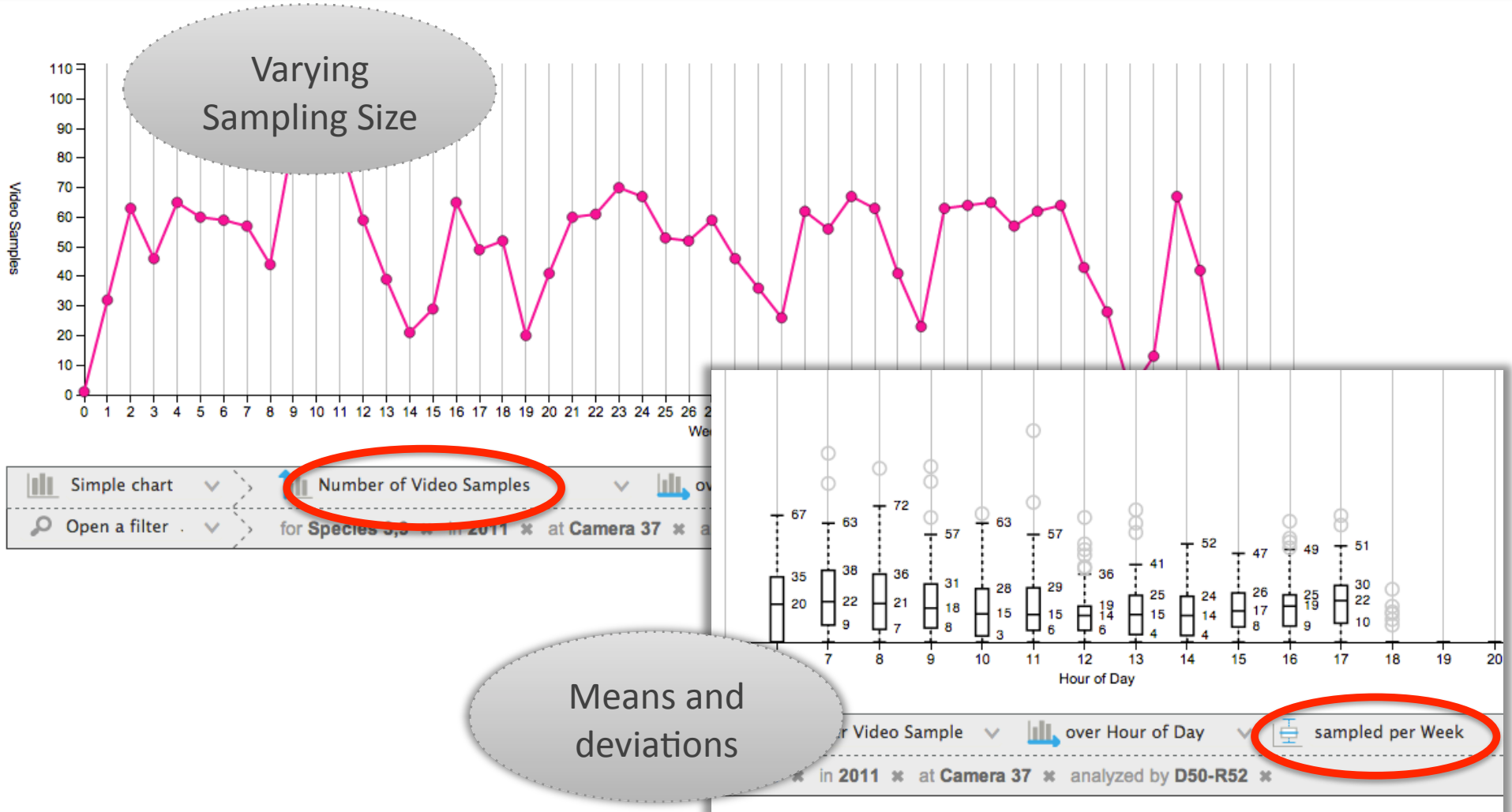


Direct interaction with graphs:

- Users choose what is represented by the Y and X axes of the graph
- Stacked charts and boxplot have a 3rd dimension
- Users can change the type of graph, while keeping the same axes
- The selected options form a title in natural language

