# WRITER RECOGNITION BY MEANS OF HANDWRITTEN TEXT OTHER THAN SIGNATURE

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# WRITER RECOGNITION: identification and verification

WRITER RECOGNITION can refer to any of two different tasks

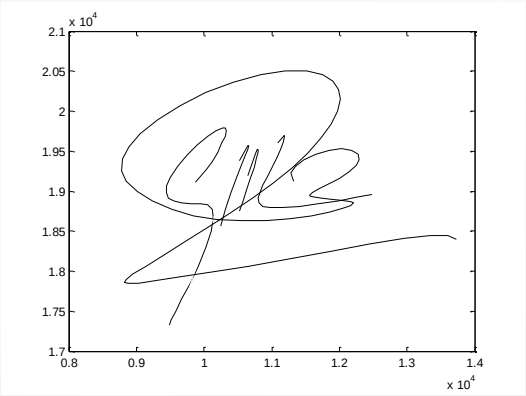
- **Writer identification**

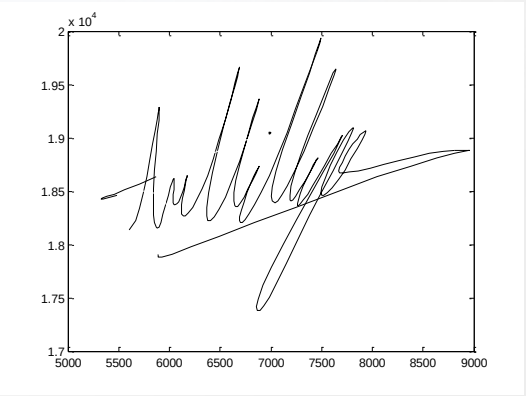
  One to many search: given a sample (word), find the most likely author

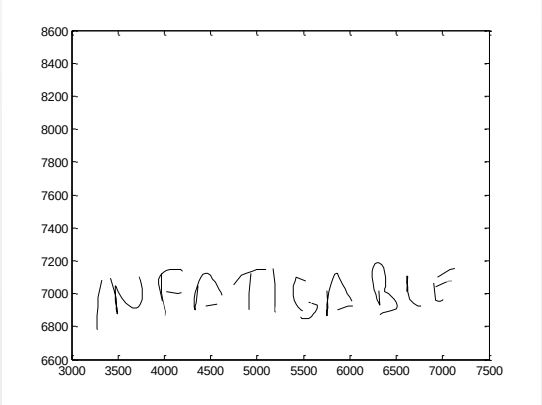
- **Writer verification**

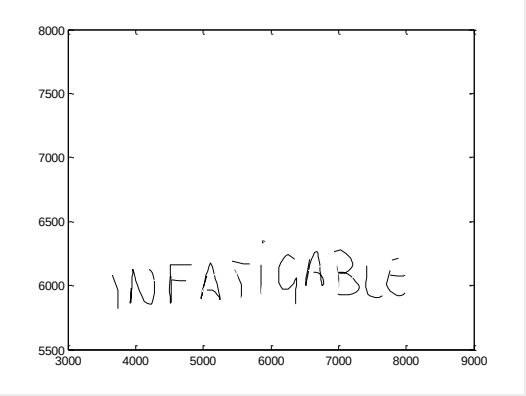
  One to one comparison: given two samples (words) determine the likelihood of having been produced by the same author

# SIGNATURES vs. WORDS




Signatures of two different people tend to be quite different (inter-writer variability). Signature puts no constraints to dissimilarities among signers.

Different writers' executions of the same word tend to be much more alike. They have to be alike, otherwise they would not be considered the same word!!! Legibility heavily constrains dissimilarities

# SIGNATURES vs. WORDS

**Historically, most of the research efforts on writer recognition are signature-based. Methods based on words or very short sequences of text do no abound.**
**Signature has a long tradition as a method to prove one's identity (banking and legal transactions…)**

Signatures of two different people tend to be quite different (inter-writer variability). Signature puts no constraints to dissimilarities among signers.

Different writers' executions of the same word tend to be much more alike. They have to be alike, otherwise they would not be considered the same word!!! Legibility heavily constrains dissimilarities

# WHY WORDS?

- Words may arise less concerns than other modalities (including signature)

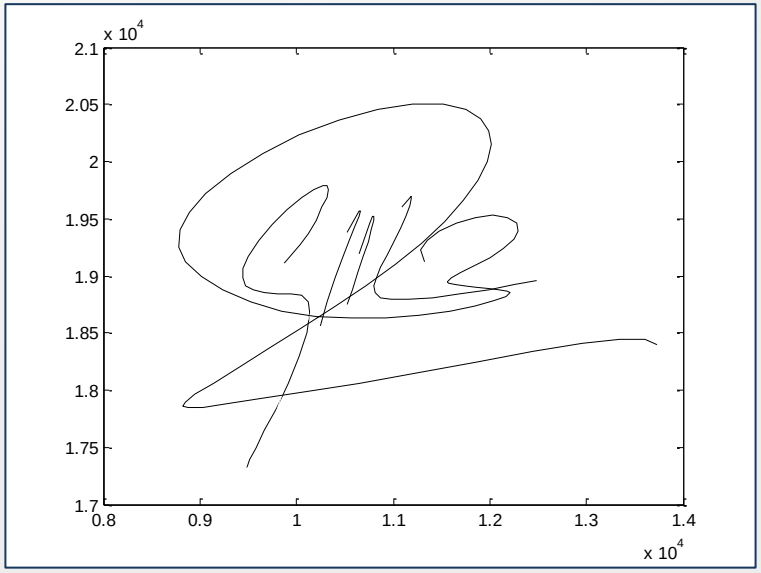
- Words have some nice properties that signatures lack:
  - Signature compromised? Uh, uh… Difficult to change…
  - **Word compromised? Change it!**

