

Evolutionary Algorithms. Developments and applications inspired by Darwinism

Pierrick Legrand

Inria, CQFD Team IMB, Institut de Mathématiques de Bordeaux, UMR CNRS 5251 Université de Bordeaux

April 2019, 12



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Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example

PART 1: Artificial Evolution

Inria, CQFD Team IMB, Institut de Mathématiques de Bordeaux, UMR CNRS 5251 Université de Bordeaux

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Images courtesy of E. Lutton.

Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example

- Artificial Darwinism
- **Evolutionary engine**
- **Genetic Algorithms**
- **Evolution strategies**
- **Genetic Programming**
- Black Box problem solving

Darwinism	Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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Darwinism	Artificial Darwinism	Evolutionary engine		
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Darwinism, evolutionism

Charles Robert Darwin (1809-1882). 1831 - 5 years on the HMS Beagle to Galapagos Islands. November 1859, book "On the origin of species".





Darwinism	Artificial Darwinism	Evolutionary engine		
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The Darwin Finch



Darwinism	Artificial Darwinism	Evolutionary engine		
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Simple mecanisms

- 1 Variations, macroscopic and microscopic, within species.
- 2 Fight for survival.
- 3 Natural selection: triumph of the lineage that has a useful variation in its environment.

Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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Artificial Darwinism

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Artificial Darwinism	Evolutionary engine		
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Artificial Darwinism

Artificial Darwinism

 Stochastic optimization which uses mechanisms inspired by the biological evolution, such as reproduction, mutation, selection and survival of the strongest individuals

Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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A set of techniques grouped under a generic term

Evolutionary Algorithms	Genetic Algorithms (GA)
	Evolution Strategies (ES)
	Genetic Programming (GP)



Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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Ingredients

POPULATION



SELECTION





Darwinism Art	ificial Darwinism	Evolutionary engine	Genetic Alg.	Evolution Strat.	Genetic Prog.	Example
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Evolutionary loop



Artificial Darwinism	Evolutionary engine		
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Optimize an "adaptation to the environment"

Potential Solutions = Individuals in a population



Artificial Darwinism	Evolutionary engine		
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Vocabulary

Evolutionary algorithms	Optimization methods
individual	solution
population	set of solutions
chromosome	coding of the solution
crossing or recombination	operation on two codes
mutation	operation on a code
environment	search space
degree of adaptation to the "Fitness" environment	value of the evaluation function
evolution	maximizing the evaluation function

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The evolutionary engine



2 Selection: select the best individuals.

 \rightarrow roulette wheel, selection on the rank, by tournament.

3 Reproduction: apply genetic operators, crossover and mutations, with probabilities P_c and P_m.

4 Replacement: to make the next generation. \rightarrow elitism, percentage of population renewal, strategies ($\mu + \lambda$) or (μ, λ).

Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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Initialisation / End of the process

Initialisation

- Sampling of the search space (random, regular)
- introduction of initial solutions
- restrictions on the search space

Stop

After N generations or after convergence...

Extraction of the solutions

The best individual of the last generation !

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Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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Discrete representation: Genetic Algorithms

Each individual is represented by a binary string.

John H. Holland (1960, 1975), David Goldberg (1989)



01011010101111001011100101 Pm 010110101010111001011100101

Mutation of the genome

Mutation

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Continuous representation: Evolution Strategies

Each individual is a vector in \mathbb{R}^n .

Hans-Paul Schwefel (1970)

Barycentric crossover

 $\begin{aligned} \forall i \in \{1,..,n\}, x_i^{children} &= \alpha x_i^{father} + (1-\alpha) x_i^{mother} \\ \alpha \text{ random value in } [-\epsilon,1+\epsilon]. \end{aligned}$

Gaussian mutation

 $\forall i \in \{1,..,n\}, x_i^{children} = x_i^{children} + N(0,\sigma) \\ \text{Two parameters } P_m \text{ and } \sigma.$

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Functional representation: Genetic programming

Create programs without programming ! Tree representation

John Koza (1990)



Function (cos(x) + 2y)(1 + x)

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GP Crossover



Artificial Darwinism	Evolutionary engine	Genetic Alg.	Genetic Prog.	Example
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GP Mutation



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Black box inverse problems solving



	Fitting	Evolutionary Algorithm	

PART 2: Cochlear implant fitting with evolutionary algorithm

Inria, CQFD Team IMB, Institut de Mathématiques de Bordeaux, UMR CNRS 5251 Université de Bordeaux

April 2019, 12

Joint work with Vincent Pean, Evelyne Lutton, Claire Bourgeois-Republique, Bruno Frachet, Jacques Levy-Vehel, and Pierre Collet. **RNTS PROJECT 041550 HEVEA**.

