Bat algorithm

developed by Xin-shein 2010.

Outline

1- Bat Behaviour

Some bats have evolved a highly sophisticated sense of hearing

2- Bat Algorithm

Hello!

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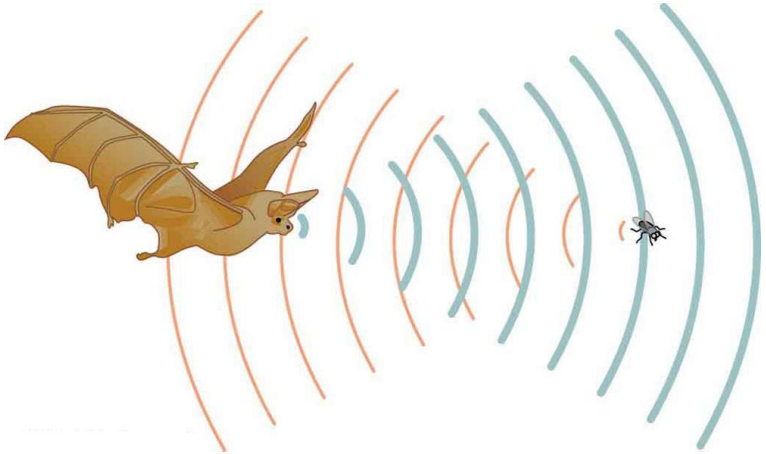
This bat algorithm is based on the echolocation behaviour of micro bats with varying pulse rates of emission and loudness

1.

Bat Behaviour

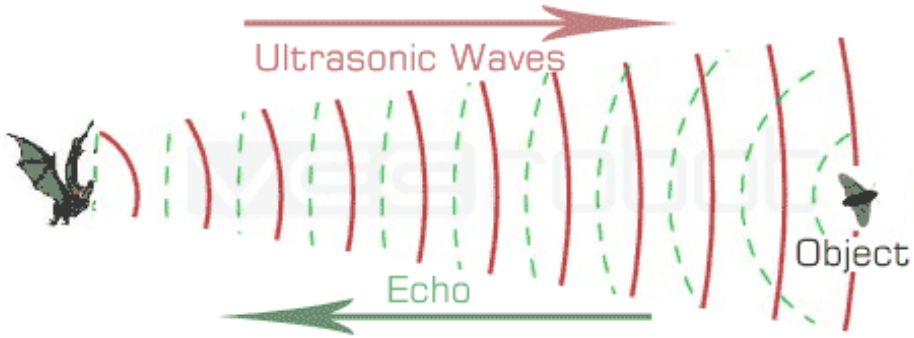
Bat Behaviour

- **Echolocation:** Some bats have evolved a highly sophisticated sense of hearing.



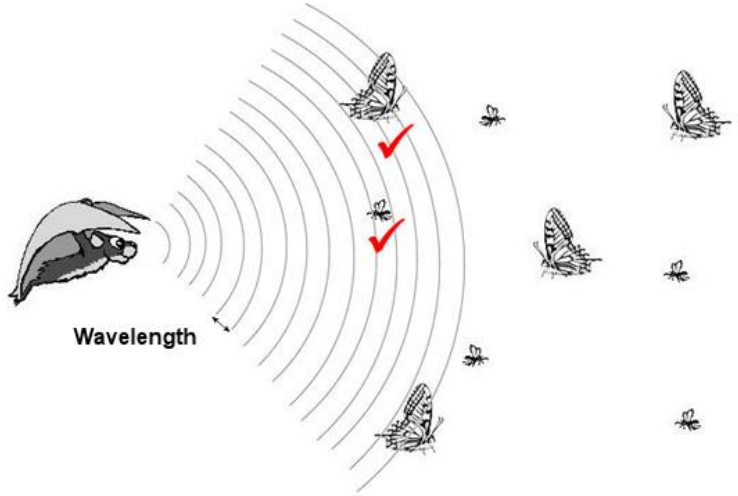
Bat Behaviour

- They emit sounds that bounce off of objects in their path, sending echoes back to the bats.

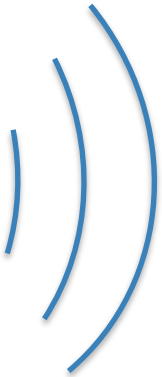


Bat Behaviour

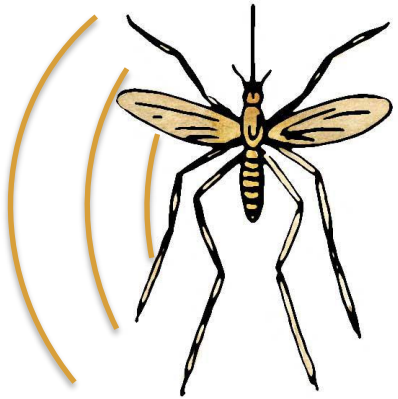
- From these echoes, the bats can determine the size of objects, distance , how fast they are travelling.



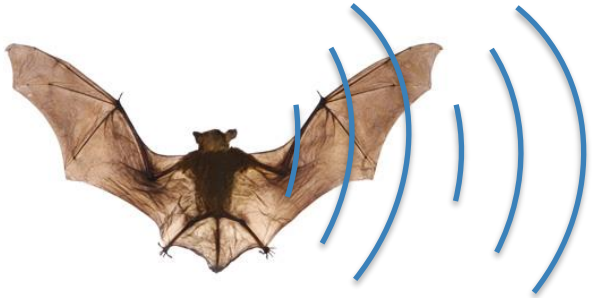
Bat Behaviour

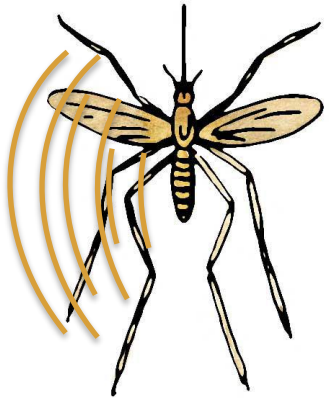


Bat Behaviour



Bat Behaviour





2.
Bat Algorithm

Bat Algorithm - Rules

1.
All bats use echolocation to sense distance, and they also `know' the **difference between food/prey and background barriers**.