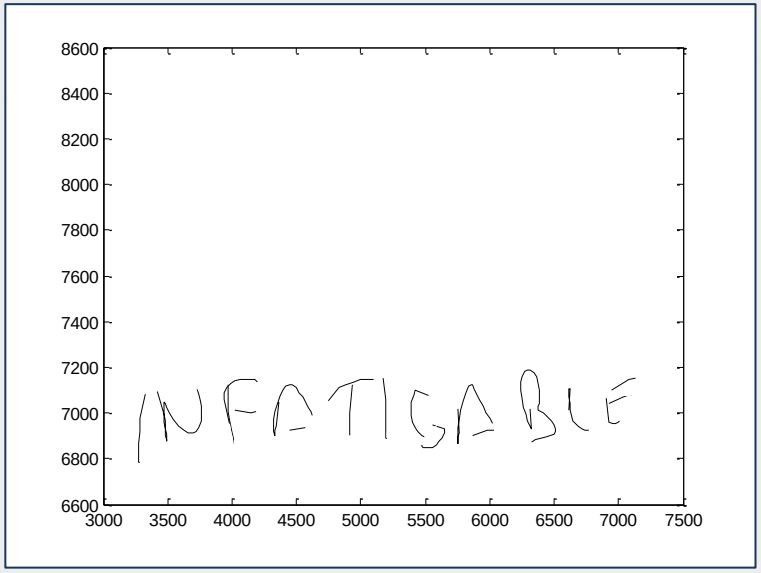
  - Signature "too short"? What a pity…
  - **Word too short? Choose a longer one or use more than one**
  - Thus, Word-based writer recognition is somehow similar to speech-based recognition

# CAN (ISOLATED) WORDS BE USED TO DISTINGUISH AMONG USERS?

## CAN ISOLATED WORDS O SHORT SEQUENCES OF TEXT BE USED TO DISCRIMINATE AMONG WRITERS?

## DO WORDS HAVE ENOUGH DISCRIMINATIVE POWER?




## CAN WORDS BE USED AS SIGNATURES?

# DISCRIMINATIVE POWER OF ISOLATED WORDS. OFFLINE CASE

- 1500 writers representative of US population.

Experimentation carried out with subsets of different sizes.

- 3 samples per individual
- word ***referred*** extracted from a longer text.
- **Verification accuracy** from ~83% to ~96%
- **Identification accuracy** up to ~87% with 900 writers, up to ~95% with 100 writers and up to ~98% with 2 writers

S. Srihari, C. Sung-Hyuk, L. Sangjik, Establishing handwriting individuality using pattern recognition techniques, in: Proceedings of the Sixth International Conference on Document Analysis and Recognition, 2001, pp. 1195–1204.

# DISCRIMINATIVE POWER OF ISOLATED WORDS. OFFLINE CASE

- 1027 writers from the US
- three samples per writer
- words **been**, ***Cohen***, ***Medical*** and ***referred*** extracted from a longer text.
- **Verification accuracy** (1500 matching pairs, 1500 non-matching pairs)
  - been: ~80%
  - Cohen: ~79%
  - Medical: ~81%
  - Referred: ~77%
  - All four combined: ~91%
- **Identification accuracy** (all 1027 writers modelled, 875 writers tested)
  - been: ~45%
  - Cohen: ~44%
  - Medical: ~47%
  - Referred: ~49%
  - All four combined: ~81%

B. Zhang, S. Srihari, Analysis of handwriting individuality using word features, in: Proceedings of the Seventh International Conference on Document Analysis and Recognition, 2003, pp. 1142–1146.

# DISCRIMINATIVE POWER OF ISOLATED WORDS. ONLINE CASE

- 15 writers.
- Prototype of a digitizing pen
- Only one session. Ten repetitions per session
- words **auch**, ***oder***, ***bitte*** and ***weit***
- Short sentence **Gutten Morgen**
- Considerable –significant- **reproducibility** (equal items written by the same writer match well) and **uniqueness** (equal items written by different writers match far less well) reported

C. Hook, J. Kempf, G. Scharfenberg, A. Novel, Digitizing pen for the analysis of pen pressure and inclination in handwriting biometrics, biometric authentication workshop, Prague 2004, Lecture Notes in Computer Science 3087 (2004) 283–294.

# DISCRIMINATIVE POWER OF ISOLATED WORDS. ONLINE CASE

- 45 writers.
- words **February**, ***January***, ***November*** and ***October***
- 25 repetitions of each word
- **Identification rate**: 95%
- No verification experiments reported

J. Chapran, Biometric writer identification: feature analysis and classification, International Journal of Pattern Recognition & Artificial Intelligence 20 (2006) 483–503.

# DISCRIMINATIVE POWER OF ISOLATED WORDS. ONLINE CASE

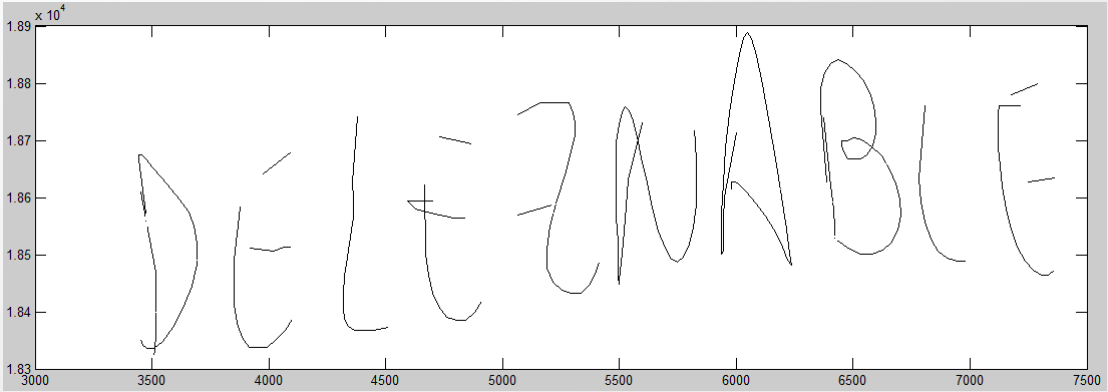
## Our results

- 320 writers.
- 16 uppercase words
- 4 repetitions of each word
- With just one word
  - **Identification** rate: up to as much as **95.6%**
  - **Verification** error: up to only **1.57%**
- With more than one word
  - identification rate increases and verification error decreases

E Sesa-Nogueras, M Faundez-Zanuy. Biometric recognition using online uppercase handwritten text, Pattern Recognition. 45 (2012) 128-144.

