inegi driving science & innovation

CONVERTING KNOWLEDGE INTO VALUE FOR OVER 35 YEARS

Since 1986

Computational use of an Artificial Bee Colony approach for Model Predictive Control

Jhonny de Sá Rodrigues
Alejandro Goldar

U.PORTO

FIBRE4YARDS SHIPYARD FOR THE FUTURE

saas Service d'Automatique et d'Analyse des Systèmes
Department of Control Engineering and System Analysis
Brussels School of Engineering

CONTENT

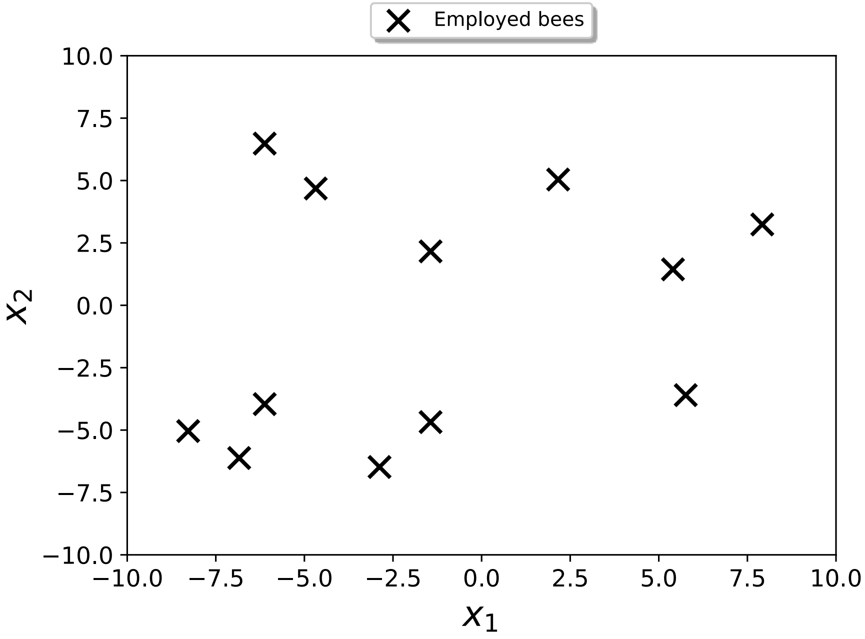
- Artificial Bee Colony algorithm
- Artificial Bee Colony algorithm proposal
- Automated Tape Laying process
- Preliminary results
- Remarks

Since 1986

U.PORTO

DEFINITION

- Zero-order search algorithm that mimics the behaviour of a bee swarm searching for food[1]
- Consists of 3 types of bees:
  - **Employed bees**
  - ✓ Perform a random search around the entire domain
  - Onlooker bees
  - ✓ Perform a search around the selected food source
  - Scout bees
  - ✓ Perform a random search similarly to the Employed bees

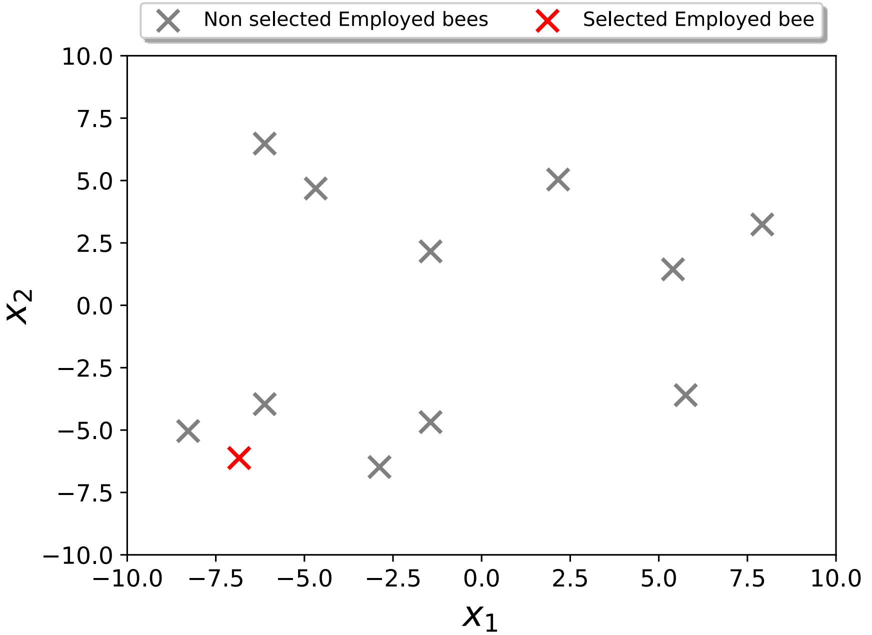


$$y = f(x_1, x_2)$$

[1] Karaboga, D., & Basturk, B. (2007). A pow erful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm. *Journal of global optimization*, *39*(3), 459-471.