Bat Algorithm - Rules

2.

Bats fly randomly with

- **velocity “vi”**
- at **position** “Xi”
- with a fixed **frequency** “f” min ,
- varying **wavelength** λ
- and **loudness** A0 to search for prey.

They can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission “r” in the range of [0, 1], depending on the proximity of their target.

velocity “vi”

wavelength λ

position “Xi”

loudness A0

frequency “f”

Bat Algorithm - Rules

3.

Although the loudness can vary in many ways, we assume that the loudness varies from a large (positive) “A0” to a minimum constant value “A min” .

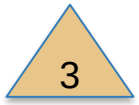
Applications

- engineering design
- classifications of gene expression data
- Protein Secondary Structure Prediction
- A fuzzy bat clustering method has been developed to solve ergonomic workplace problems

f = **2**
x = 4
v = 3
A = **1**
r = **0**

f = **6**
x = 8
v = 7
A = **0,3**
r = **0.5**

Goal



f = **3**
x = 5
v = 4
A = **0,6**
r = **0.3**

Equation used

▷1 $$f_i = f_{\min} + (f_{\max} - f_{\min})\beta,$$

▷2 $$\boldsymbol{v}_i^t = \boldsymbol{v}_i^{t-1} + (\boldsymbol{x}_i^{t-1} - \boldsymbol{x}_*) f_i,$$

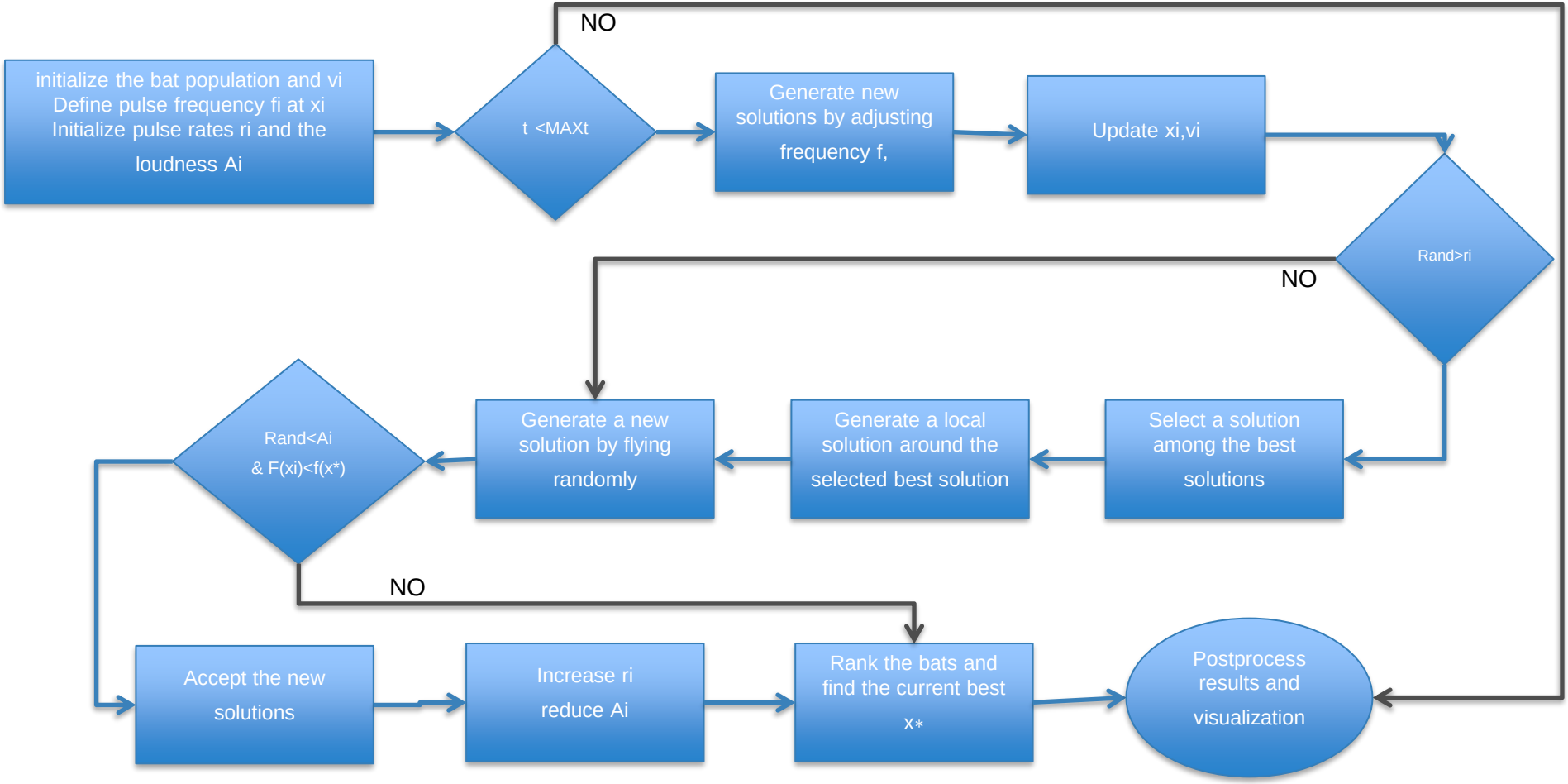
▷3 $$\boldsymbol{x}_i^t = \boldsymbol{x}_i^{t-1} + \boldsymbol{v}_i^t,$$