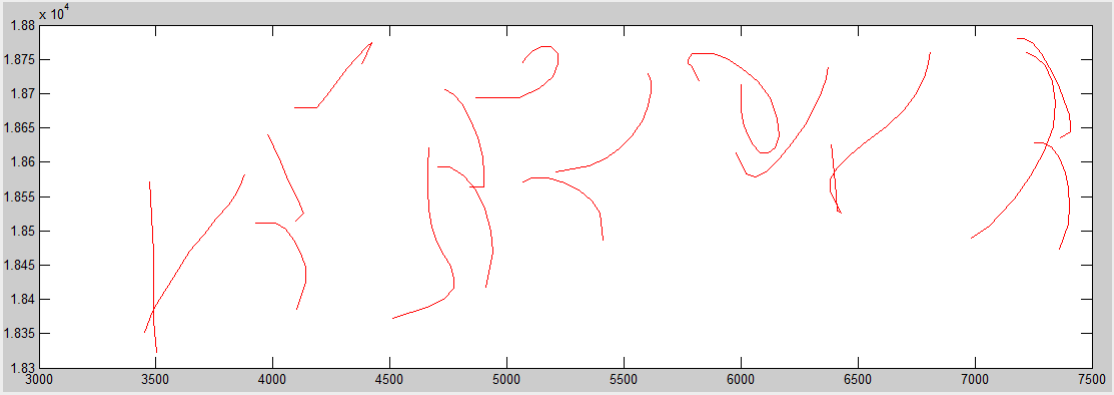
# WHAT IS IN an ONLINE WORD?

In an online word, there is what is seen…




Sequence of **pen-down strokes** (on-surface trajectories)

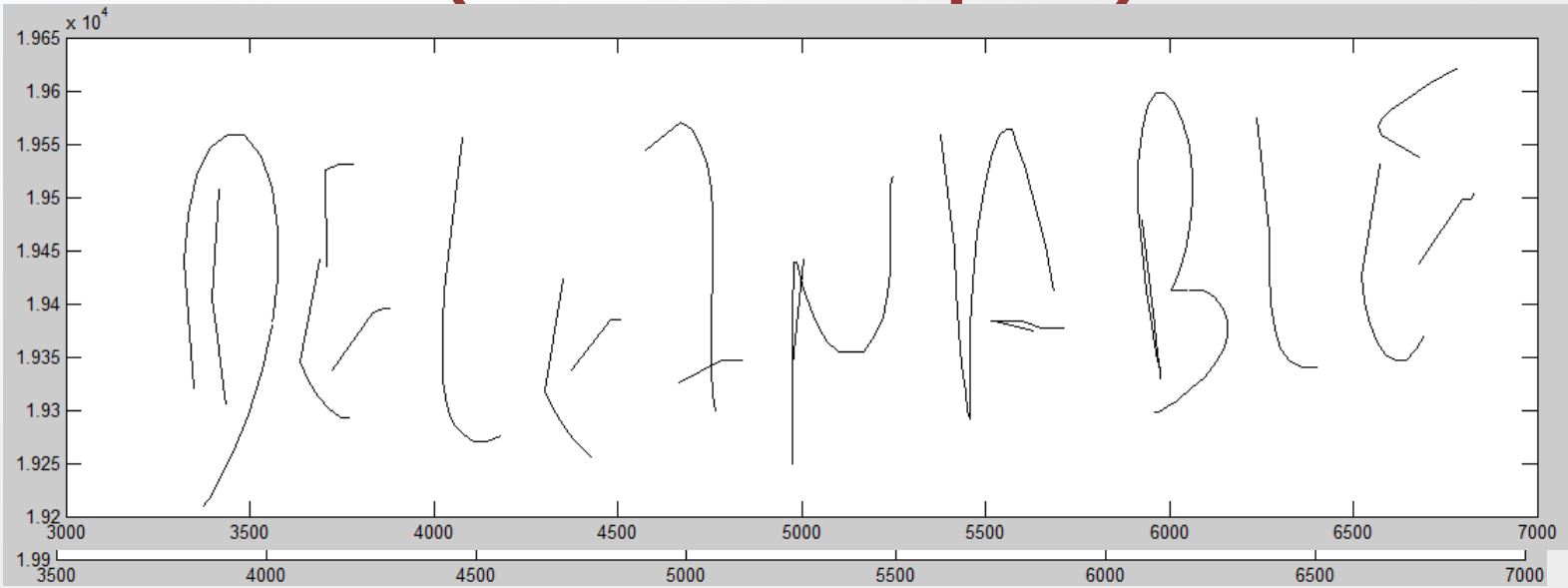
…but also what is not seen !!!