FLEXIBLE VISUALIZATION

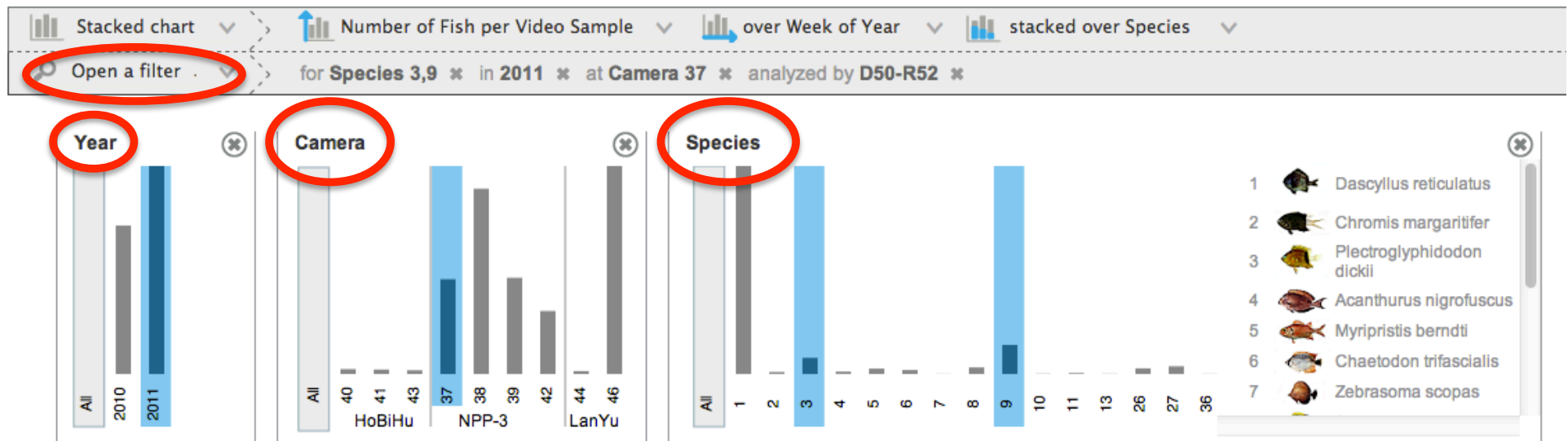
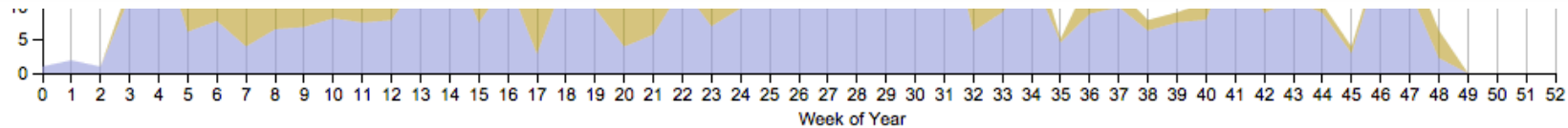
It can also address some uncertainty issues