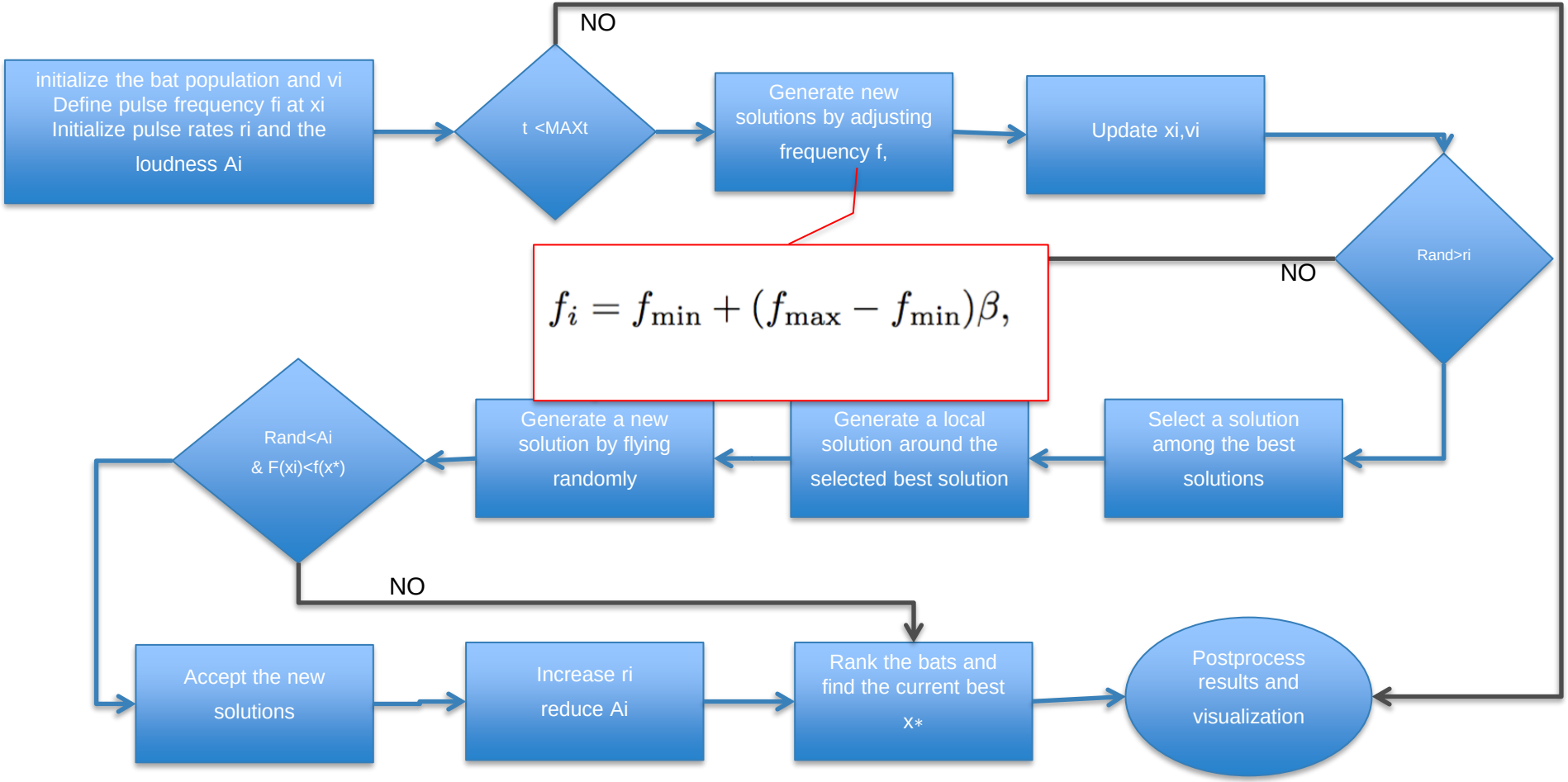
▷4 $$A_i^{t+1} = \alpha A_i^t, \quad r_i^{t+1} = r_i^0[1 - \exp(-\gamma t)],$$