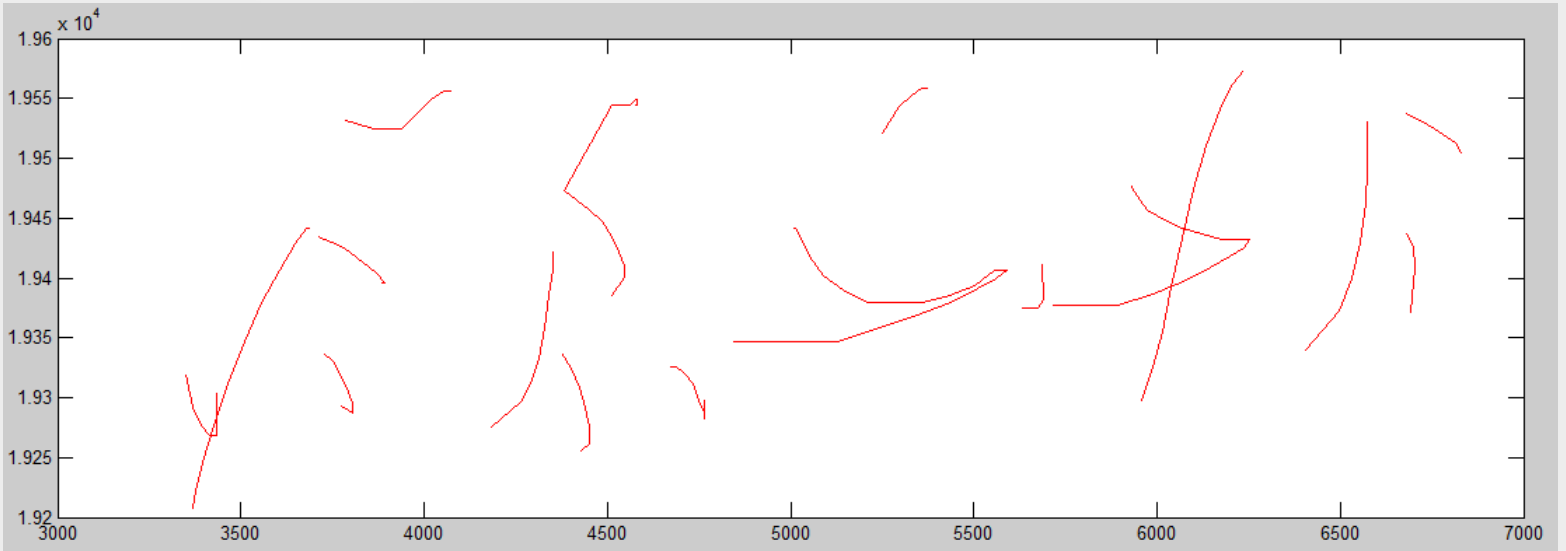



Sequence of **pen-up strokes** (in-air trajectories)

# WHAT IS IN an ONLINE WORD?

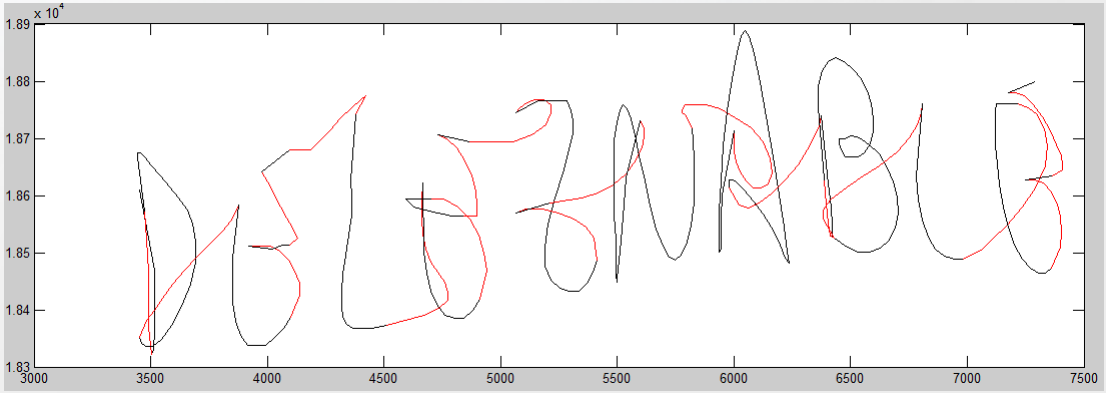
## (other examples)



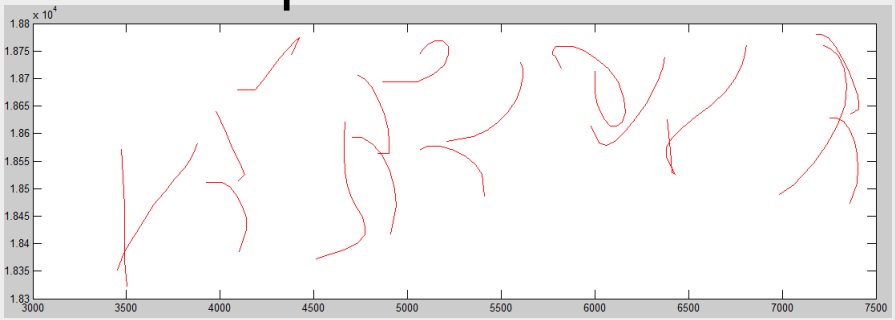



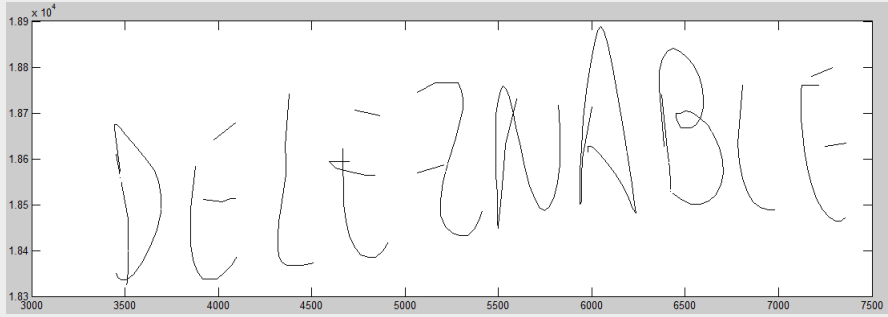
# WHAT IS IN an ONLINE WORD?

