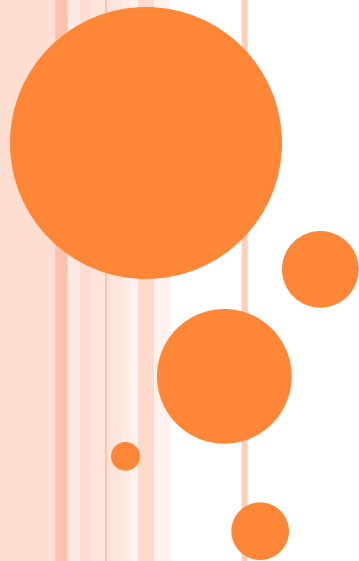


Parameter Control Mechanisms in Differential Evolution: A Tutorial Review and Taxonomy

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Outline

- **Introduction**
- **Proposed Taxonomy**
- **A Quick Review**
- **Research Directions**

Differential Evolution (DE)

Each individual x_i serves as the target vector once.

For each target vector, a **mutant vector** v_i is generated by

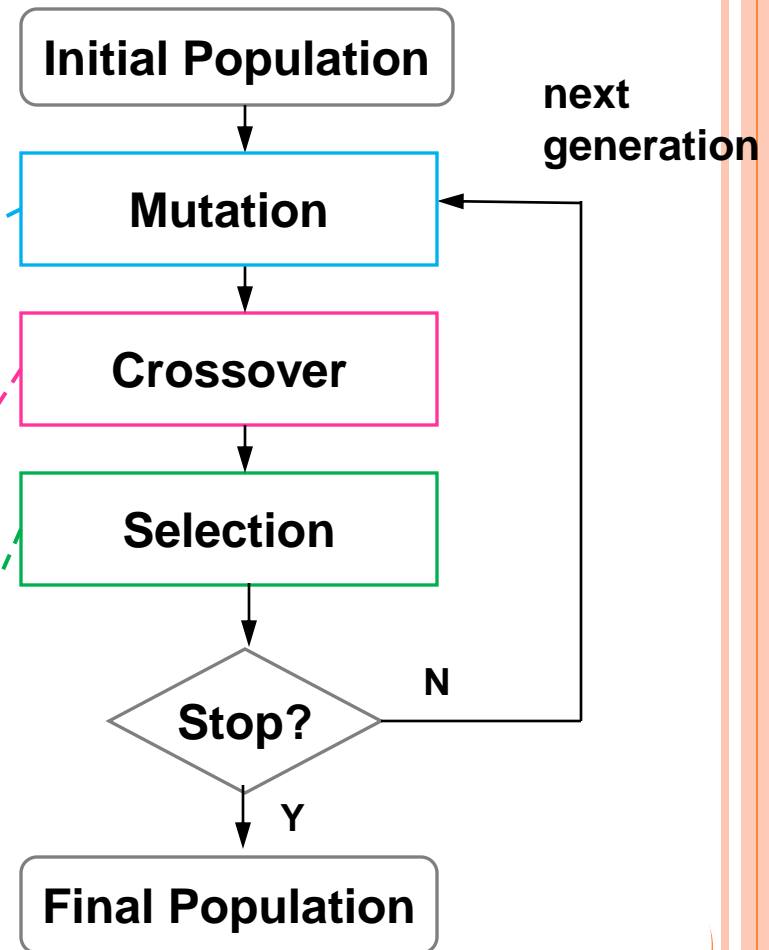
$$v_i = x_{r1} + F \cdot (x_{r2} - x_{r3})$$

A **trial vector** u_i is generated by

$$u_{ij} = \begin{cases} v_{ij}, & \text{if } U_j(0,1) \leq CR \vee j = j_{rnd} \\ x_{ij}, & \text{otherwise} \end{cases}$$