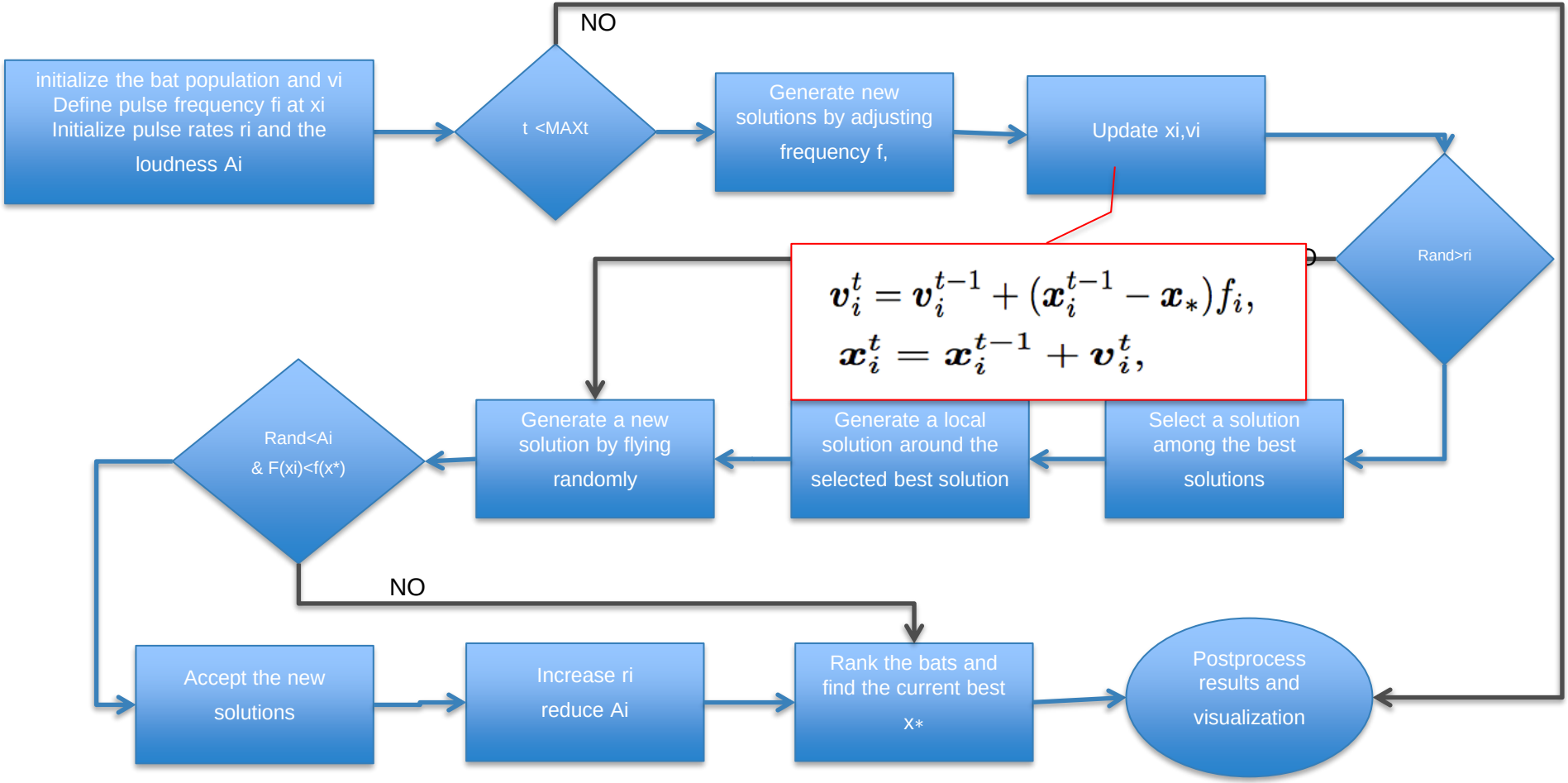
▷5 $$A_i^t \to 0, \quad r_i^t \to r_i^0, \quad \text{as } t \to \infty.$$

pseudo code

```
Objective function f (x), x = (x1, ...,xd)T
Initialize the bat population xi (i = 1,2, ...,n) and vi
Define pulse frequency fi  at xi
Initialize pulse rates ri and the loudness Ai
while(t <Max number of iterations)
Generate new solutions by adjusting frequency, and updating velocities and locations/solutions
    if ( rand > ri )
    Select a solution among the best solutions
    Generate a local solution around the selected best solution
    end if
    Generate a new solution by flying randomly
    if(rand <Ai  & f (xi) < f (x*))
    Accept the new solutions
    Increase ri and reduce Ai
    end if
Rank the bats and find the current best x*
end while
Postprocess results and visualization
```


initialize the bat population and vi
Define pulse frequency fi at xi
Initialize pulse rates ri and the
loudness Ai
t <MAXt
NO
Generate new
solutions by adjusting
frequency f,
Update xi,vi
Rand>ri
NO
Select a solution
among the best
solutions
Generate a local
solution around the
selected best solution
Generate a new
solution by flying
randomly
Rand<Ai
& F(xi)<f(x*)
NO
Accept the new
solutions
Increase ri
reduce Ai
Rank the bats and
find the current best
x*
Postprocess
results and
visualization


initialize the bat population and vi
Define pulse frequency fi at xi
Initialize pulse rates ri and the
loudness Ai
t <MAXt
NO
Generate new solutions by adjusting frequency f,
Update xi,vi
Rand>ri
NO
$f_i = f_{\min} + (f_{\max} - f_{\min})\beta,$
Select a solution among the best solutions
Generate a local solution around the selected best solution
Generate a new solution by flying randomly
Rand<Ai
& F(xi)<f(x*)
NO
Accept the new solutions
Increase ri
reduce Ai
Rank the bats and find the current best
x*
Postprocess results and
visualization