		Fitting	Evolutionary Algorithm	
Introduct	ion			

Physiological basis of audition Audition Deafness

Cochlear Implants

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Interactive Evolutionary Algorithms

Experiments

Introduction ●○		Fitting	Evolutionary Algorithm	

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This project is a collaboration between mathematicians, computer scientists and medical practitioners. The following institutions are involved in this project:

- Hopital Avicenne (B. Frachet)
- Innotech (V. Péan)

Introduction

- Institut de Mathématiques and University of Bordeaux (P. Legrand)
- INRIA Bordeaux, CQFD TEAM (P. Legrand)
- INRIA Saclay, AVIZ TEAM (E. Lutton)
- INRIA Saclay, REGULARITY TEAM (J. Levy-Vehel)
- MXM-Neurelec
- University of Bourgogne (C. Bourgeois-Republique)
- University of Strasbourg (P. Collet)

The aim is to

- Simplify the process of cochlear implants fitting (after a deaf patient has been surgically implanted).
- Make the implant more adaptable to the environment.

Audition ●○○○○○○	Fitting	Evolutionary Algorithm	

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	Audition	Fitting	Evolutionary Algorithm	
Audition				

Transmission of sound to the cochlea

The external ear receives the wave of acoustic pressure.



2. A diagram (not to scale) of the human ear (reprinted with permission from [85]).



CQFD IMB/INRIA/UBX

	Audition ○●○○○○○	Fitting	Evolutionary Algorithm	
Audition				

Transmission of sound to the cochlea

The **external ear** receives the wave of acoustic pressure. The **middle ear** transforms the acoustic wave onto a mechanical vibration.



2. A diagram (not to scale) of the human ear (reprinted with permission from [85]).



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	Audition ○●○○○○○	Fitting	Evolutionary Algorithm	
Audition				

Transmission of sound to the cochlea

The **external ear** receives the wave of acoustic pressure. The **middle ear** transforms the acoustic wave onto a mechanical vibration. This mechanical vibration moves the oval window (which is connected to the middle ear) and the fluid contained in the **cochlea** is set into motion.



2. A diagram (not to scale) of the human ear (reprinted with permission from [85]).


	Audition ○●○○○○○	Fitting	Evolutionary Algorithm	
Audition				

Transmission of sound to the cochlea

The **external ear** receives the wave of acoustic pressure. The **middle ear** transforms the acoustic wave onto a mechanical vibration. This mechanical vibration moves the oval window (which is connected to the middle ear) and the fluid contained in the **cochlea** is set into motion. The variations of pressure in the fluid generates a movement of the basilar membrane.



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	Audition ○○●○○○○	Fitting	Evolutionary Algorithm	
Audition				

Coding of the cochlea

The basilar membrane is a filter.



▲ 3. Diagram of the basilar membrane showing the base and the apex. The position of maximum displacement in response to sinusoids of different frequency (in Hz) is indicated.

	Audition	Fitting	Evolutionary Algorithm	
Audition				
Coding of the au	ditive nerve			

Frequencies coding

• The movement of the basilar membrane encodes information of the frequency in the acoustic signal.

	Audition	Fitting	Evolutionary Algorithm	
Audition				
Coding of the au	ditive nerve			

Frequencies coding

- The movement of the basilar membrane encodes information of the frequency in the acoustic signal.
- The sensory cells which are on the basilar membrane oscillate with the membrane.

	Audition	Fitting	Evolutionary Algorithm	
Audition				
Coding of the au	ditive nerve			

Frequencies coding

- The movement of the basilar membrane encodes information of the frequency in the acoustic signal.
- The sensory cells which are on the basilar membrane oscillate with the membrane.
- The movement of the sensory cells liberates an electro-chimical substance which leads to discharge the neurons. Then these electrical impulses correspond to an excitation at a given position on the basilar membrane.