$$j = 1, 2, \dots, D$$

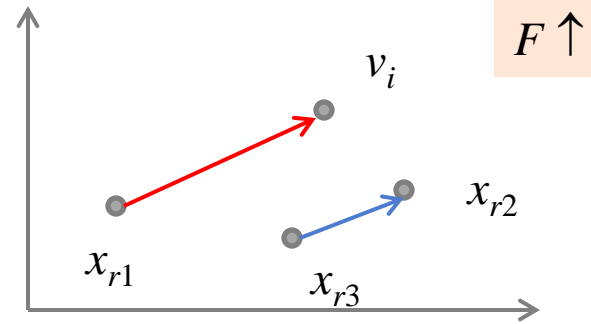
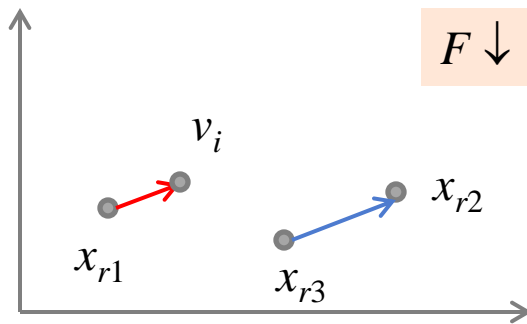
The trial vector is accepted if it is not worse than the target vector.



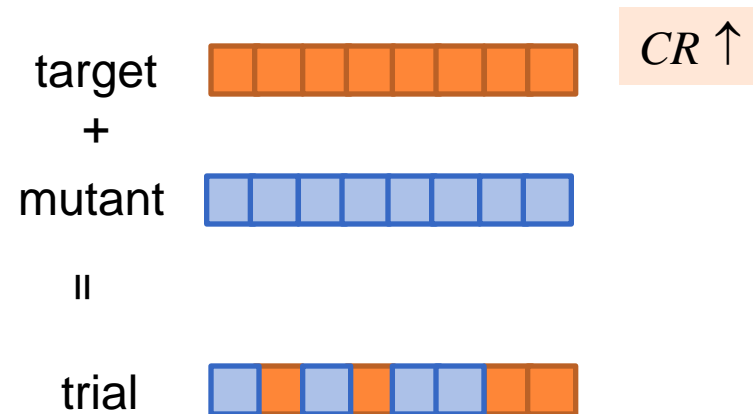
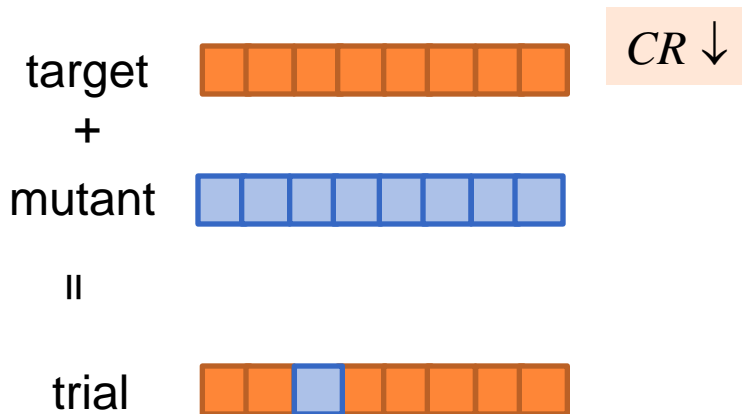
- Population size (NP)

Parameters of DE

○ Scaling Factor (F) $v_i = x_{r1} + F \cdot (x_{r2} - x_{r3})$



○ Crossover Rate (CR)