initialize the bat population and vi
Define pulse frequency fi at xi
Initialize pulse rates ri and the
loudness Ai
t <MAXt
NO
Generate new
solutions by adjusting
frequency f,
Update xi,vi
Rand>ri
$v_i^t = v_i^{t-1} + (x_i^{t-1} - x_*) f_i,$
$x_i^t = x_i^{t-1} + v_i^t,$
Select a solution
among the best
solutions
Generate a local
solution around the
selected best solution
Generate a new
solution by flying
randomly
Rand<Ai
& F(xi)<f(x*)
NO
Accept the new
solutions
Increase ri
reduce Ai
Rank the bats and
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Postprocess
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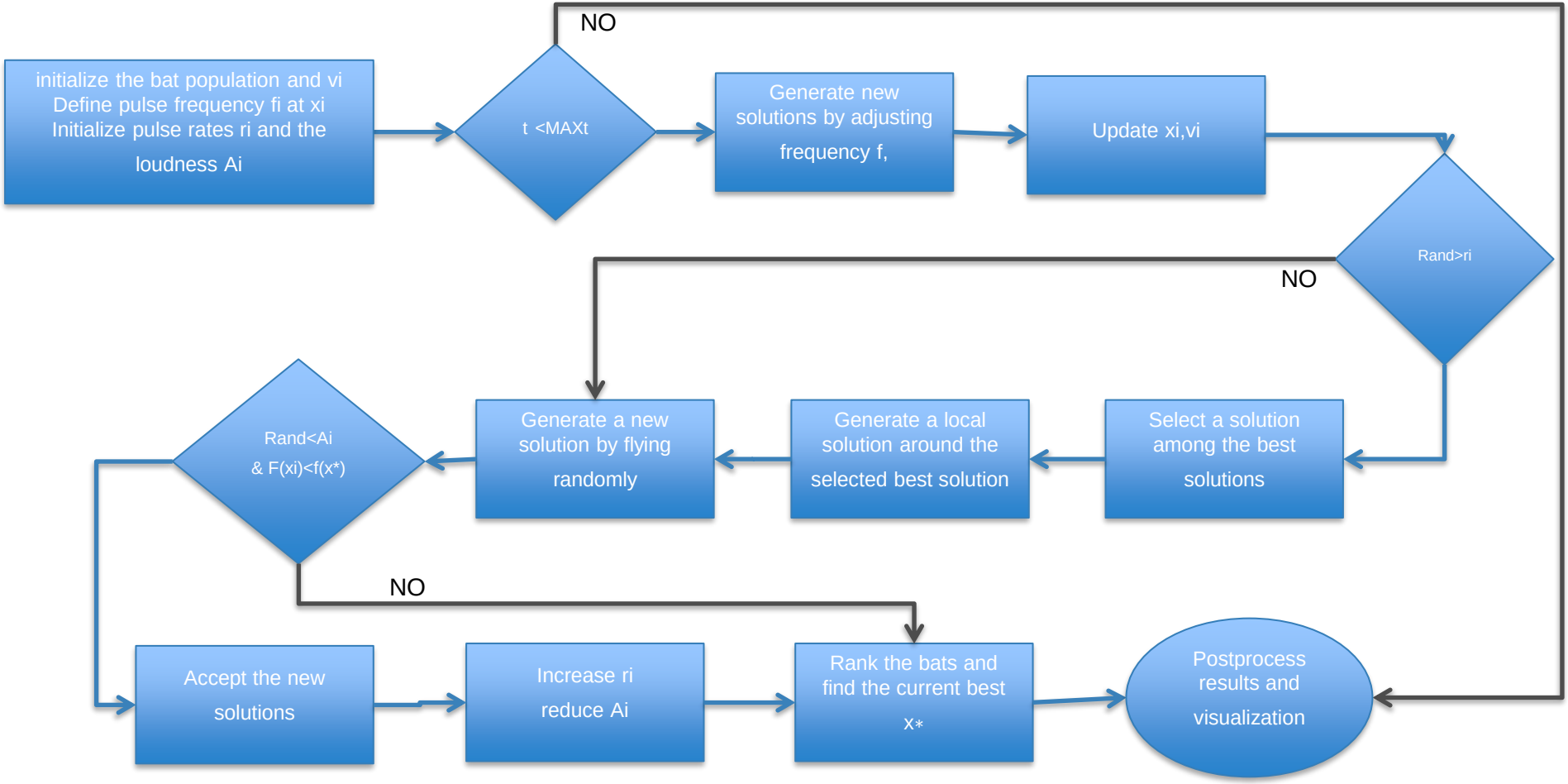
initialize the bat population and vi
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t <MAXt
NO
Generate new
solutions by adjusting
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Update xi,vi
Rand>ri
NO
Select a solution
among the best
solutions
Generate a local
solution around the
selected best solution
Generate a new
solution by flying
randomly
Rand<Ai
& F(xi)<f(x*)
NO
Accept the new
solutions
Increase ri
reduce Ai
Rank the bats and
find the current best
x*
Postprocess
results and
visualization

example

Assume that

- F min=0
- F max =10

Initialize

t=1

t=2

t=3

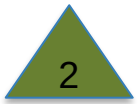
f =
x =
v =
A =
r =

f =
x =
v =
A =
r =

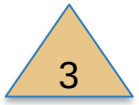
f =
x =
v =
A =
r =

Initialize (random) t=1 t=2 t=3

f = **2**
x =
v =
A = **1**
r = **0**



f = **6**
x =
v =
A = **0,8**
r = **0.2**



f = **3**
x =
v =
A = **0,9**
r = **0.1**

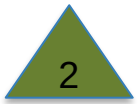
Initialize (random)

t=1

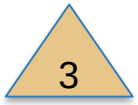
t=2

t=3

f = **2**
x = 4
v = 3
A = **1**
r = **0**



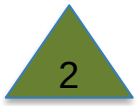
f = **6**
x = 8
v = 7
A = **0,8**
r = **0.2**



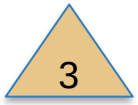
f = **3**
x = 5
v = 4
A = **0,9**
r = **0.1**

Initialize (random) t=1 t=2 t=3

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
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v = 4
A = 0,9
r = 0.1

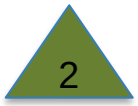
f = **7**
x =
v =
A = 1
r = 0

f = **3**
x =
v =
A = 0.8
r = 0.2

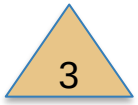
f = **4**
x =
v =
A = 0.9
r = 0.1

Initialize (random) t=1 t=2 t=3

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

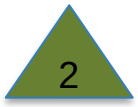
f = **7**
x = **35**
v = **31**
A = 1
r = 0

f = **3**
x =
v =
A = 0.8
r = 0.2

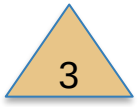
f = **4**
x =
v =
A = 0.9
r = 0.1

Initialize (random) t=1 t=2 t=3

f = 2
x = 4
v = 3
A = 1
r = 0



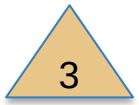
f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

f = **7**
x = **35**
v = **31**
A = 1
r = 0

f = **3**
x =
v =
A = 0.8
r = 0.2



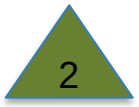
f = **4**
x =
v =
A = 0.9
r = 0.1

$$\boldsymbol{v}_i^t = \boldsymbol{v}_i^{t-1} + (\boldsymbol{x}_i^{t-1} - \boldsymbol{x}_*) f_i,$$