	Audition ○○○○●○○	Fitting	Evolutionary Algorithm	
Audition				

Coding of the auditive nerve



Example : Transmission to the brain. The acoustic information is conveyed to

the brain by electric impulses.

	Audition ○○○○○●○	Fitting	Evolutionary Algorithm	
Audition				



	Audition	Fitting	Evolutionary Algorithm	
Deafness				

Temporal and frequential informations



If the sensory cells are damaged, the auditive system cannot transform the acoustic pressure wave to neuronal impulses.

	Implants ●○○○	Fitting	Evolutionary Algorithm	

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Cochlear implant				

Goal :

To directly stimulate the neurons of the auditive nerve by inserting electrodes in the cochlea.



lition	Implants	Fitting	Evolutionary Algorithm	
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Cochlear implants allow to deaf people to hear again if

• The auditive nerve is not damaged.



	Implants ○○●○	Fitting	Evolutionary Algorithm	

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	Implants ○○●○	Fitting	Evolutionary Algorithm	

Cochlear implants allow to deaf people to hear again if

• The auditive nerve is not damaged.

In 2006, 70000 people were implanted. In 2019, 500000.

Most of the implantations are successful

	Implants	Fitting	Evolutionary Algorithm	
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Cochlear implants allow to deaf people to hear again if

• The auditive nerve is not damaged.

- Most of the implantations are successful
- Possibility to hear again

	Implants	Fitting	Evolutionary Algorithm	
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Cochlear implants allow to deaf people to hear again if

• The auditive nerve is not damaged.

- Most of the implantations are successful
- Possibility to hear again
- Possibility to hear during a phone call

	Implants	Fitting	Evolutionary Algorithm	
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Cochlear implants allow to deaf people to hear again if

• The auditive nerve is not damaged.

- Most of the implantations are successful
- Possibility to hear again
- Possibility to hear during a phone call
- Possibility to listen to music.

	Implants	Evolutionary Algorithm	
	0000		

Cochlear implants allow to deaf people to hear again if

The auditive nerve is not damaged.

- Most of the implantations are successful
- Possibility to hear again
- Possibility to hear during a phone call
- Possibility to listen to music.
- But some people still encounter difficulties and they prefer to turn off the implant.

	Implants	Evolutionary Algorithm	
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Cochlear implants allow to deaf people to hear again if

The auditive nerve is not damaged.

In 2006, 70000 people were implanted. In 2019, 500000.

- Most of the implantations are successful
- Possibility to hear again
- Possibility to hear during a phone call
- Possibility to listen to music.
- But some people still encounter difficulties and they prefer to turn off the implant.

This population motivated our work



- A The sound is captured by the microphone, digitalized and processed.
- B The signal is sent to the implant through the skin.
- C The implant gets informations from the outer processor and distributes these informations to the electrodes in the cochlea. Each electrode corresponds to a frequency band of the sound.
- D The nerve endings transmit the electric impulses to the brain and they are interpreted as sounds.

	Fitting ●○○	Evolutionary Algorithm	

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		Fitting ○●○	Evolutionary Algorithm	
Difficulties				



		Fitting ○●○	Evolutionary Algorithm	
Difficulties				

• Which frequency for each electrode ?



		Fitting ○●○	Evolutionary Algorithm	
Difficulties				

- Which frequency for each electrode ?
- Which intensity range for each electrode ?

		Fitting ○●○	Evolutionary Algorithm	
Difficulties				

- Which frequency for each electrode ?
- Which intensity range for each electrode ?
- How many electrodes simultaneously activated ?

		Fitting ○●○	Evolutionary Algorithm	
Difficulties				

- Which frequency for each electrode ?
- Which intensity range for each electrode ?
- How many electrodes simultaneously activated ?
- Should we avoid the activation of two consecutive electrodes ?

• ...

		Fitting ○●○	Evolutionary Algorithm	
Difficulties				

- Which frequency for each electrode ?
- Which intensity range for each electrode ?
- How many electrodes simultaneously activated ?
- Should we avoid the activation of two consecutive electrodes ?

• ...

Finding the answer to these questions is a **difficult optimization problem**. This difficulty is not only related to the **dimension of the search space** but also to other causes: **Environment**, **Tiredness**, **brain adaptation**...