Parameters of DE

○ Suggestions on parameter values

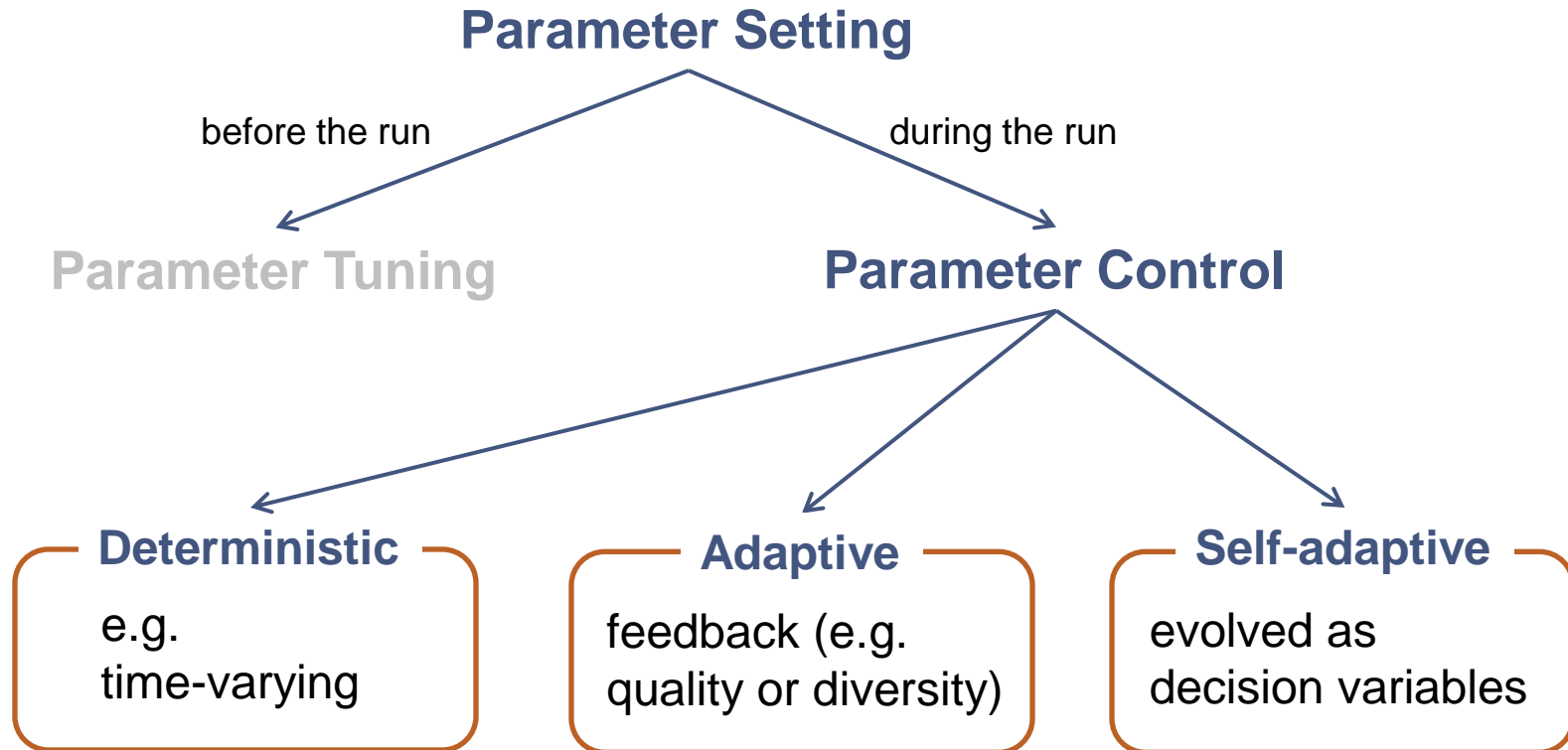
F	CR	Reference
[0.4, 1.0]	0.1, 0.9	Storn & Price1997
0.9	0.9	Liu & Lampinen 2002
	0.5	Ali & Törn 2004
0.9	0.9	Rönkkönen et al. 2005
0.5	0.5	Kaelo & Ali 2006
≥ 0.6	≥ 0.6	Zielinski et al. 2006
[0.35, 0.37]	0.5	Salman et al. 2007

Parameters of DE

- **Different parameter values are required for different**
 - **problem instances**
 - **mutation strategies**
 - **search stages**
 - **search regions**

- **We need to determine the parameter values dynamically (online).**

Parameter Control Paradigms



Parameter Control Paradigms

- There are many “adaptive” or “self-adaptive” DE algorithms.

The screenshot shows a Google Scholar search interface. The search bar contains the text "adaptive 'differential evolution'". Below the search bar, it indicates "About 14,900 results (0.03 sec)". The results are listed under the "Articles" section. The first result is a book titled "Adaptive Differential Evolution" by J Zhang and AC Sanderson (2009). The second result is a paper titled "Self-adaptive differential evolution algorithm for numerical optimization" by AK Qin and PN Suganthan (2005). The third result is a paper titled "A fuzzy adaptive differential evolution algorithm" by J Liu and J Lampinen (2005). The fourth result is a paper titled "JADE: adaptive differential evolution with optional external archive" by J Zhang and AC Sanderson (2009). The fifth result is a paper titled "Self-adaptive differential evolution" by MGH Omran, A Salman, and AP Engelbrecht (2005). The sixth result is a paper titled "Performance comparison of self-adaptive and adaptive differential evolution algorithms" by J Brest, B Bošković, S Greiner, V Žumer, and MS Maučec (2007). The interface includes filters for "Any time" (Since 2013, Since 2012, Since 2009, Custom range...), "Sort by relevance" and "Sort by date", and checkboxes for "include patents", "include citations", and "Create alert".