A word can be regarded as a sequence of alternated pen-up and pen-down strokes …



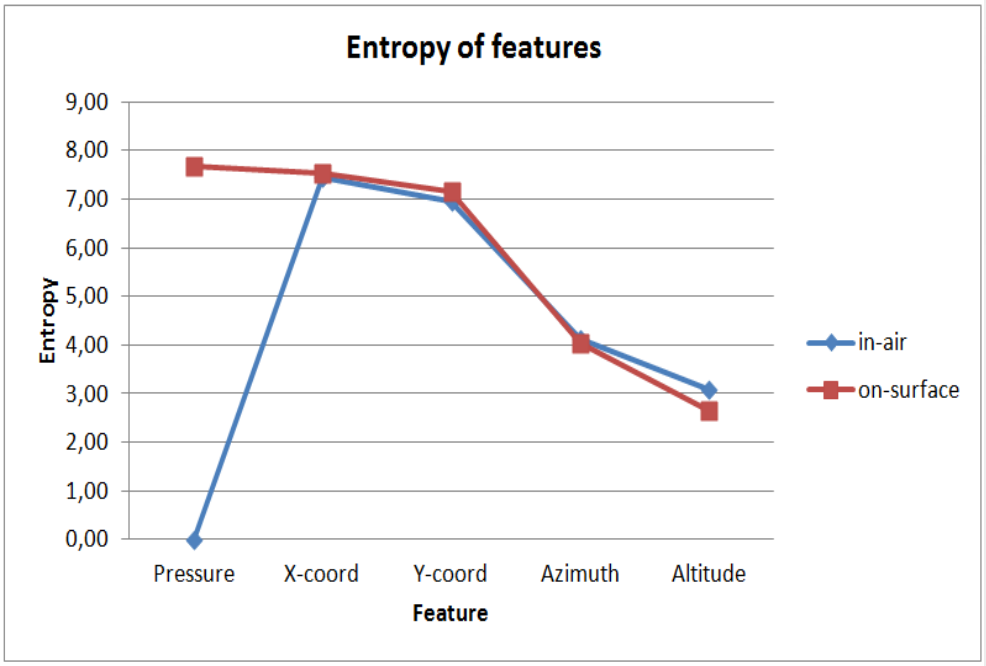

… but also as a pair of sequences: one of pen-up and one of pen down strokes



# IS THERE INFORMATION IN THE PEN-UP STROKES?

Quite a lot!!!




| | Pen downs | Pen ups |
|---|---|---|
| **Pressure** | 7.67 | 0.0 |
| **X-coord** | 7.52 | 7.44 |
| **Y-coord** | 7.14 | 6.96 |
| **Azimuth** | 4.05 | 4.12 |
| **Altitude** | 2.64 | 2.64 |

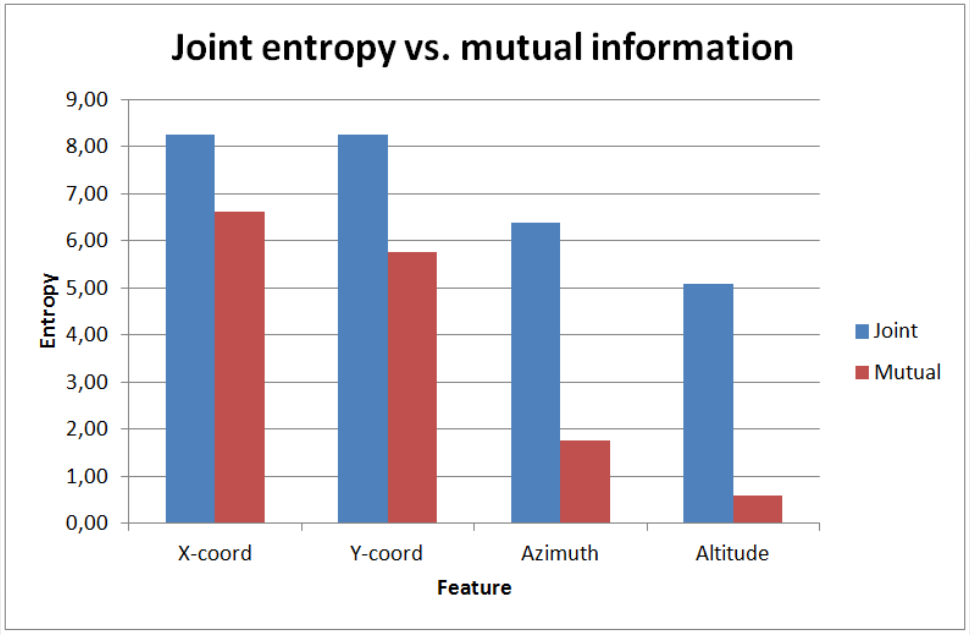
**Information (entropy) of features in bits**

E Sesa-Nogueras, M Faundez-Zanuy, J [redacted] of in-air and on-surface trajectories in online handwriting, Publication pending in Co [redacted]

J Mekyska

# IS THE INFORMATION IN PEN-UP STROKES NON-REDUNDANT ?

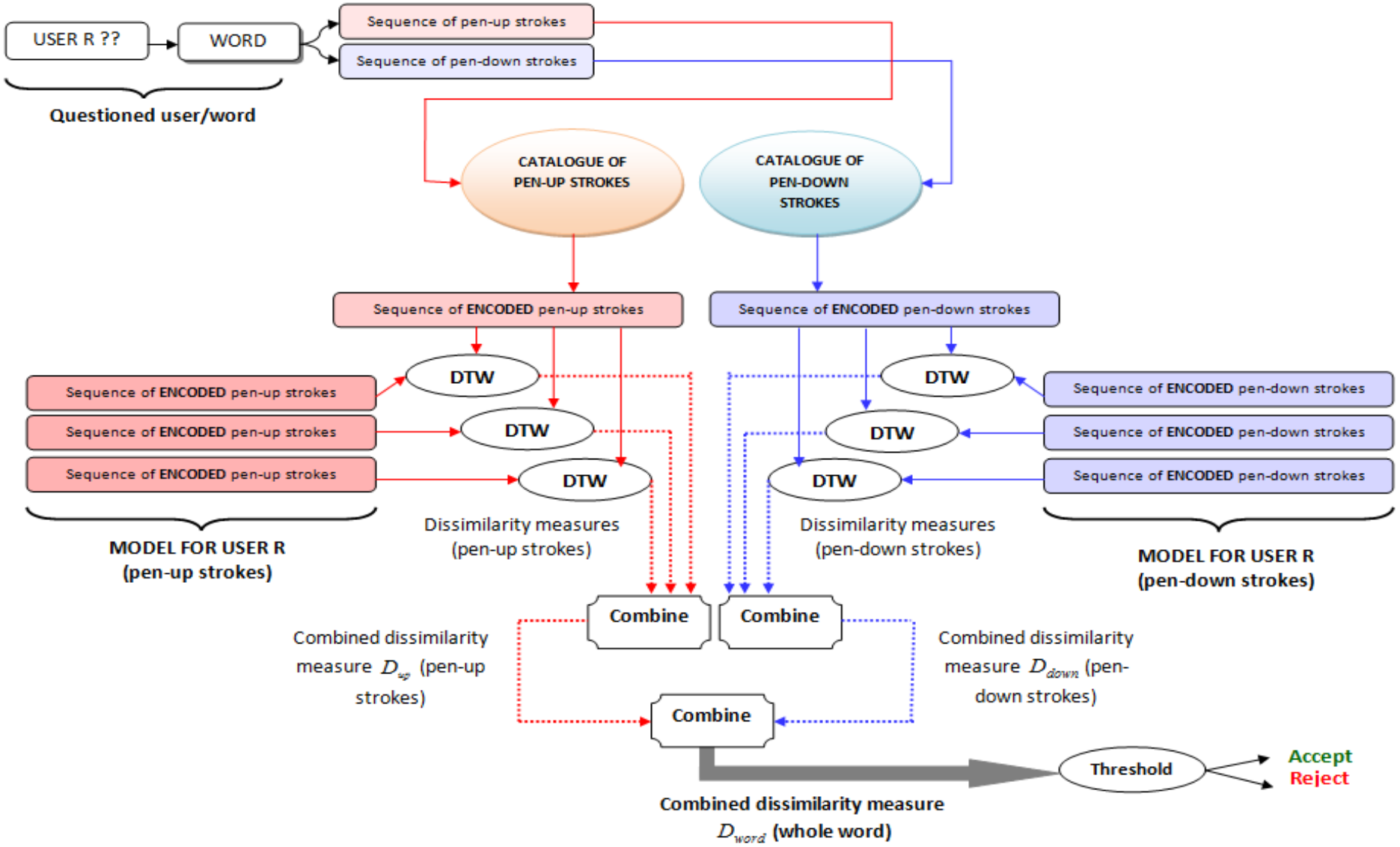
To some extent, yes it is!