DEFINITION

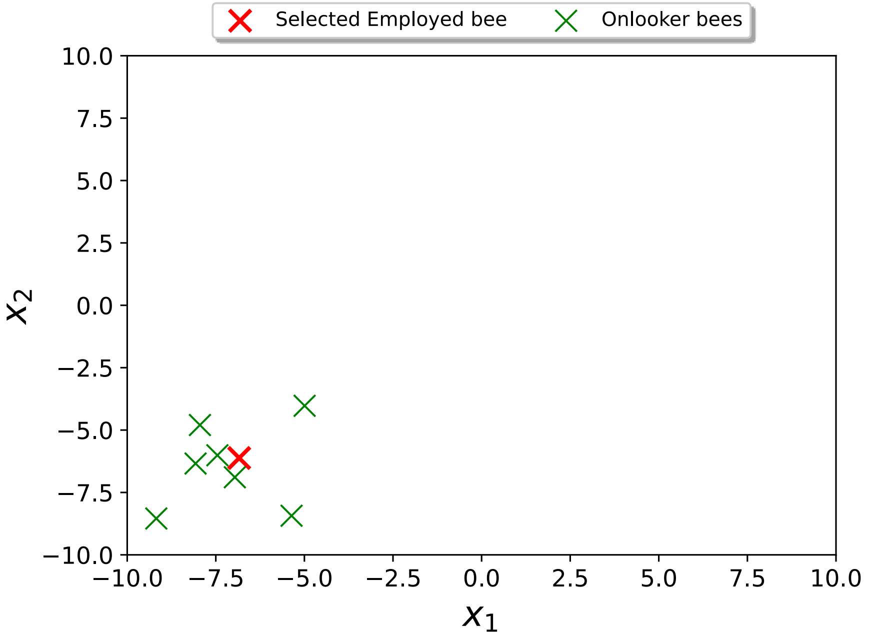
- Consists of 3 types of bees:
  - **Employed bees**
  - ✓ Perform a random search around the entire domain
  - Onlooker bees
  - ✓ Perform a search around the selected food source
  - Scout bees
  - ✓ Perform a random search similarly to the Employed bees



$$y = f(x_1, x_2)$$

DEFINITION

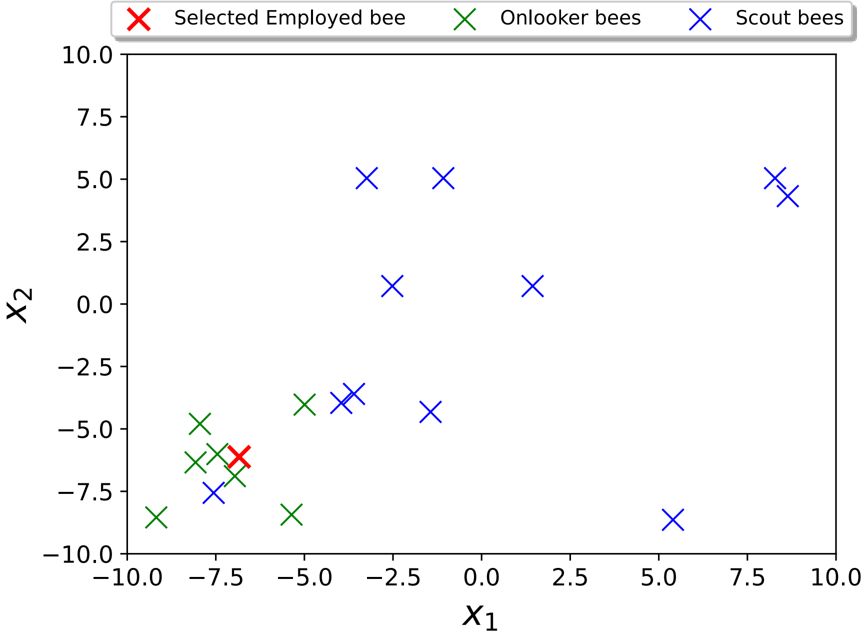
- Consists of 3 types of bees:
  - Employed bees
  - ✓ Perform a random search around the entire domain
  - Onlooker bees
  - ✓ Perform a search around the selected food source
  - Scout bees
  - ✓ Perform a random search similarly to the Employed bees



$$y = f(x_1, x_2)$$

DEFINITION

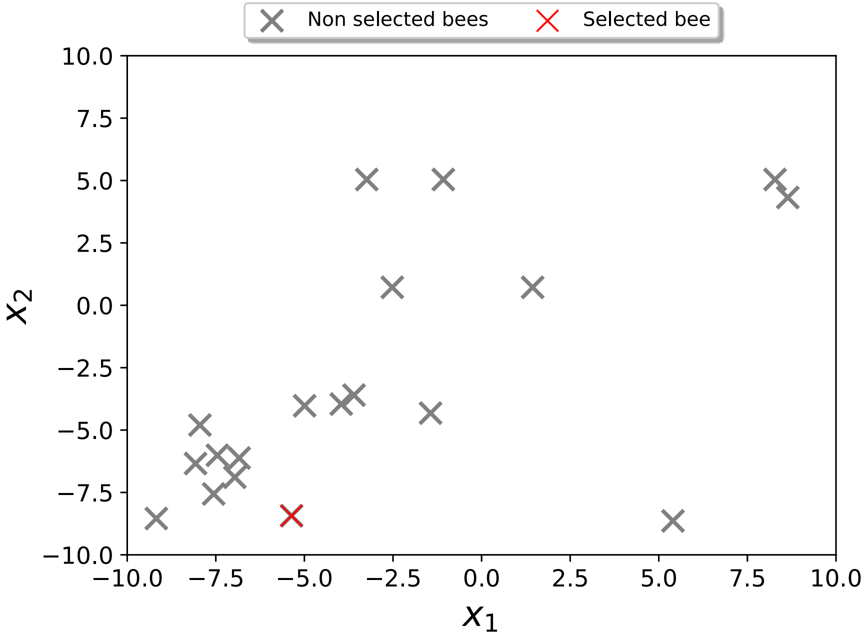
- Consists of 3 types of bees:
  - Employed bees
  - ✓ Perform a random search around the entire domain
  - Onlooker bees
  - ✓ Perform a search around the selected food source
  - **Scout bees**
  - ✓ Perform a random search similarly to the Employed bees



$$y = f(x_1, x_2)$$

DEFINITION

- Consists of 3 types of bees:
  - Employed bees
  - ✓ Perform a random search around the entire domain
  - Onlooker bees
  - ✓ Perform a search around the selected food source
  - **Scout bees**
  - ✓ Perform a random search similarly to the Employed bees