Google

adaptive "differential evolution"

Scholar About 14,900 results (0.03 sec)

Articles

Legal documents

Any time
Since 2013
Since 2012
Since 2009
Custom range...

Sort by relevance
Sort by date

include patents
 include citations

Create alert

[\[BOOK\] Adaptive Differential Evolution](#)
J Zhang, AC Sanderson - 2009 - books.google.com
Optimization problems are ubiquitous in academic research and real-world applications such as in engineering, finance, and scientific areas. What coefficients of a neural network minimize classification errors? What combination of bids maximizes the outcome in an ...
Cited by 21 Related articles All 5 versions Cite More

[Self-adaptive differential evolution algorithm for numerical optimization](#)
AK Qin, PN Suganthan - ..., 2005. The 2005 IEEE Congress on, 2005 - ieeexplore.ieee.org
Abstract In this paper, we propose a novel self-adaptive differential evolution algorithm (SaDE), where the choice of learning strategy and the two control parameters F and CR are not required to be pre-specified. During evolution, the suitable learning strategy and ...
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[A fuzzy adaptive differential evolution algorithm](#)
J Liu, J Lampinen - Soft Computing, 2005 - Springer
Abstract. The differential evolution algorithm is a floating-point encoded evolutionary algorithm for global optimization over continuous spaces. The algorithm has so far used empirically chosen values for its search parameters that are kept fixed through an ...
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[JADE: adaptive differential evolution with optional external archive](#)
J Zhang, AC Sanderson - Evolutionary Computation, IEEE ..., 2009 - ieeexplore.ieee.org
Abstract A new differential evolution (DE) algorithm, JADE, is proposed to improve optimization performance by implementing a new mutation strategy "DE/current-to-p best" with optional external archive and updating control parameters in an adaptive ...
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[Self-adaptive differential evolution](#)
MGH Omran, A Salman, AP Engelbrecht - Computational intelligence and ..., 2005 - Springer
Abstract Differential Evolution (DE) is generally considered as a reliable, accurate, robust and fast optimization technique. DE has been successfully applied to solve a wide range of numerical optimization problems. However, the user is required to set the values of the ...
Cited by 99 Related articles BL Direct All 4 versions Cite More

[Performance comparison of self-adaptive and adaptive differential evolution algorithms](#)
J Brest, B Bošković, S Greiner, V Žumer, MS Maučec - Soft Computing, 2007 - Springer
Abstract Differential evolution (DE) has been shown to be a simple, yet powerful, evolutionary algorithm for global optimization for many real problems. Adaptation, especially

Proposed Taxonomy

- 3-field notation for the DE variants

the number of difference vectors

the vector to be mutated

the crossover scheme

x / **y** / **z**

rand/1/bin

best/2/bin

current-to-rand/1/bin

rand/1/exp

rand/2/exp

Proposed Taxonomy

- 3-field notation for the parameter control mechanisms

x / y / z

- **the number of candidate values of a parameter**
 - **dis** (discrete) / **con** (continuous)
- **the number of parameter values used in a single generation**
 - **1** / **mul** (multiple) / **idv** (individual) / **var** (variable)
- **information used to adjust parameter values**
 - **rnd** (random) / **pop** (population) / **par** (parent) / **idv** (individual)

Proposed Taxonomy

- We classify 23 recent studies into nine categories.

Category	Algorithms
con / 1 / pop	DEPD, FADE, ADEA
con / mul / rnd	NSDE
con / mul / pop	SaDE, SaNSDE, JADE, JADE2, SaJADE
con / idv / rnd	jDE, jDE-2, CSDE, MOSADE
con / idv / pop	RADE, ISADE
con / idv / par	SPDE, SDE, DESAP, DEMOsWA
con / idv / idv	SFLSDE, SspDE
con / var / pop	APDE
dis / mul / pop	DEBR

con / 1 / pop

○ Example: **DEPD** (Ali and Törn, 2004)