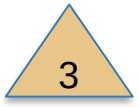
= 3 + (4-0) * 7 = 31

Initialize (random) t=1 t=2 t=3

f = 2
x = 4
v = 3
A = 1
r = 0



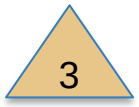
f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

f = **7**
x = **35**
v = **31**
A = 1
r = 0

f = **3**
x =
v =
A = 0.8
r = 0.2



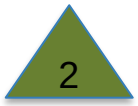
f = **4**
x =
v =
A = 0.9
r = 0.1

$$x_i^t = x_i^{t-1} + v_i^t,$$

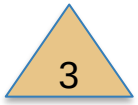
= 4 + 31 = 35

Initialize (random) t=1 t=2 t=3

f = 2
x = 4
v = 3
A = 1
r = 0



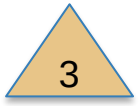
f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

f = **7**
x = **35**
v = **31**
A = 1
r = 0

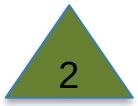
f = **3**
x = **39**
v = **31**
A = 0.8
r = 0.2



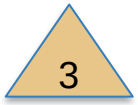
f = **4**
x = **29**
v = **24**
A = 0.9
r = 0.1

Initialize (random) t=1 t=2 t=3

f = 2
x = 4
v = 3
A = 1
r = 0



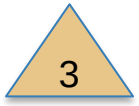
f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

f = **7**
x = **35**
v = **31**
A = 1
r = 0

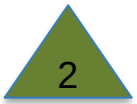
f = **3**
x = **39**
v = **31**
A = 0.8
r = 0.2



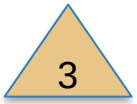
f = **4**
x = **29**
v = **24**
A = 0.9
r = 0.1