2-IN-1 WIDGETS

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Filtering & Overviewing



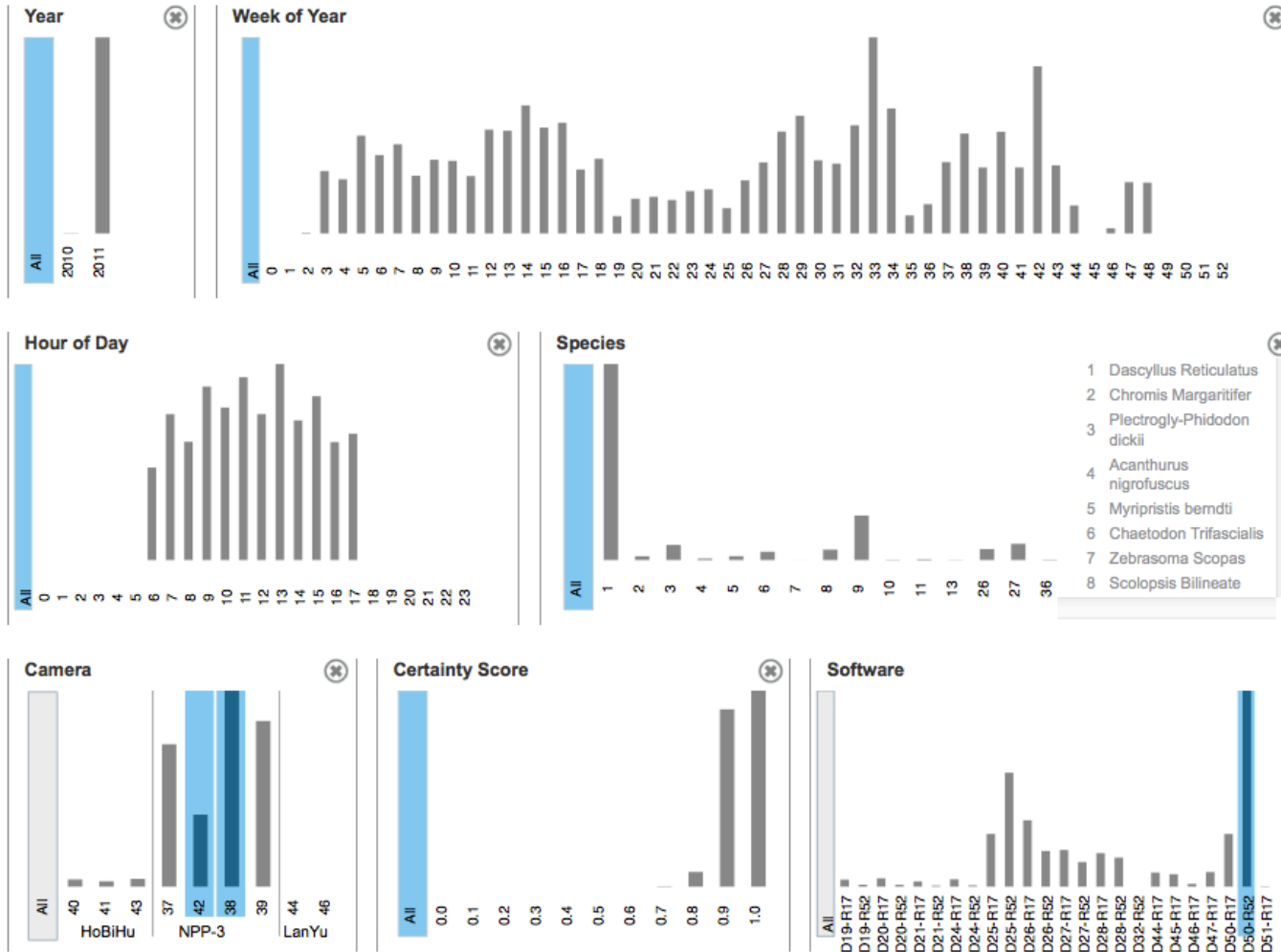
Basic filtering options....

- Filter on all data dimensions
- Display only the filters of interest
- Users compose their widget environment

...with data overviews

- Filtering widgets display histograms
- The Y axis is that of the main graph
- The X axis is the filter's values

DATA FILTERING ALSO PROVIDES MULTIDIMENSIONAL VISUALIZATIONS



CONCLUSION

Uncertainty from image processing

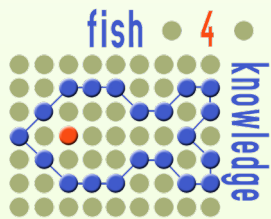
- Traditional visualizations need simplification
- Traditional evaluations need extension to biases evaluation

Provenance

- It concerns multi-factorial uncertainties & nested interpretations

Multidimensional visualization

- Our tool addresses preliminary data exploration
- 1st principle: direct interaction with graph axes
- 2nd principle: 2-in-1 widgets for filtering and overviewing



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AND NOW A LIVE DEMO!

<http://f4k.project.cwi.nl/demo/ui/>

But do you have questions?