- Fixed **CR** value
- Increase **F** as the difference of fitness between the best and worst individuals decreases

$$F = \begin{cases} \max\{F_{\min}, 1 - |f_{\max} / f_{\min}|\}, & \text{if } |f_{\max} / f_{\min}| < 1, \\ \max\{F_{\min}, 1 - |f_{\min} / f_{\max}|\}, & \text{otherwise.} \end{cases}$$

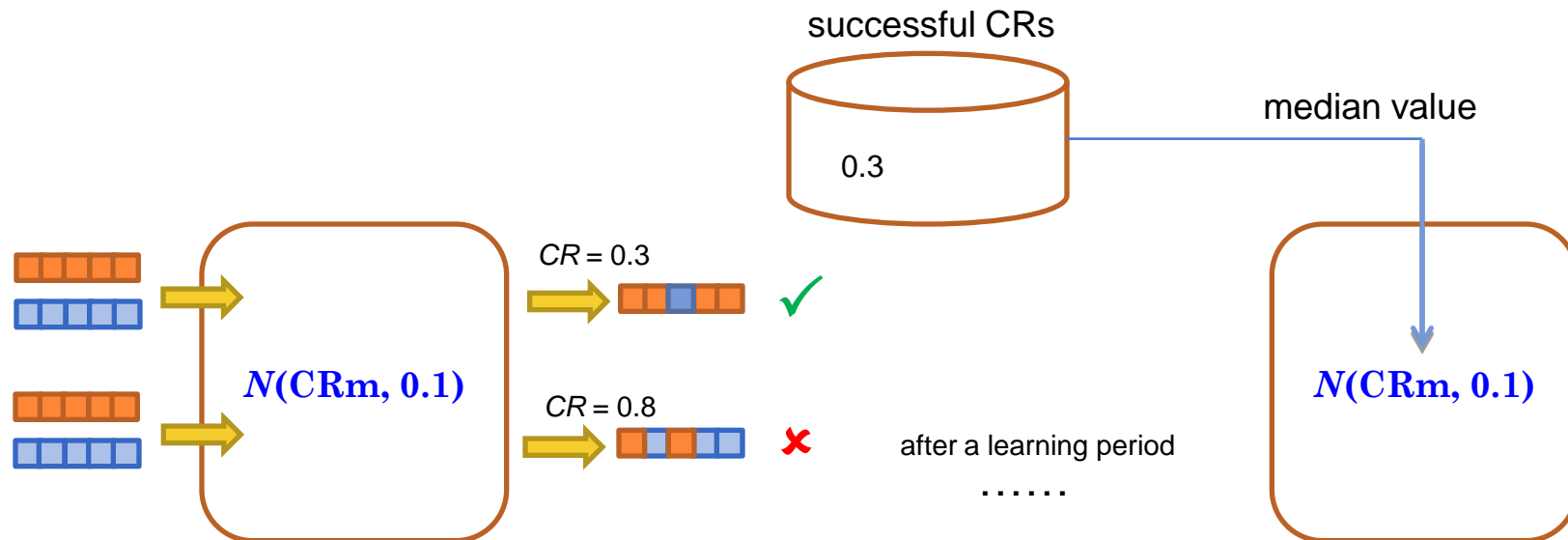
○ Other population-based information

- **diversity** (genotypic or phenotypic distance) **within a generation or between generations** (e.g. **FADE**)
- **distribution along the Pareto front** (e.g. **ADEA**)

con / mul / pop

○ Example: SaDE (Qin et al. 2009)

- Generate F/CR values by normal distribution
 - $F \sim N(0.5, 0.5)$
- Record the successful CR values in a learning period
 - successful: the trial vector is accepted



con / mul / pop

○ Design issues

- random distributions for generating the parameter value
 - normal / Cauchy (e.g. SaDE / **SaNSDE** & **JADE**)
- learning period (*LP*)
 - $LP = 1$ / $LP > 1$
- calculation of distribution parameters
 - median / weighted sum (e.g. SaDE / SaNSDE & JADE)