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2

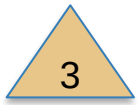


f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

f = 7
x = 35
v = 31
A = 1
r = 0

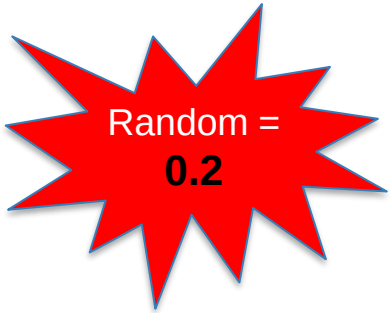
f = 3
x = 39
v = 31
A = 0.8
r = 0.2

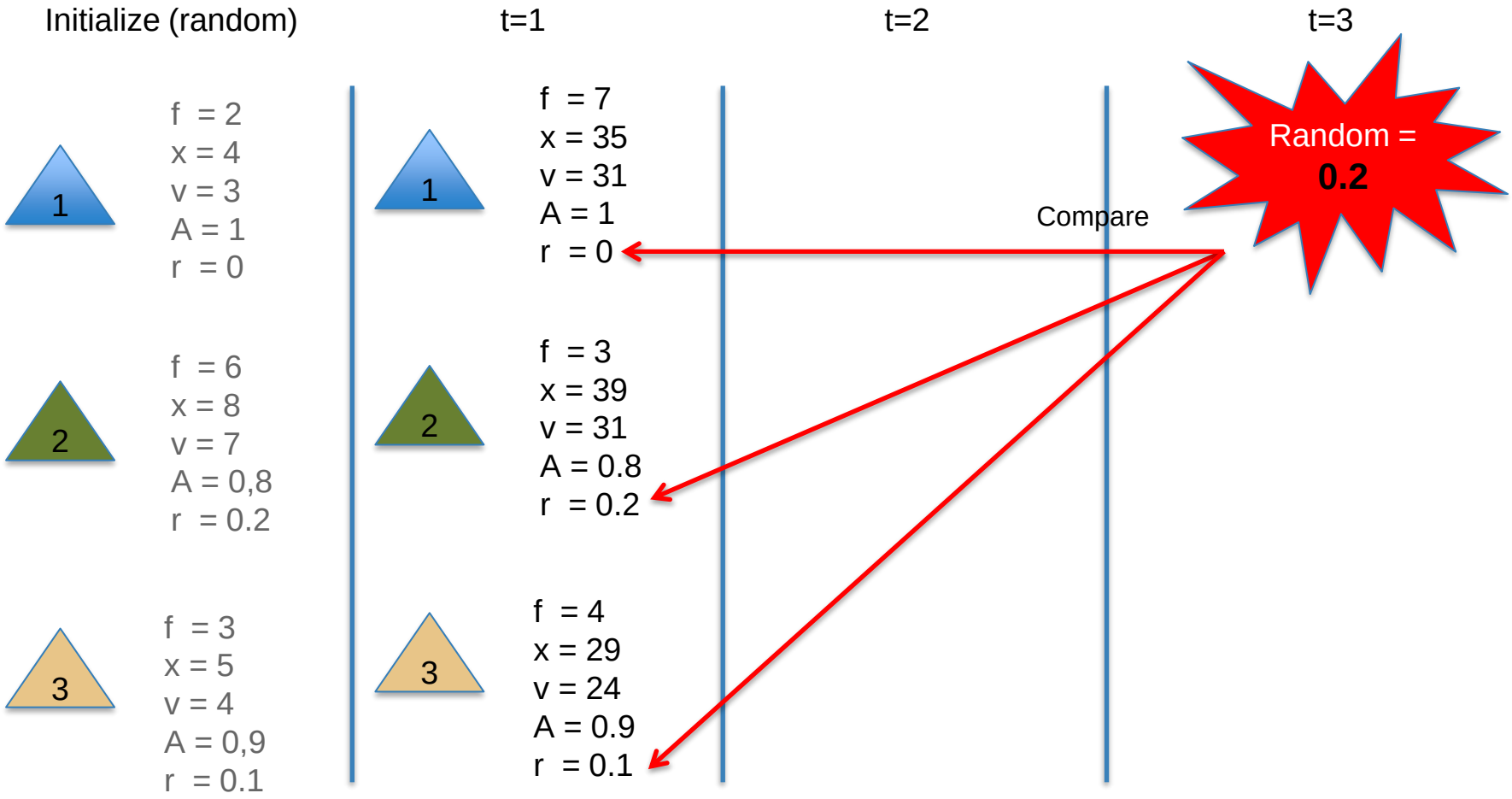


f = 4
x = 29
v = 24
A = 0.9
r = 0.1

t=2

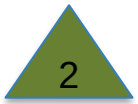
t=3



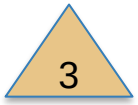

Initialize (random)
t=1
t=2
t=3
1
f = 2
x = 4
v = 3
A = 1
r = 0
2
f = 6
x = 8
v = 7
A = 0,8
r = 0.2
3
f = 3
x = 5
v = 4
A = 0,9
r = 0.1
1
f = 7
x = 35
v = 31
A = 1
r = 0
2
f = 3
x = 39
v = 31
A = 0.8
r = 0.2
3
f = 4
x = 29
v = 24
A = 0.9
r = 0.1
Compare
Random =
0.2

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2

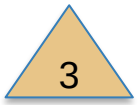


f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

f = 7
x = 35
v = 31
A = 1
r = 0

f = 3
x = 39
v = 31
A = 0.8
r = 0.2

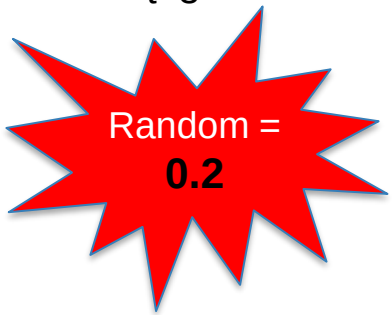


f = 4
x = 29
v = 24
A = 0.9
r = 0.1

t=2

f = 7
x =
v = 31
A = 1
r = 0

t=3



Initialize (random)

t=1

t=2

t=3

1

f = 2
x = 4
v = 3
A = 1
r = 0

2

f = 6
x = 8
v = 7
A = 0,8
r = 0.2

3

f = 3
x = 5
v = 4
A = 0,9
r = 0.1

1

f = 7
x = 35
v = 31
A = 1
r = 0

2

f = 3
x = 39
v = 31
A = 0.8
r = 0.2

3

f = 4
x = 29
v = 24
A = 0.9
r = 0.1

4

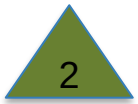
f = 7
x = **36**
v = 31
A = 1
r = 0

Random = **0.2**

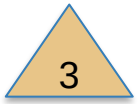
$$\mathbf{x}_{\text{new}} = \mathbf{x}_{\text{old}} + \epsilon A^t,$$

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2

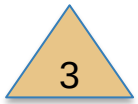


f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

f = 7
x = 35
v = 31
A = 1
r = 0

f = 3
x = 39
v = 31
A = 0.8
r = 0.2

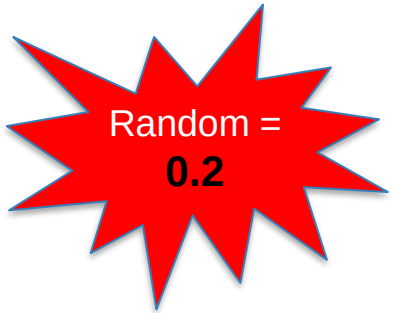


f = 4
x = 29
v = 24
A = 0.9
r = 0.1

t=2

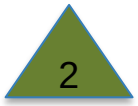
f = 7
x = **36**
v = 31
A = 1
r = 0

t=3



Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



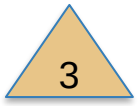
f = 6
x = 8
v = 7
A = 0,8
r = 0.2

f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

f = 7
x = 35
v = 31
A = 1
r = 0

f = 3
x = 39
v = 31
A = 0.8
r = 0.2

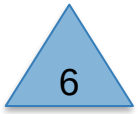


f = 4
x = 29
v = 24
A = 0.9
r = 0.1

t=2

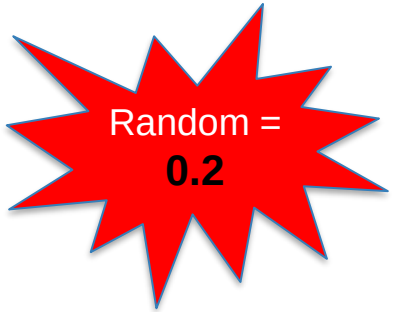
f = 7
x = **36**
v = 31
A = 1
r = 0

Random Solution



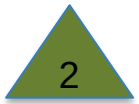
f = 5
x = **7**
v = 6
A = .7
r = .2

t=3

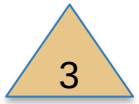


Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2

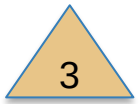


f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

f = 7
x = 35
v = 31
A = 1
r = 0
F(x)=0.2

f = 3
x = 39
v = 31
A = 0.8
r = 0.3
F(x)=0.3

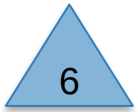


f = 4
x = 29
v = 24
A = 0.9
r = 0.3
F(x)=0.4

t=2

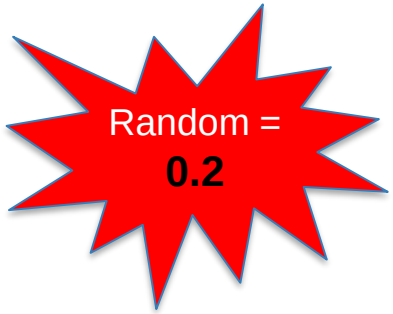
f = 7
x = 36
v = 31
A = 1
r = 0.4
F(x)=0.2