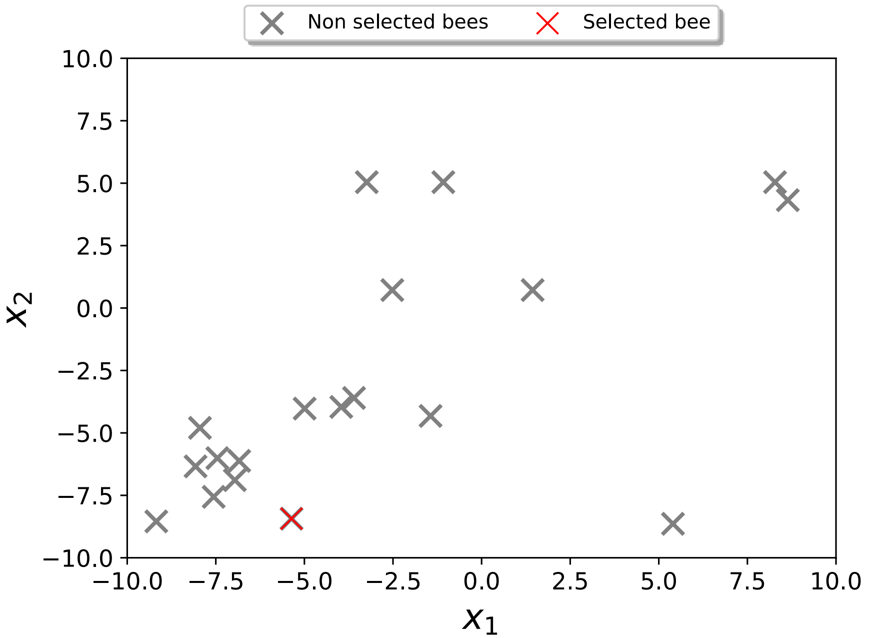


$$y = f(x_1, x_2)$$

DEFINITION

- Check the termination conditions

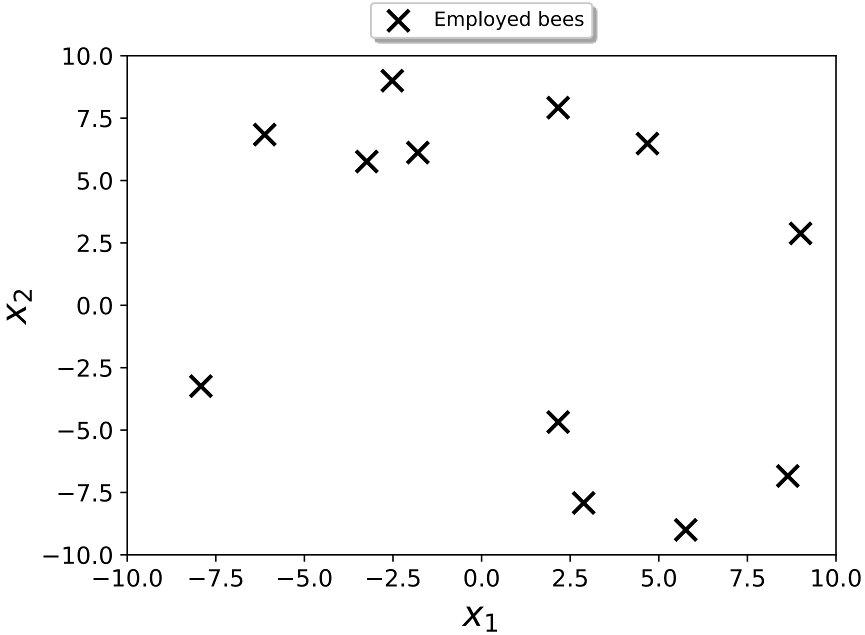
```
if Termination == True:
    Terminate the algorithm
else:
    Generate new Employed bees and
    repeat the algorithm
```



$$y = f(x_1, x_2)$$

PROPOSAL

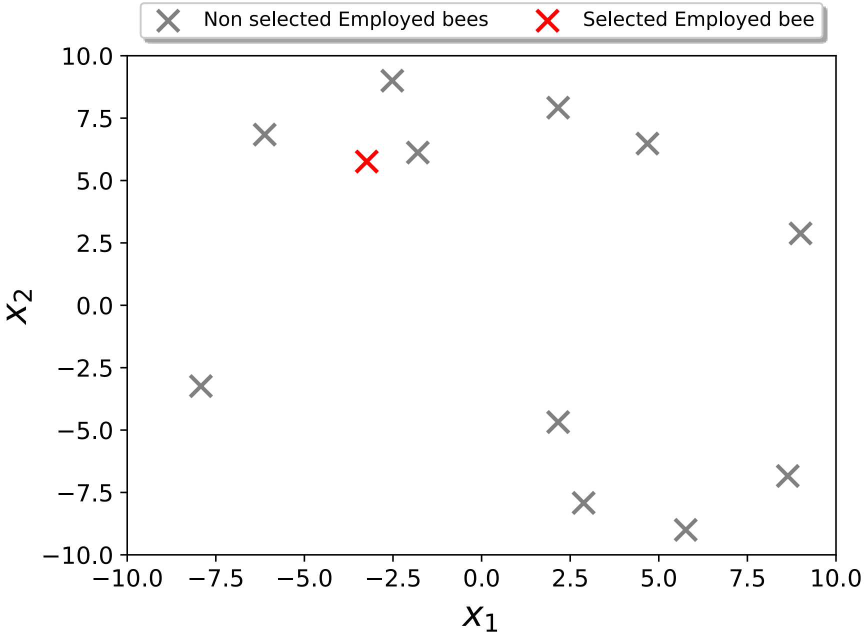
1. Define the Employed bees, and evaluate them