		Fitting ○○●	Evolutionary Algorithm	
Manual fitting				

• Determinate the functional electrodes.



		Fitting ○○●	Evolutionary Algorithm	
Manual fitting				

- Determinate the functional electrodes.
- Determinate the intensity thresholds T (threshold) and C (comfort).



		Fitting ○○●	Evolutionary Algorithm	
Manual fitting				

- Determinate the functional electrodes.
- Determinate the intensity thresholds T (threshold) and C (comfort).
- The practitioner distributes logarithmically the frequency bands on the electrodes (by his background).



		Fitting ○○●	Evolutionary Algorithm	
Manual fitting				

- Determinate the functional electrodes.
- Determinate the intensity thresholds T (threshold) and C (comfort).
- The practitioner distributes logarithmically the frequency bands on the electrodes (by his background).
- Then many tests with the patient.



		Fitting ○○●	Evolutionary Algorithm	
Manual fitting				

- Determinate the functional electrodes.
- Determinate the intensity thresholds T (threshold) and C (comfort).
- The practitioner distributes logarithmically the frequency bands on the electrodes (by his background).
- Then many tests with the patient.

The results are often good but the complete process can take years for some patients.



	Fitting	Evolutionary Algorithm ●○○	

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	Fitting	Evolutionary Algorithm	
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Contribution: Interactive Evolutionary Algorithm

Stochastic optimization which uses mechanisms inspired by the biological evolution, such as reproduction, mutation, selection and survival of the strongest individuals. An interactive evolutionary algorithm is a classical evolutionary algorithm with a fitness function given by a human.



Contribution: Interactive Evolutionary Algorithm

Stochastic optimization which uses mechanisms inspired by the biological evolution, such as reproduction, mutation, selection and survival of the strongest individuals. An interactive evolutionary algorithm is a classical evolutionary algorithm with a fitness function given by a human.

The potential solutions of the problem are individuals in a population.





Contribution: Interactive Evolutionary Algorithm

Stochastic optimization which uses mechanisms inspired by the biological evolution, such as reproduction, mutation, selection and survival of the strongest individuals. An interactive evolutionary algorithm is a classical evolutionary algorithm with a fitness function given by a human.

The potential solutions of the problem are individuals in a population.



			Fitting	Evolutionary Algorithm ○○●		
Automatic fitting method						

Algorithm

• Manual fitting by an expert (for this patient).


		Fitting	Evolutionary Algorithm ○○●	

- Manual fitting by an expert (for this patient).
- Initial Population : 4 parents (=4 fittings *P*1, *P*2, *P*3, *P*4) randomly generated (in the range [*T*, *C*] of each electrode).

	Fitting	Evolutionary Algorithm ○○●	

- Manual fitting by an expert (for this patient).
- Initial Population : 4 parents (=4 fittings *P*1, *P*2, *P*3, *P*4) randomly generated (in the range [*T*, *C*] of each electrode).
- **Evaluation** of the population by the patient during auditive tests (VCV and ASSE). Each individual obtains an evaluation : *N*1, *N*2, *N*3, *N*4.

	Fitting	Evolutionary Algorithm ○○●	

- Manual fitting by an expert (for this patient).
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- **Evaluation** of the population by the patient during auditive tests (VCV and ASSE). Each individual obtains an evaluation : *N*1, *N*2, *N*3, *N*4.
- Generation of children (3 individuals, *E*1, *E*2, *E*3). Two individuals are randomly selected, the best is selected with a high probability. The previous selection is repeated. In this way, two individuals are selected and then crossed in order to obtain a child. This child undergo mutation with a probability *pm*.

		Fitting	Evolutionary Algorithm	

- Manual fitting by an expert (for this patient).
- Initial Population : 4 parents (=4 fittings *P*1, *P*2, *P*3, *P*4) randomly generated (in the range [*T*, *C*] of each electrode).
- **Evaluation** of the population by the patient during auditive tests (VCV and ASSE). Each individual obtains an evaluation : *N*1, *N*2, *N*3, *N*4.
- Generation of children (3 individuals, *E*1, *E*2, *E*3). Two individuals are randomly selected, the best is selected with a high probability. The previous selection is repeated. In this way, two individuals are selected and then crossed in order to obtain a child. This child undergo mutation with a probability *pm*.
- **Evaluation** of the 3 children by the patient: *NE*1, *NE*2, *NE*3.