| | Redundancy |
|---|---|
| X-coord | 80.1 % |
| Y-coord | 69.7 % |
| Azimuth | 27.4% |
| Altitude | 11.4% |

E Sesa-Nogueras, M Faundez-Zanuy, J Mekyska. An information analysis of in-air and on-surface trajectories in online handwriting, Publication pending in Cognitive Science

# OVERVIEW OF THE RECOGNITION SYSTEM



# EXPERIMENTAL RESULTS

## DATABASE

- **BiosecurId**
  - Multimodal: 8 biometric traits: speech, iris, face … and handwritten text.
  - 400 users with balanced gender distribution. 30 users screened out => final number of **users: 370**
  - Data collected in **4 sessions** in a time span of 4 months
  - **16 uppercase Spanish words**, each one written in a single line (one below the other)
  - Data (features):
    - **X, Y coordinates**
    - **Pressure**
    - **Altitude and azimuth**
    - Time-stamp and button status (discarded)

# EXPERIMENTAL RESULTS

## DATABASE

- **THE WORDS…**

1. BIODEGRADABLE (13)
2. DELEZNABLE (10)
3. DESAPROVECHAMIENTO (18)
4. DESBRIZNAR (10)
5. DESLUMBRAMIENTO (15)
6. DESPEDAZAMIENTO (15)
7. DESPRENDER (10)
8. ENGUALDRAPAR (12)
9. EXPRESIVIDAD (12)
10. IMPENETRABLE (12)
11. INEXPUGNABLE (12)
12. INFATIGABLE (11)
13. INGOBERNABLE (12)
14. MANSEDUMBRE (11)
15. ZAFARRANCHO (11)
16. ZARRAPASTROSA (13)

# EXPERIMENTAL RESULTS

**SETTINGS**

Database (370 users) partitioned into TWO disjoint SETS

SET 1:

- 50 users
- All four sessions considered
- Used to
  - Build the catalogues (EXOCATALOGUES)
  - Determine the values of some parameters

SET 2:

- **320 users** (further partitioning possible)
- Sessions 1 to 3 used to build models
- Session 4 used for testing

# EXPERIMENTAL RESULTS (320 users) IDENTIFICATION RATES

**Identification rate is the percentage of well identified users**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| UP | 82,2% | 69,1% | 87,8% | 71,9% | 82,8% | 86,3% | 70,3% | 70,6% |
| DOWN | 81,6% | 72,8% | 88,4% | 75,3% | 81,3% | 84,1% | 71,9% | 73,4% |
| UP&DOWN | 93,4% | 87,5% | **95,6%** | 86,9% | 95,0% | 93,8% | 82,2% | 87,5% |

DESAPROVECHAMIENTO (18)

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| UP | 73,8% | 75,3% | 79,4% | 78,8% | 74,1% | 60,3% | 63,8% | 62,8% |
| DOWN | 78,8% | 67,8% | 79,7% | 80,9% | 79,4% | 66,9% | 60,9% | 67,5% |
| UP&DOWN | 91,6% | 83,8% | 93,4% | 90,9% | 90,6% | 84,1% | **80,6%** | 83,4% |

ZAFARRANCHO (11)

# EXPERIMENTAL RESULTS (320 users)
# VERIFICATION ERROR RATES

**Verification error rate is the minimum value of ½(probability of a false rejection + probability of a false acceptance)**

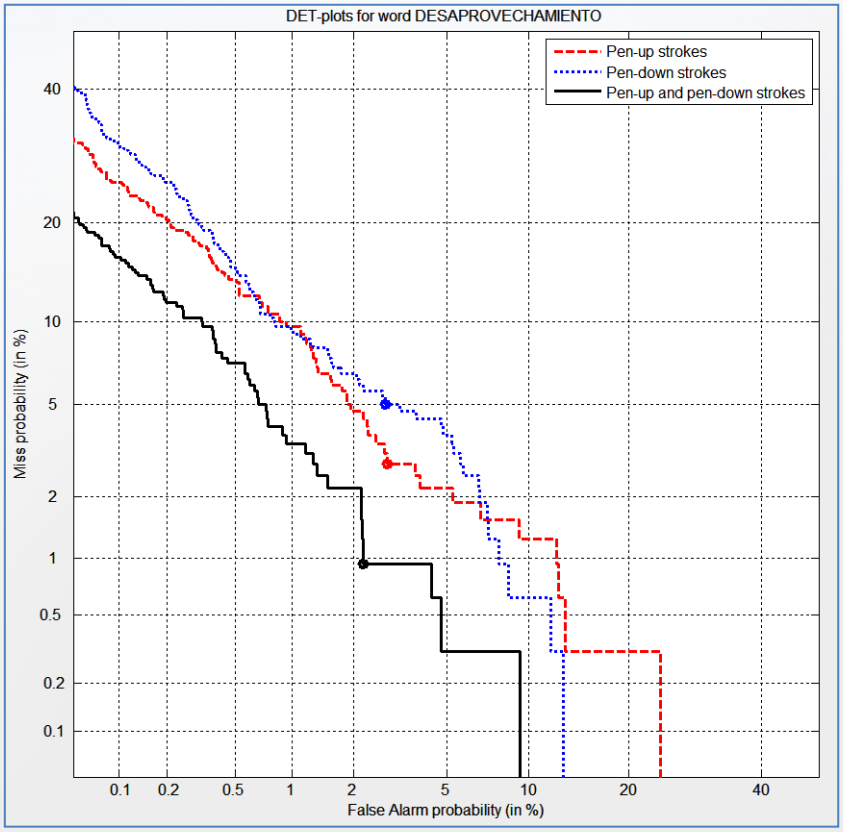
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| UP | 4,08% | 7,59% | 2,82% | 5,29% | 3,75% | 4,08% | 5,70% | 6,95% |
| DOWN | 4,27% | 4,63% | 3,89% | 5,31% | 3,93% | 4,81% | 7,27% | 6,12% |
| UP&DOWN | 2,46% | 2,92% | **1,57%** | 3,38% | 2,58% | 3,46% | 4,42% | 4,32% |