$$y = f(x_1, x_2)$$

PROPOSAL

1. Define the Employed bees, and evaluate them
2. Select the best Employed bee

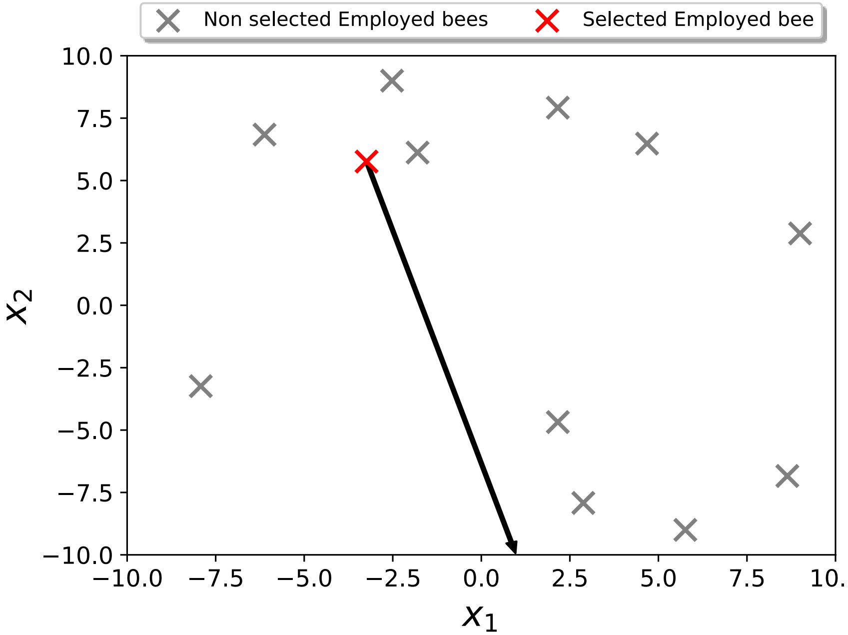


$$y = f(x_1, x_2)$$

PROPOSAL

1. Define the Employed bees, and evaluate them
2. Select the best Employed bee
3. Calculate the gradient of the selected Employed bee

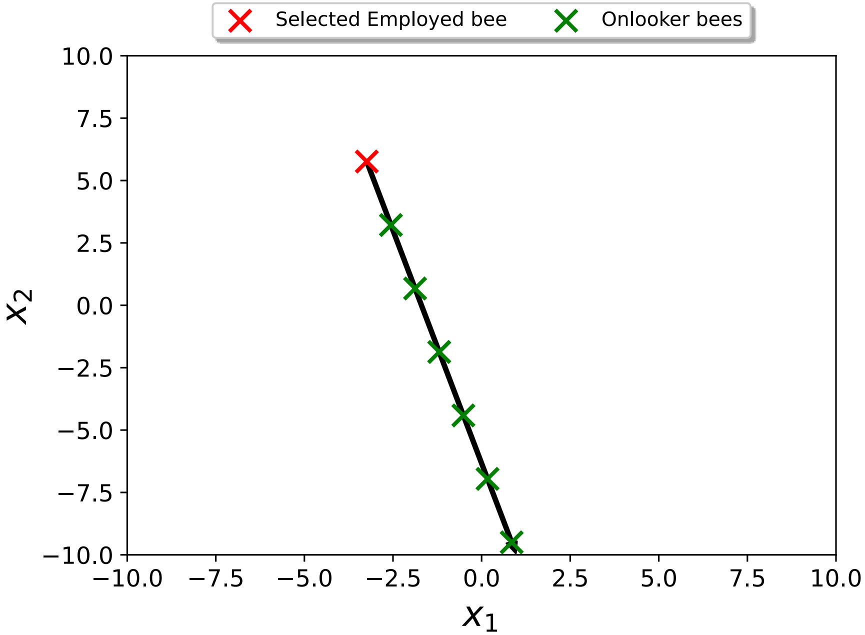
$$-\nabla f$$



$$y = f(x_1, x_2)$$

PROPOSAL

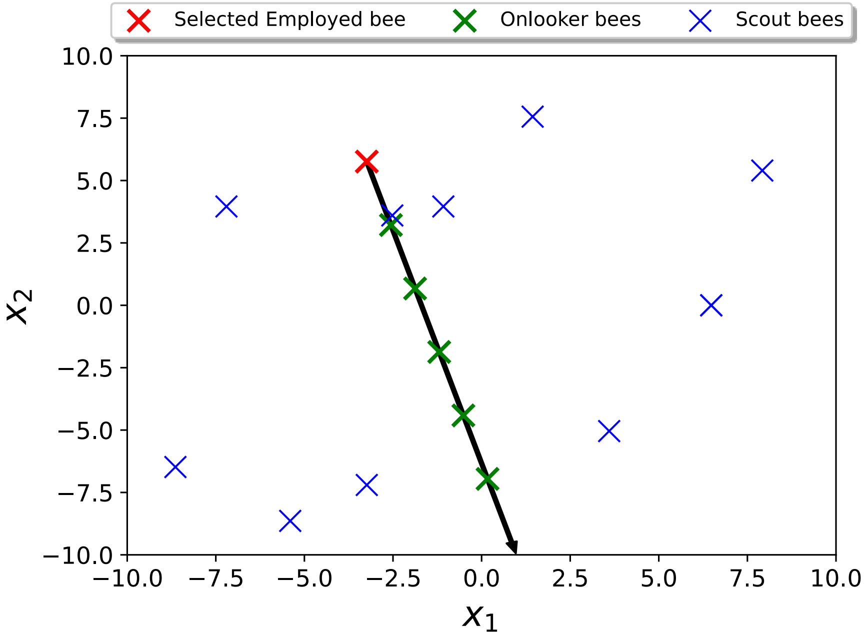
1. Define the Employed bees, and evaluate them
2. Select the best Employed bee
3. Calculate the gradient of the selected Employed bee
4. Define the Onlooker bees along the descent direction