		Fitting	Evolutionary Algorithm ○○●	

- Manual fitting by an expert (for this patient).
- Initial Population : 4 parents (=4 fittings *P*1, *P*2, *P*3, *P*4) randomly generated (in the range [*T*, *C*] of each electrode).
- **Evaluation** of the population by the patient during auditive tests (VCV and ASSE). Each individual obtains an evaluation : *N*1, *N*2, *N*3, *N*4.
- Generation of children (3 individuals, *E*1, *E*2, *E*3). Two individuals are randomly selected, the best is selected with a high probability. The previous selection is repeated. In this way, two individuals are selected and then crossed in order to obtain a child. This child undergo mutation with a probability *pm*.
- **Evaluation** of the 3 children by the patient: *NE*1, *NE*2, *NE*3.
- Generation of the new population among *P*1, *P*2, *P*3, *P*4, *E*1, *E*2, *E*3. Random selection of 2 individuals, selection of the best evaluation. A new population is obtained: *F*1, *F*2, *F*3 and *F*4.

		Fitting	Evolutionary Algorithm	Experiments ●○○
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Audio test				

VCV test

The Vowel-Consonant-Vowel (VCV) test is used in clinics to evaluate how well a listener can recognize consonants under different conditions. The stimuli consist of audio recordings of an adult speaking VCV nonsense words. The vowel context is /a/-/a/.



ASSE test

- Fifteen speech sounds that can be selected
- Selected speech sound presented 3 times
- Scoring is binary
 - Correct: sound heard
 - False: sound not heard

		Fitting	Evolutionary Algorithm	Experiments ○○●
Results				

Patient	ASSE manual	ASSE auto	VCV manual	VCV auto
S1	4/7	7/7	20%	27%
S2	5/7	6/7	35%	37%
S3	5/7	6/7	45%	52%
S4	4/7	7/7	20%	27%

- This method allows to explore a large number of various possible fitting.
- First evolutionary algorithm on mobile device.
- Fast and easy to use.

PART 3: Evolutionary computation for EEG classification

Inria, CQFD Team IMB, Institut de Mathématiques de Bordeaux, UMR CNRS 5251 Université de Bordeaux

April 2019, 12

Joint work with Marie Chavent, Frédérique Faïta and Laurent Vezard

EEG data Acquisition Acquisition Protocole

Feature Extraction Slope Criterion

Evolutionary Algorithm Design Results



Goals

- Characterize the state of alertness of a person from his electroencephalogram (EEG).
- Create a brain-computer interface.
- Influence a person's state of alertness with synthesized music.



EEG data Acquisition Acquisition Protocole

Feature Extraction Slope Criterion

Evolutionary Algorithm Design Results



- First EEG recording: subject in a normal state of alertness: "normal"
- Second EEG recording: subject in a state of low vigilance: "relax"



Feature Extraction

Evolutionary Algorithm





- EEG headset installation time: 45 minuts.
- Subject with open eyes.
- Sampling frequency: 256Hz.
- Recording time: 3 minuts (46000 sample points).

Campaigns:

- 58 electrodes renumbered from 1 to 58
- Subjects under 35, right-handed and non-smoker
- 58 subjects \Rightarrow 16 preserved

Relaxation session

20 minutes with a recorded voice offering 3 exercises:

- Autogenic training [Schultz1958]: repetition of sentences, self-hypnosis.
- Progressive muscle relaxation [Jacobson1974].
- Mental visualization (familiar places, smells, noises).

Feature Extraction

Evolutionary Algorithm

3 minutes of EEG recording before relaxation.