DESAPROVECHAMIENTO (18)

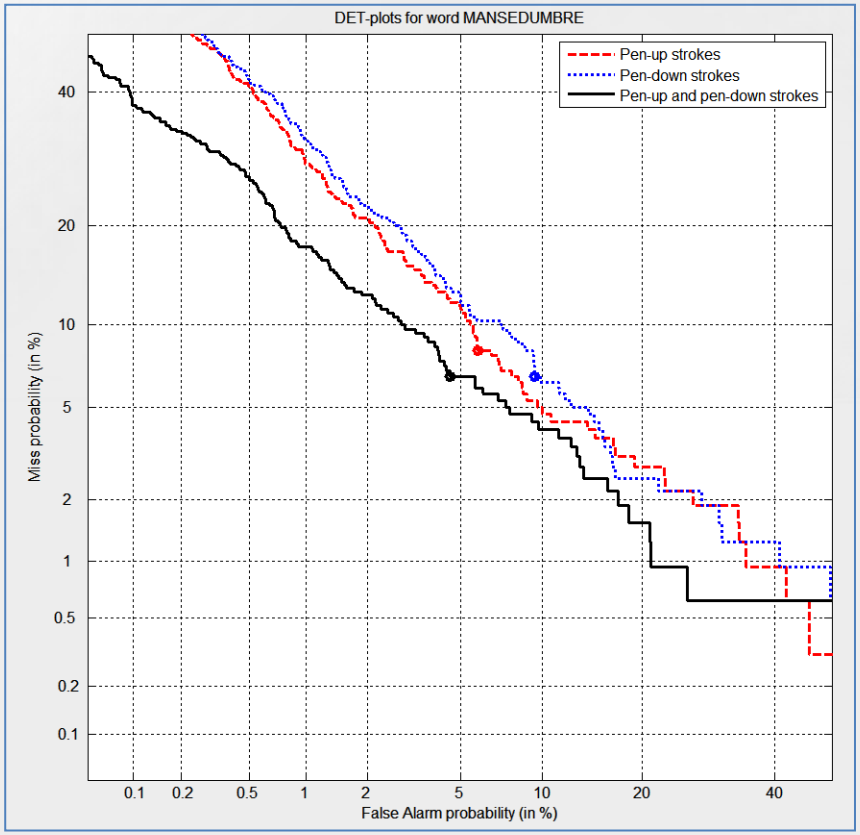
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| UP | 6,32% | 5,58% | 4,46% | 4,44% | 5,46% | 6,98% | 7,13% | 7,28% |
| DOWN | 4,75% | 6,30% | 4,22% | 4,20% | 5,10% | 7,98% | 7,39% | 6,96% |
| UP&DOWN | 3,71% | 3,57% | 2,72% | 2,00% | 3,65% | **5,55%** | 5,40% | 5,27% |

MANSEDUMBRE (11)

# EXPERIMENTAL RESULTS (320 users)
# VERIFICATION. BEST & WORST WORDS




DESAPROVECHAMIENTO (18)



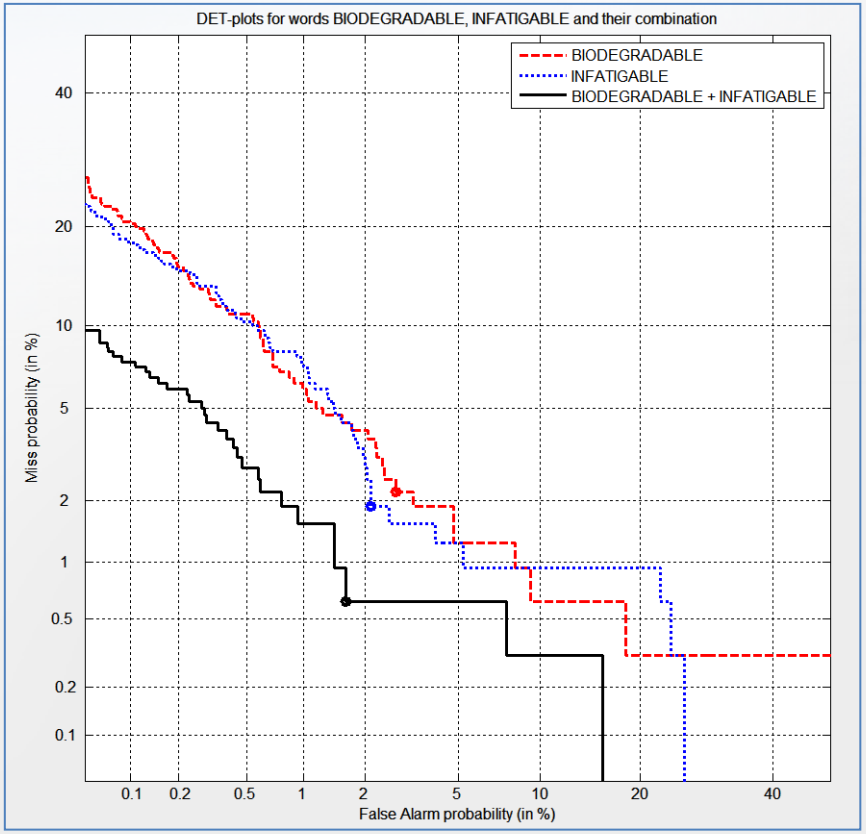

MANSEDUMBRE (11)