$$y = f(x_1, x_2)$$

PROPOSAL

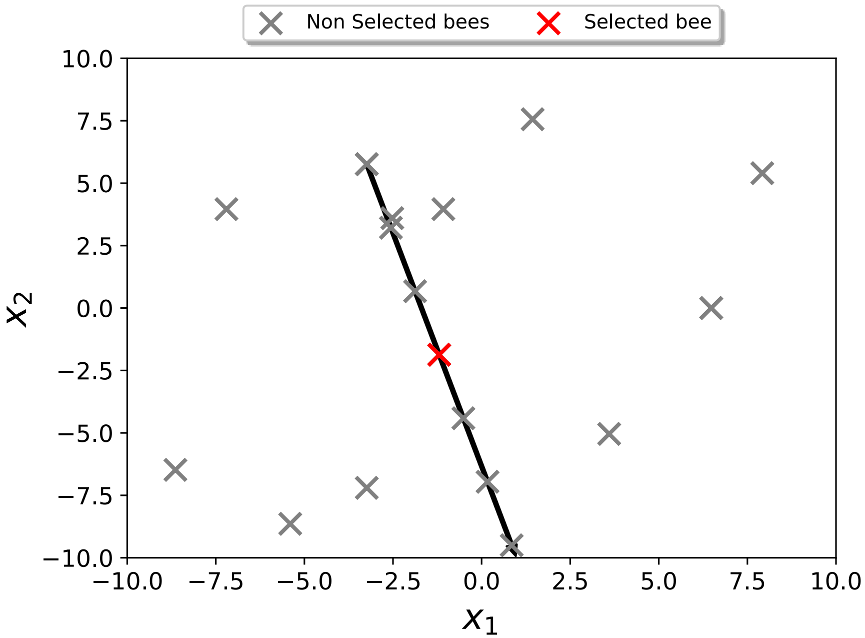
1. Define the Employed bees, and evaluate them
2. Select the best Employed bee
3. Calculate the gradient of the selected Employed bee
4. Define the Onlooker bees along the descent direction
5. Define the Scout bees, and evaluate all the bees



$$y = f(x_1, x_2)$$

PROPOSAL

1. Define the Employed bees, and evaluate them
2. Select the best Employed bee
3. Calculate the gradient of the selected Employed bee
4. Define the Onlooker bees along the descent direction
5. Define the Onlooker bees, and evaluate all the bees
6. Select the best bee

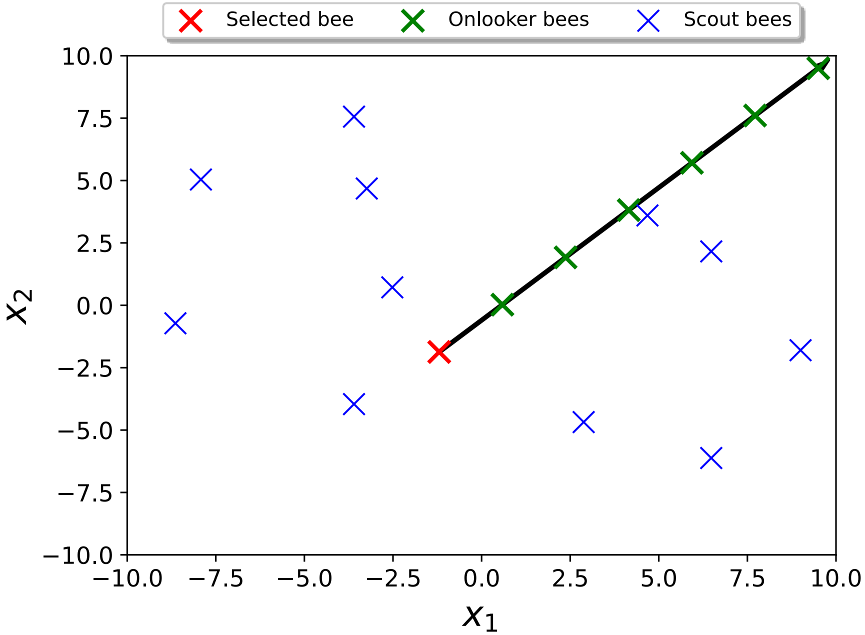


$$y = f(x_1, x_2)$$

PROPOSAL

1. Define the Employed bees, and evaluate them
2. Select the best Employed bee
3. Calculate the gradient of the selected Employed bee
4. Define the Onlooker bees along the descent direction
5. Define the Onlooker bees, and evaluate all the bees
6. Select the best bee

```
if Termination == True:
    Terminate the algorithm
else:
    Generate new Onlooker bees, new
    Scout bees, and repeat
```