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AF4Ret	and the second and the se	and survey and the
E7-Bet	and	and and and and and and
F5-Bet	have been and a second a se	ann man have have
F3Bet	a provide the second of the second and the second and the second and the second and the second of the second s	Mr. Marine
F1-Bet	and the second and the second of the second	and marked and the second
F2-Rel	Martin and a second	and a market and a second
E2-Ref	and the second and the se	mmmmmmm
F4-Fluit	and the second second and the second s	mmmmmmm
FE-Ref	a contraction of the second of	and an and a second
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FC3-Rel		an www.
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TARM	have a share a sh	and a strange that a strate when the
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CP3Ref	and all a second and the fail of the fail of the	and a start way
CP1-Ref	and and any open water and the for the for the second and the seco	and a stranger of the second s
CP2-Rel	a a about the second of the second and the second of the s	monorman
DP2-Ref	and a set of the set o	month of the second of the
CP4Rd	and the second second and the second second and the second s	all ward of the second of the second
CP6-Ref	and the second se	and a sub- and a sub- and a sub-
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P3.DA	the second recently and a second recently and the second second second second second second second second second	and not be the total
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Pa-Bel	and a second	montane
P2-Rel	and the second of the	and and the second
P4Rel	and a second and the second of the second of the second second second second second second second second second	and and the state of the state
PG-Ret	and the second	and a survey of the second
15 Hel		and the A set Automation
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POD-Ref	and a transferration of the second	and and and a second
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10-4404		N DAL NORTH ON
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3 minutes of EEG recording after relaxation.

Alpha waves

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FPz-Bel	an and the state of the state o	the state of the second state was a state of the	And a second a
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F5-Rei	the man we want when a second when we want the second when the second when the second when the second secon	mound and a manual and the	and a summer when a summer was a summer when the summer when the summer sum
F3Rol	man have man have and the service of	man man man and a man man man	man man man and the second and the second
F1-Rel	and and a strange and	man and a farman of he	and a second way way and a second the second second and the second s
E2-Bel	the set of	and the property of the second s	and the second sec
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FERei	many the stand when the state of the state o	and manufactor and a summer and	and the second second second second second second
F8-Bei	man and the strand and the second of the second stranger with	a how we we have the more more many war how	and a state of the
FCS-Bef	many and a start way and a same way the all show on	and an and the second and a second with the second of the	man man man and a man man man was
FC3-Ref	and the man war	and a manufacture and the second second	and a second and the
FC1-Ref	and a superior and a superior and and a superior	man man and a man a man a man	and a second and a s
FCz-Ref	the second	and the second of the second o	and a start way and a start of the start of
FU2-Het	the second way was a second of the second of	WWW. WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW	and a start of the
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C5Bei	The second state when the second state all many	among and an and and and and and and and and	and a many and a second and a second and a second
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C1-Rei	have for more thank the set of th	man way was a way way and	and a support the second and the sec
C2Rel	and the war		and and the second of the seco
C2Re	and the second of the second	and the stand of the second and the mail	
C4-Ref	the second when a sub-she as the	and the second states and the maintained and the second states and	
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TP2-Bet	and an another the stand and a stand and a stand and a stand and a stand	agriguance the the man the man have not been	and a second with a star a strange through the strange and the second
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CP1 Ref	man for man man and the start and the start of the start		and a second and the second and the second s
CPz-Ref	and the second and the second second		and a suprementation of the second and the
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P3-Rel	and the state of t		and a second and a
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P4-Rel	may have more any any and		and a superior and a superior and the su
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-			
10:49:23	Pa 😜		

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EEG data Acquisition Acquisition Protocole

Feature Extraction Slope Criterion

Evolutionary Algorithm Design Results



EEG data Acquisition	Feature Extraction ○●○○○○	
Slope Criterion		

The dyadic grid gives a spatio-frequential representation of the discrete dyadic wavelet decomposition



- Alpha: 8 - 12Hz.

- Waves characteristics of a relaxed state.



Linear regression between 4 and 16Hz.

- Alpha: 8 12Hz.
- Waves characteristics of a relaxed state.



Linear regression between 4 and 16Hz.



- Alpha: 8 12Hz.
- Waves characteristics of a relaxed state.



Linear regression between 4 and 16Hz.

2 ^x 10⁸ 0 Dente calculée entre 4 et 16 Hz ÷₽ état normal 0 état relaxé **** -104 10 20 30 40 50 58 Numéro de l'électrode

Slope criterion, sum on subjects for each electrode

Feature Extraction

Evolutionary Algorithm

Slope Criterion



Slope criterion, sum on electrodes for each subjects

- ⇒ Very strong inter-subject variability
- ⇒ This criterion that does not allow to build a powerful classifier for different subjects.