con / idv / rnd

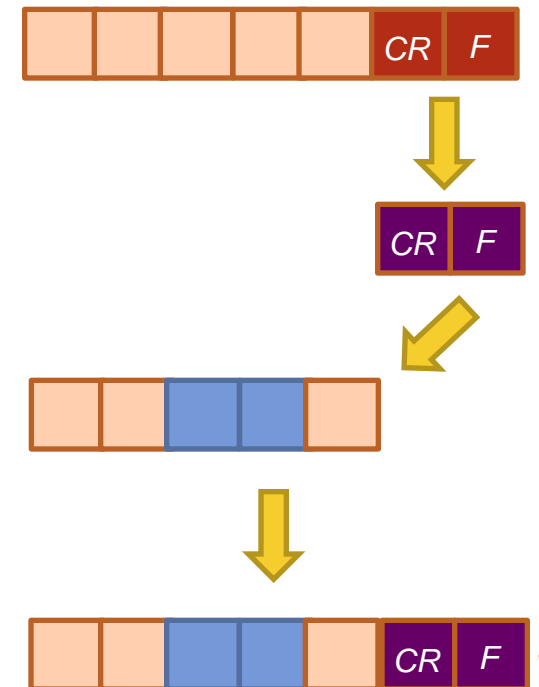
○ Example: **jDE** (Brest et al. 2006)

- Each individual records its parameter values.
- The values undergo random perturbation probabilistically.

$$F_{i,g+1} = \begin{cases} U_1(F_{\min}, F_{\max}), & \text{if } U_2(0,1) < \tau_1, \\ F_{i,g}, & \text{otherwise.} \end{cases}$$

$$CR_{i,g+1} = \begin{cases} U_3(0,1), & \text{if } U_4(0,1) < \tau_2, \\ CR_{i,g}, & \text{otherwise.} \end{cases}$$

- Good parameter values lead to good trial vectors and survive together with the trial vectors.



con / idv / rnd

○ Design issues

- random distributions for perturbation
 - uniform / Cauchy (e.g. jDE / **CSDE**)
- population information (\Rightarrow **con / idv / pop**)
 - change the parameter values only for low-quality individuals (e.g. **RADE**)
 - lower the parameter values for high-quality individuals (e.g. **ISADE**)
- individual information (\Rightarrow **con / idv / idv**)
 - use local search to enhance the values (e.g. **SFLSDE**)
 - record the history of the use of parameter values for each individual (e.g. **SspDE**)

con / idv / par

○ Example: **SPDE** (Abbass 2002)

- Each individual records its parameter values.
- Parameter values evolve as the decision variable values evolve.



$$CR_i = CR_{r1} + N(0,1) \cdot (CR_{r2} - CR_{r3})$$

○ Design issues

- the way to calculate the new parameter values based on parents' values (e.g. **DEMOwSA**)

$$CR_i = \frac{CR_i + CR_{r1} + CR_{r2} + CR_{r3}}{4} \cdot e^{\tau \cdot N(0,1)}$$

con / var / pop

○ Example: **APDE** (Zaharie and Petcu 2004)