# EXPERIMENTAL RESULTS (320 users)
# VERIFICATION ERROR RATES
# COMBINATION OF TWO WORDS

| | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | W13 | W14 | W15 | W16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 2,19 | 0,63 | 1,56 | 1,25 | 1,25 | 1,56 | 3,44 | 1,88 | 1,88% | 1,25 | 0,63 | 1,88 | 2,50 | 1,88 | 2,50 |
| W2 | | 1,88 | 1,88 | 1,88 | 2,19 | 2,81 | 2,19 | 2,19 | 1,25 | 1,88 | 1,88 | 2,50 | 2,81 | 3,44 | 2,81 |
| W3 | | | 1,56 | 0,94 | 1,56 | 2,19 | 1,25 | 0,94 | 0,94 | 0,94 | 0,63 | 0,63 | 1,25 | 3,13 | 1,56 |
| W4 | | | | 2,19 | 2,50 | 2,50 | 1,56 | 0,94 | 1,56 | 1,25 | 0,94 | 1,56 | 1,25 | 2,50 | 2,81 |
| W5 | | | | | 3,44 | 1,88 | 2,81 | 1,88 | 3,44 | 1,88 | 1,56 | 2,19 | 0,94 | 2,50 | 1,88 |
| W6 | | | | | | 2,81 | 2,81 | 3,44 | 1,88 | 1,25 | 0,63 | 3,44 | 1,56 | 2,50 | 2,81 |
| W7 | | | | | | | 1,25 | 3,13 | 4,38 | 2,19 | 1,56 | 2,50 | 4,06 | 2,81 | 2,81 |
| W8 | | | | | | | | 2,19 | 3,75 | 3,44 | 3,13 | 0,94 | 1,56 | 4,38 | 3,75 |
| W9 | | | | | | | | | 3,13 | 2,81 | 2,50 | 1,88 | 3,75 | 3,13 | 2,50 |
| W10 | | | | | | | | | | 2,50 | 1,25 | 1,88 | 3,13 | 2,50 | 2,81 |
| W11 | | | | | | | | | | | 1,88 | 2,19 | 2,50 | 2,50 | 3,75 |
| W12 | | | | | | | | | | | | 2,19 | 1,56 | 4,06 | 3,44 |
| W13 | | | | | | | | | | | | | 3,75 | 3,44 | 2,50 |
| W14 | | | | | | | | | | | | | | 4,38 | 4,38 |
| W15 | | | | | | | | | | | | | | | 6,88 |

With one word, best was 1.57 and worst was 5.55

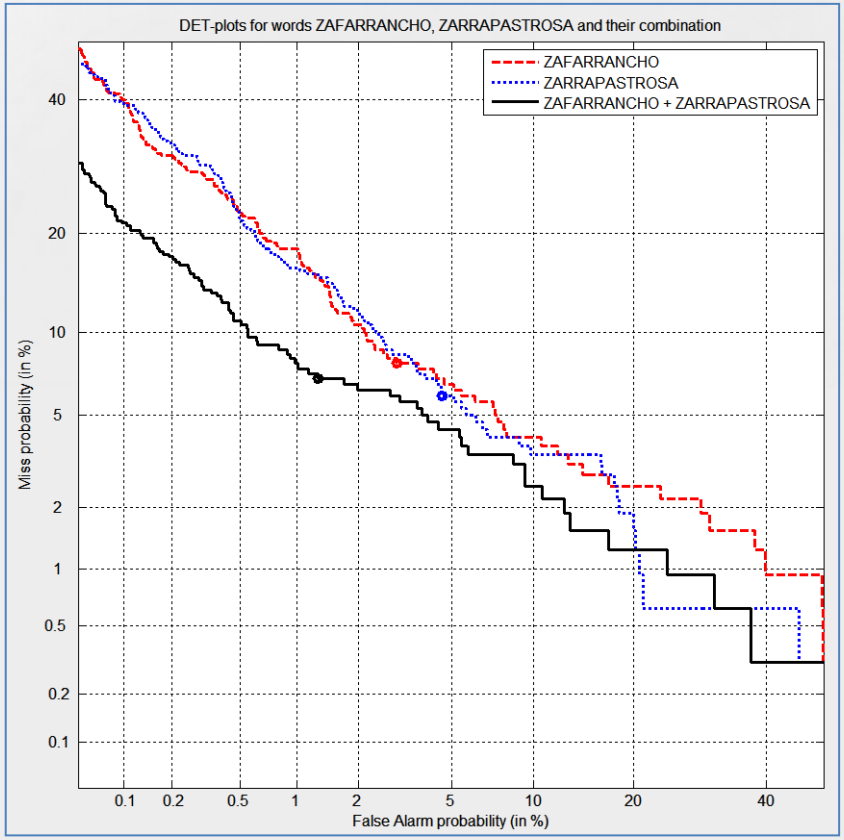
# EXPERIMENTAL RESULTS (320 users) VERIFICATION. BEST & WORST PAIRS




**BIODEGRADABLE (12)**

**+**

**INFATIGABLE (11)**




ZAFARRANCHO (11)

+

ZARRAPASTROSA (13)

# EXPERIMENTAL RESULTS (320 users)
# COMBINATION OF SEVERAL WORDS

## Identification

| | BEST | WORST |
|---|---|---|
| **1 word** | 95.6% | 80.6% |
| **2 words** | 99.7% | 92.5% |
| **3 words** | 100% | 96.88% |
| **4 words** | 100% | 97.81% |

## Verification

| | BEST | WORST |
|---|---|---|
| **1 word** | 1.57% | 5.55% |
| **2 words** | 0.63% | 6.88% |
| **3 words** | 0.65% | 3.12% |
| **4 words** | 0.53% | 2.78% |

**Accuracy tends to increase when (more) words are combined**

THANK YOU VERY MUCH
FOR YOUR ATTENTION