Feature Extraction

Evolutionary Algorithm

Slope Criterion

Classification: Usual methods

	K nearest	Binary	Random	Discriminant	Sparse Discriminant
	neighbors	decision trees	forests	PLS	PLS
Mean	37.28	33.98	32.03	40.63	36.25
Standard Deviation	10.47	5.15	6.46	8.55	7.96

Mean and standard deviations of Correct Classification Rates for different classification methods applied on slope criterion.

This approach is not efficient

Our contribution: Design a relevant **evolutionary algorithm** to solve this task of classification.

 \Rightarrow Find the relevant electrodes.

 \Rightarrow Find the relevant frequencies for the calculation of the slope criterion.

EEG data Acquisition Acquisition Protocole

Feature Extraction Slope Criterion

Evolutionary Algorithm Design Results



Design

Feature Extraction

Evolutionary Algorithm

Example of a genome in the evolutionary algorithm



Feature Extraction

Evolutionary Algorithm

Design

Relationship between the genome and the calculation of the slope criterion



Feature Extraction

Evolutionary Algorithm

Results

Average correct classification rate

Evaluation	CCR	
Method	Mean	Standard deviation
CART	86.68	1.87
SVC	83.49	2.37

Average and standard deviations of the correct classification rates obtained for the 100 runs of the evolutionary algorithm and for two methods of evaluation.

Results

Best genome

Evaluation	BEST genome		
method	Selected	Selected	Correct classification
	electrode	frequency (Hz)	rates
CART	F4	1/8, 1/4, 2, 4 et 64	89, 33%
SVC	F2	1/32, 1/16, 2, 4, 8, 64 et 128	89,33%

Table summarizing the two best genomes found during the 100 runs of the genetic algorithm with two methods of evaluation.

PART 4: Regularity estimation with Genetic Programming

Inria, CQFD Team IMB, Institut de Mathématiques de Bordeaux, UMR CNRS 5251 Université de Bordeaux

April 2019, 12

Joint work with Leonardo Trujillo, Gustavo Olague and Jacques Levy-Vehel

Introduction

Hölderian Regularity

Contribution



Introduction

Hölderian Regularity

Contribution



Introduction	Hölderian Regularity	Contribution
00		

Signal Regularity

- In science and engineering there is one fundamental task: Analyzing and processing signals (natural or artificial) to extract useful information.
- Signals can be too big; where is the information located?
- Usually its smart to focus where signal variation is high (for visual data, you can think of borders, corners and textured areas)



O. Le Meur, P. Le Callet, D. Barba, and D. Thoreau. A Coherent Computational Approach to Model Bottom-Up Visual Attention. IEEE Trans. Pattern Anal. Mach. Intell. 28, 5 (May 2006), 802-817.

Introduction

Hölderian Regularity

Contribution



Hölderian Regularity

Contribution

Hölder exponent

Mathematical tool that measures the regularity of a signal around each point.




Hölderian Regularity ○○● Contribution

General motivation





Hölderian envelope of signal f at point x_0

- For real-world signals the Hölder exponent must be estimated for each point.
- Several estimation methods exist, but most methods are SLOW or highly parameterized;
- Therefore there use is not common (particularly in computer vision applications where speed can be of importance)

Introduction

Hölderian Regularity

Contribution



lerian Regularity

Contribution ○●○○

- Evolve estimators of the pointwise Hölder exponent for 2D signals with Genetic Programming!
- GP evolves estimators that are ACCURATE and FAST!
- Evolution is a one-shot process, evolved estimators can be used of-the shelf!



Hölderian Regularity

Contribution ○●○○

- Evolve estimators of the pointwise Hölder exponent for 2D signals with Genetic Programming!
- GP evolves estimators that are ACCURATE and FAST!
- Evolution is a one-shot process, evolved estimators can be used of-the shelf!



- Leonardo Trujillo, Pierrick Legrand, Gustavo Olague, and Jacques Levy-Vehel. 2012. Evolving estimators of the pointwise Hölder exponent with Genetic Programming. Information Sciences 209 (Nov. 2012), 61-79.
- Humies Award Finalist, GECCO 2013.

Hölderian Regularity

Contribution ○○●○

Results: Real Images



Original Image



GP-Estimator



Traditional Method



GP-Estimator