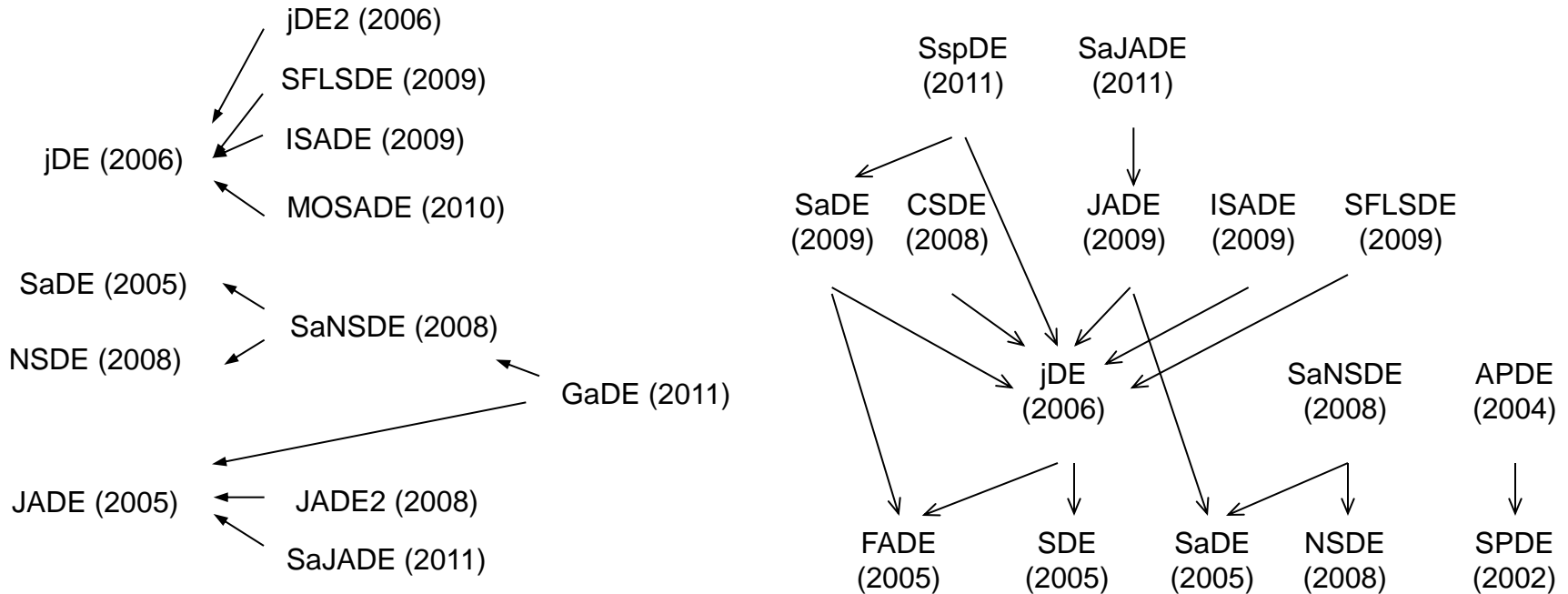
- Parameter values are associated with variables.
- Relationships between the parameter values and the variance of values of decision variables are investigated.
- Values of **CR** and **F** are adjusted alternately.

$$CR_i = \begin{cases} -(F_i^2 N - 1) + \sqrt{(F_i^2 N - 1)^2 - N(1 - c_i)}, & \text{if } c_i \geq 1 \\ CR_{\min} & \text{otherwise} \end{cases}$$

$$c_i(g+1) = \gamma \frac{\text{Var}(x^i(g))\text{Var}(f(g))}{\text{Var}(x^i(g+1))\text{Var}(f(g+1))}$$

$$\text{Var}(f(g)) = \frac{1}{M} \sum_{j=1}^M \text{Var}(f_j(g))$$

Some Relationships



Design Inheritance

Performance Comparison

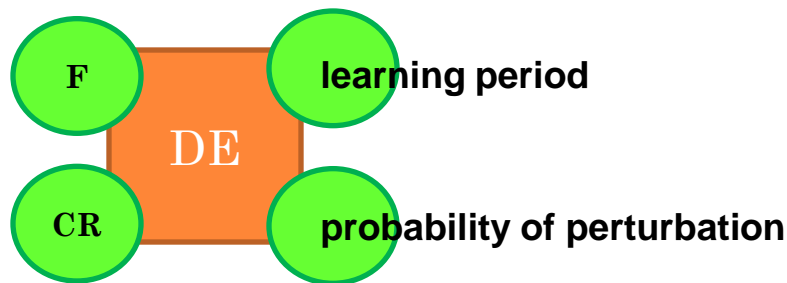
A ← B (derived)

A ← B (better)

Research Directions

○ Making the algorithm **simpler**

- avoid extra parameters like learning period or probability.

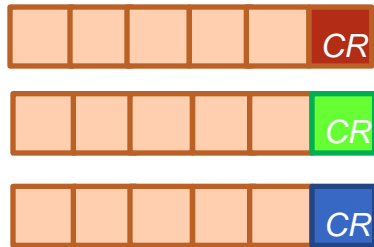


○ Considering **problem-oriented information**

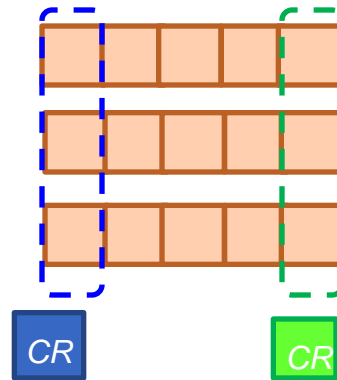
- Quality & diversity information have been used.
- Problem information (unimodal/multimodal, separable/non-separable, etc.) has rarely been considered.
- $\cdot/\cdot/\text{pop}$, $\cdot/\cdot/\text{idv}$, then $\cdot/\cdot/\text{prb}$?
⇒ **LMDE** (Takahama and Sakai 2012)