$$y = f(x_1, x_2)$$

PROPOSAL

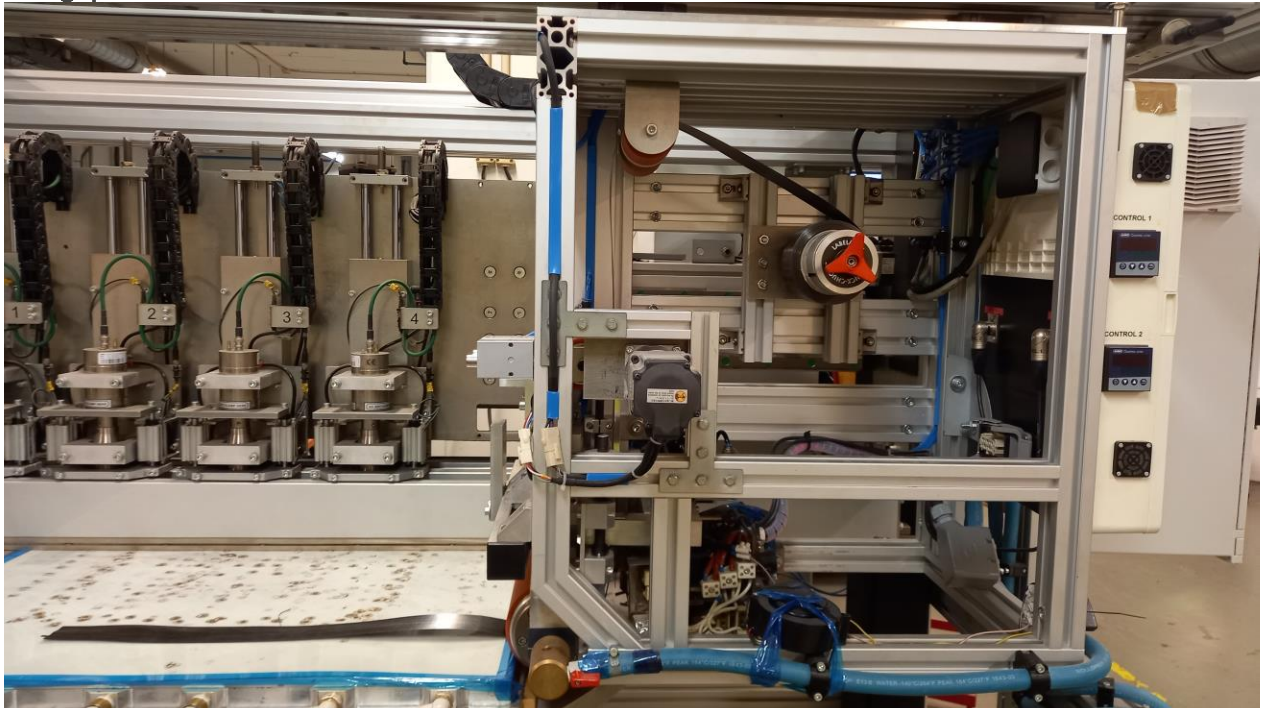
Summing up

1. Start the Employed Bee search
2. Calculate the Employed bee fitness
3. Perform a Greedy selection
4. Calculate the gradient
5. Generate the Onlooker bees
6. Generate Scout bees
7. Calculate the onlooker and scout fitness
8. Perform a greedy selection
9. Check the convergence condition
    1. If the condition is met, stop
    2. Otherwise, repeat from step 3

MOTIVATION

Automated Tape Laying Process

- Temperature control for a composite material manufacturing process



MOTIVATION

Constraints handling

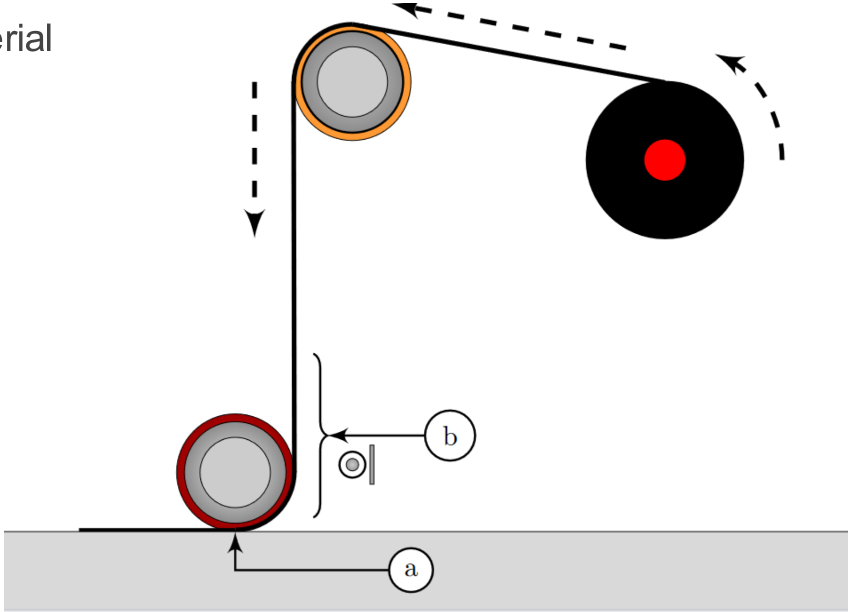
- Temperature control for a composite material manufacturing process
- Constraints:
  1. Nip Point Temperature

     $T_{np} = 200\,°C$

  2. Maximum allowable temperature

     $T_{max} = 280\,°C$

     Moving away from a value



a) Nip Point
b) Heating zone

MOTIVATION

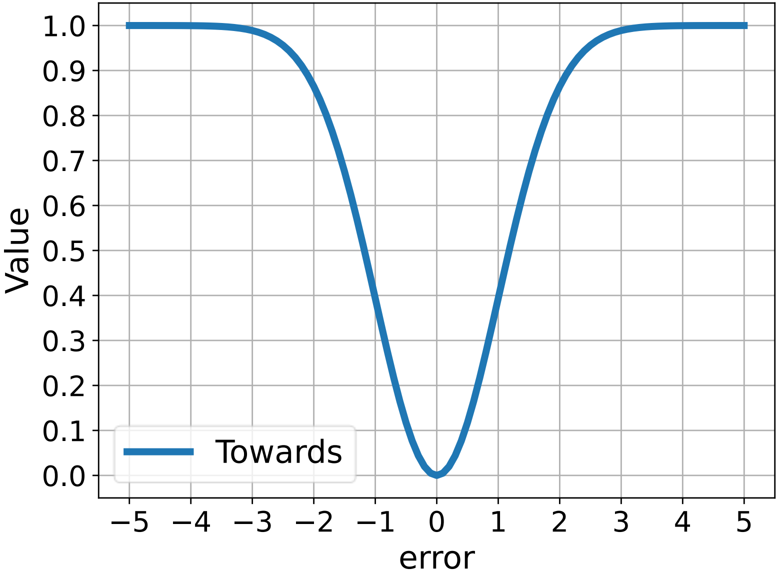
Constraints handling

- Temperature control for a composite material manufacturing process
- Constraints:
  1. Nip Point Temperature
     $T_{np} = 200\,°C$
  2. Maximum allowable temperature
     $T_{max} = 280\,°C$