Random Solution



f = 5
x = 7
v = 6
A = .7
r = .2
F(x)=0.6

t=3



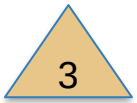
Assume f(x*)= 4

Acceptance criteria:
Rand< Ai & F(xi) < f(x*)

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0

f = 6
x = 8
v = 7
A = 0,8
r = 0.2

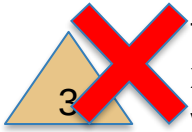


f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

f = 7
x = 35
v = 31
A = 1
r = 0
F(x)=0.2

f = 3
x = 39
v = 31
A = 0.8
r = 0.3
F(x)=0.3

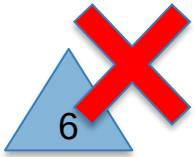


f = 4
x = 29
v = 24
A = 0.1
r = 0.3
F(x)=0.4

t=2

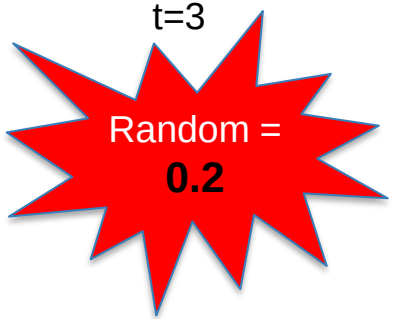
f = 7
x = 36
v = 31
A = 1
r = 0.4
F(x)=0.2

Random Solution



f = 5
x = 7
v = 6
A = .7
r = .2
F(x)=0.6

t=3

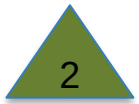


Assume f(x*)= 4

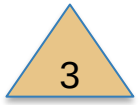
Acceptance criteria:
Rand< Ai & F(xi) < f(x*)

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

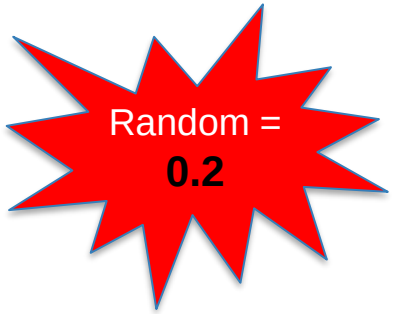
f = 7
x = 35
v = 31
A = 1
r = 0
F(x)=0.2

f = 3
x = 39
v = 31
A = 0.8
r = 0.3
F(x)=0.3

t=2

f = 7
x = 36
v = 31
A = 1
r = 0.4
F(x)=0.2

t=3

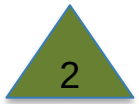


Assume f(x*)= 4

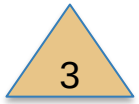
Acceptance criteria:
Rand< Ai & F(xi) < f(x*)

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

t=1

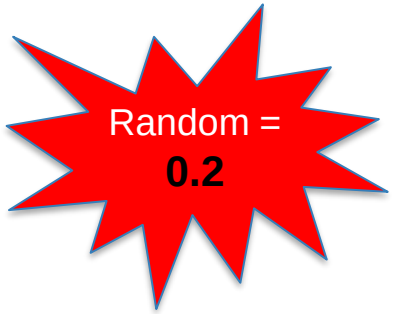
f = 7
x = 35
v = 31
A = 0.9
r = 0.1
F(x)=0.2

f = 3
x = 39
v = 31
A = 0.7
r = 0.4
F(x)=0.3

t=2

f = 7
x = 36
v = 31
A = 0.9
r = 0.5
F(x)=0.2

t=3

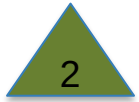


Assume f(x*)= 4

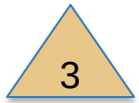
Acceptance criteria:
Rand< Ai & F(xi) < f(x*)

Initialize (random)

f = 2
x = 4
v = 3
A = 1
r = 0



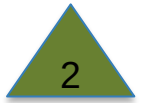
f = 6
x = 8
v = 7
A = 0,8
r = 0.2



f = 3
x = 5
v = 4
A = 0,9
r = 0.1

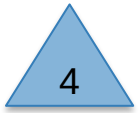
t=1

f = 7
x = 35
v = 31
A = 0.9
r = 0.1
F(x)=0.2



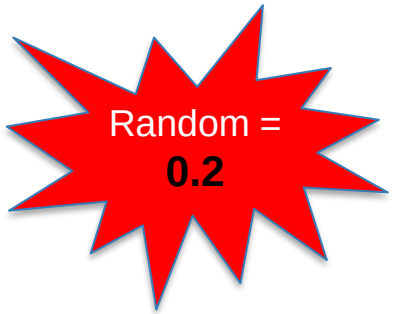
f = 3
x = 39
v = 31
A = 0.7
r = 0.4
F(x)=0.3

t=2



f = 7
x = 36
v = 31
A = 0.9
r = 0.5
F(x)=0.2

t=3



Assume f(x*)= 4

Acceptance criteria:
Rand< Ai & F(xi) < f(x*)

Select best X*
X*=1

Thanks