Research Directions

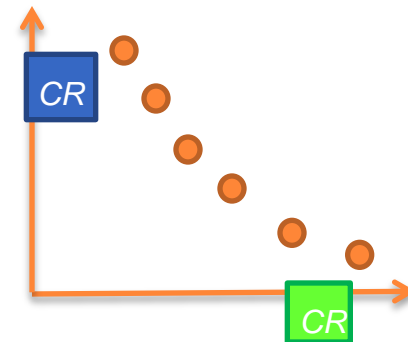
- Adapting with respect to **multiple objectives**



• `./idv/.`



`./var/.,`

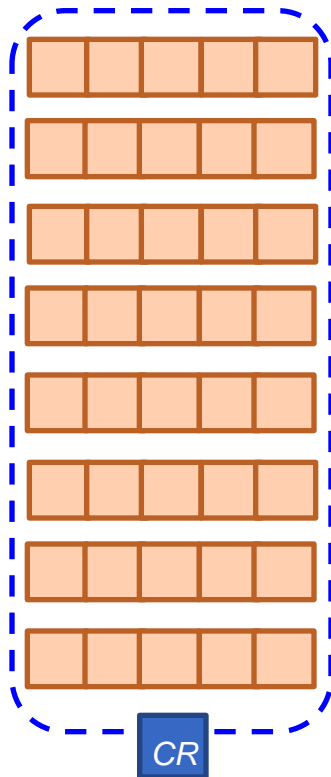


then `./obj/.` ?

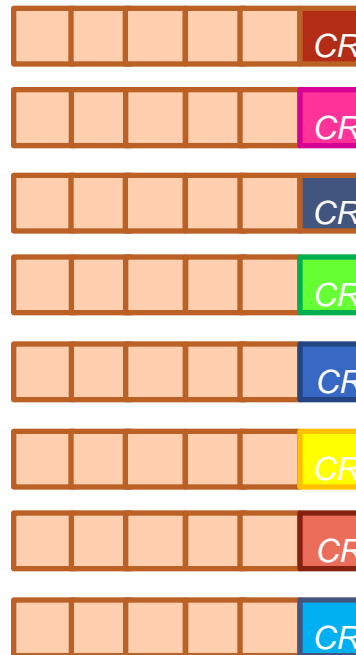
⇒ **OW-MOSaDE** (Huang et al. 2009)

Research Directions

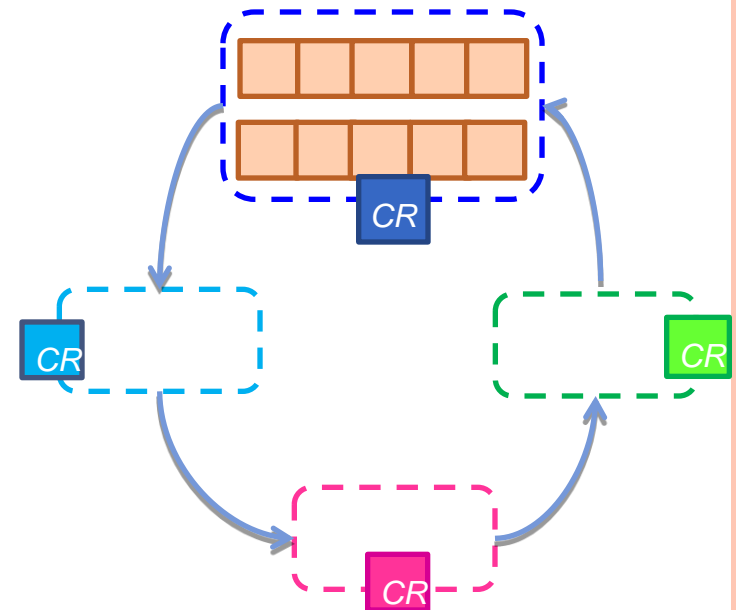
- Doing parameter control through **distributed DE**



./1/.



./idv/.,



then ./sub-pop/. ?
⇒ **FACPDE** (Weber et al. 2010)

**Thank you very much
for your attention!**