Moving away from a value

$$e_{np} = T_{np} - T_{np}^{*}$$

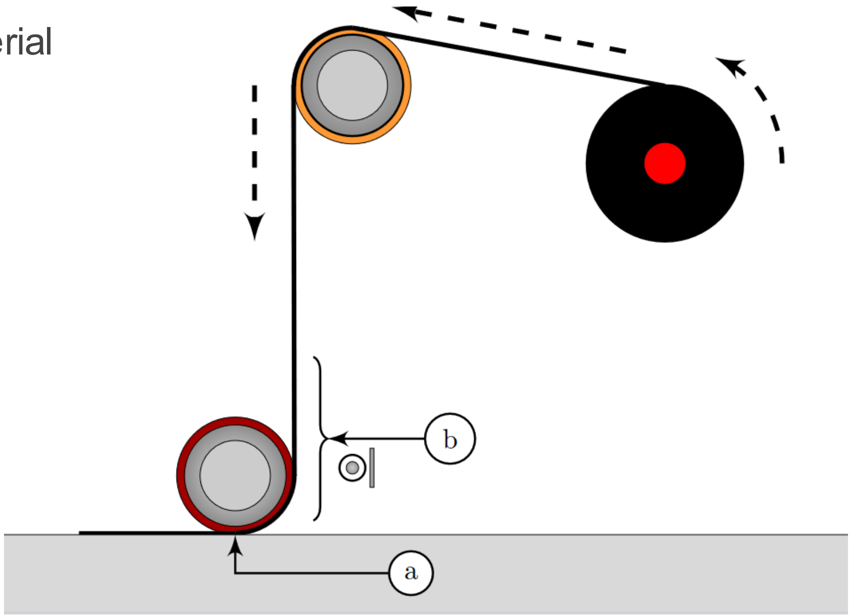
$$g(e_{np}) = 1 - e^{\frac{-e_{np}^{2}}{2\cdot\sigma}}$$



MOTIVATION

Constraints handling

- Temperature control for a composite material manufacturing process
- Constraints:
    1. Nip Point Temperature
       $T_{np} = 200\,°C$
       Moving towards a value
    2. Maximum allowable temperature
       $T_{max} = 280\,°C$



a) Nip Point
b) Heating zone

MOTIVATION

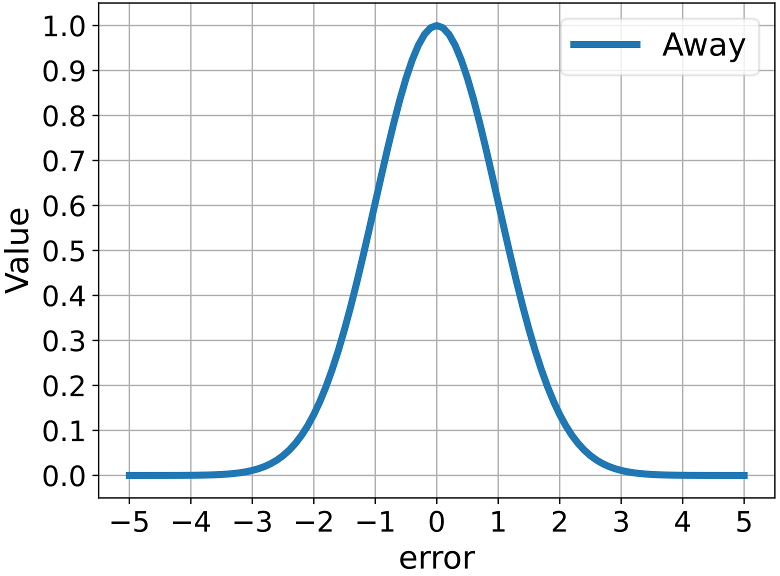
Constraints handling

- Temperature control for a composite material manufacturing process
- Constraints:
  1. Nip Point Temperature
     $T_{np} = 200\,°C$
     Moving towards a value

  2. Maximum allowable temperature
     $T_{max} = 280\,°C$

$$e_{max} = T_{max} - T^{*}_{max}$$

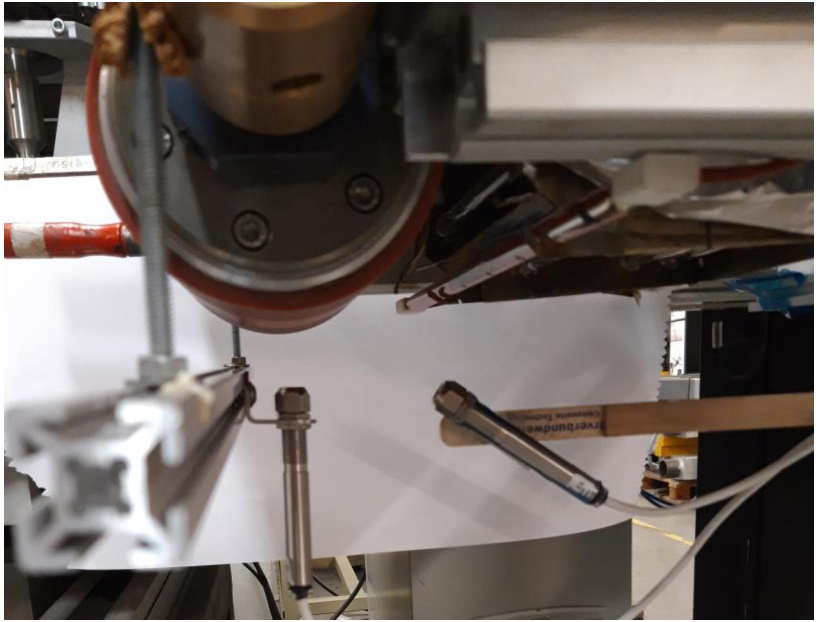
$$g(e_{max}) = e^{\frac{-e_{np}^{2}}{2\cdot\sigma}}$$

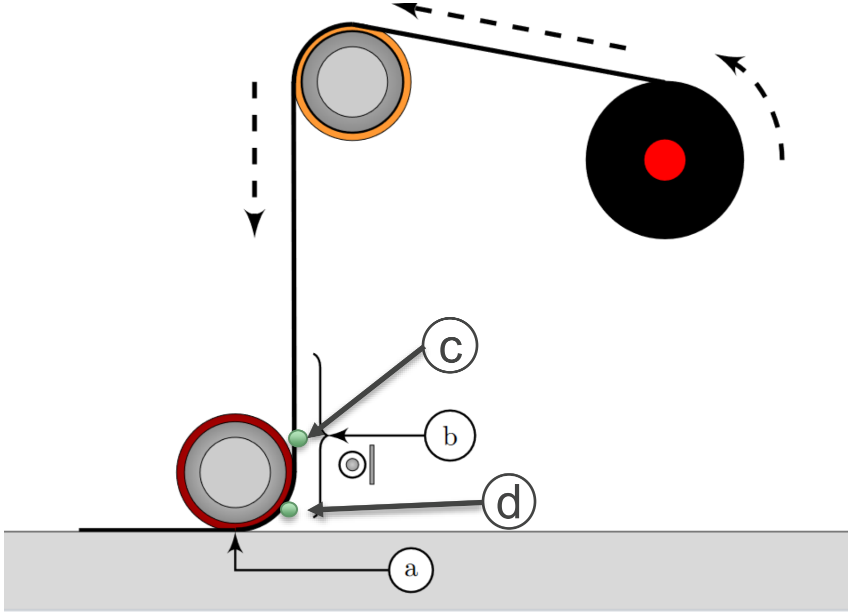


MOTIVATION

First results

- Sensor 1: Pyrometer. Original machine equipment.
- Sensor 2: Pyrometer. For validation.





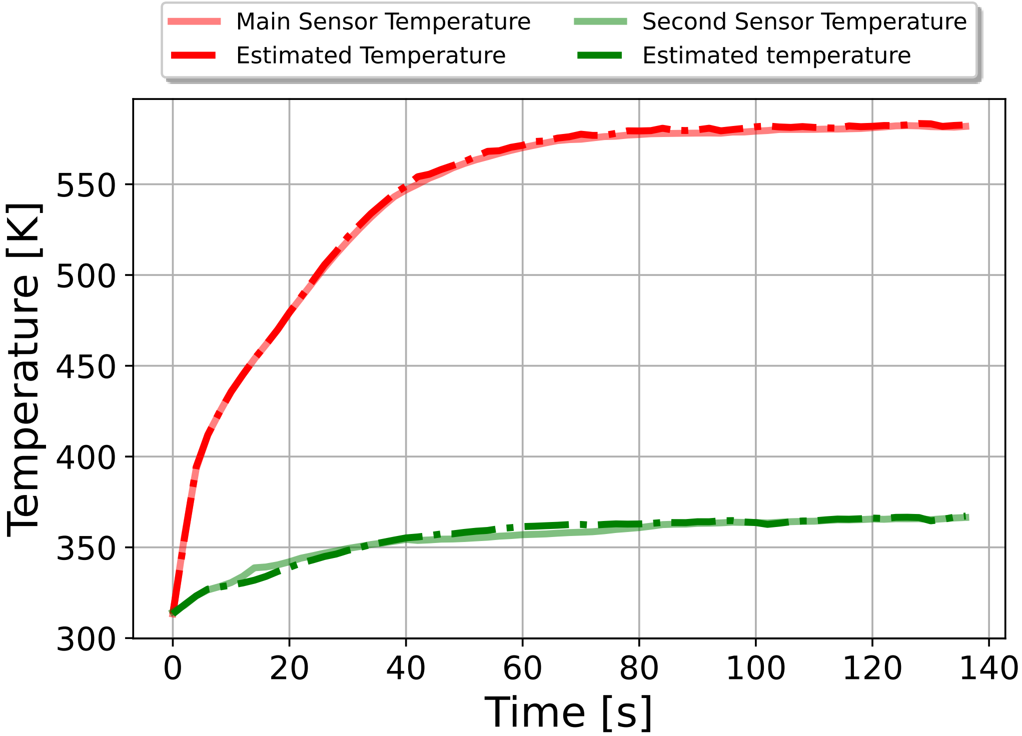
a) Heating zone
b) Nip Point
c) Sensor 1
d) Sensor 2

MOTIVATION

First results

- Real data
  - Inputs
  - Outputs

- Process model:
  - Finite differences



Summing up

- As the bees are independent of each other, the algorithm can be parallelized, saving computational time.
    - Multiprocessing/Multithreading

- The proposed artificial bee colony algorithm is suitable for a state estimation process.

- The proposed algorithm is a first step to implement Model Predictive Control, for a composite material manufacturing process.

CONVERTING KNOWLEDGE INTO VALUE FOR OVER 35 YEARS

Since 1986

Thanks for your attention

jsrodrigues@inegi.up.pt

INSTITUTE OF SCIENCE AND INNOVATION IN MECHANICAL AND INDUSTRIAL ENGINEERING

www.inegi.pt

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 101006860