

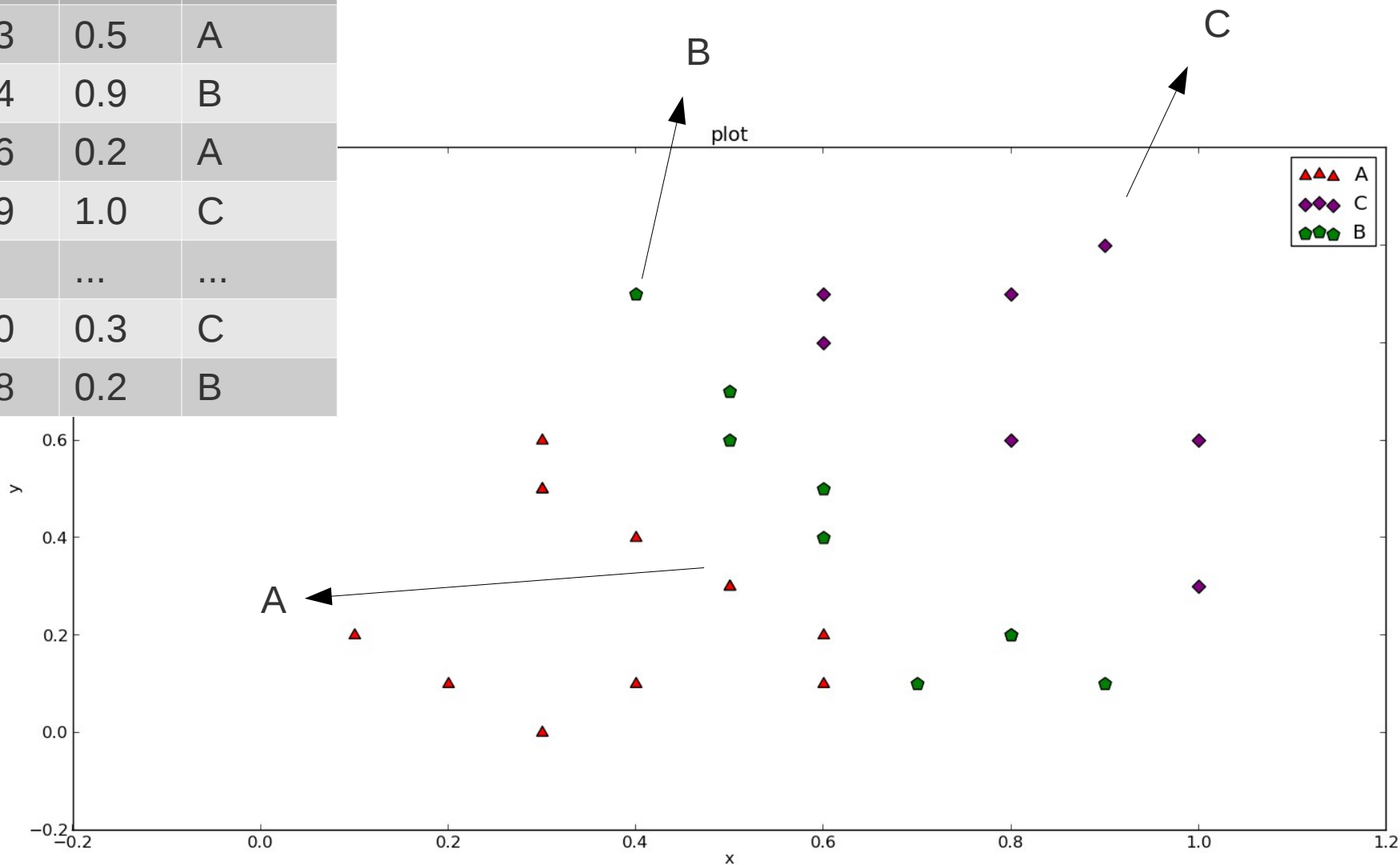
# Grammatical Evolution untuk Ekstraksi Fitur dengan Pengukuran Multi Fitness



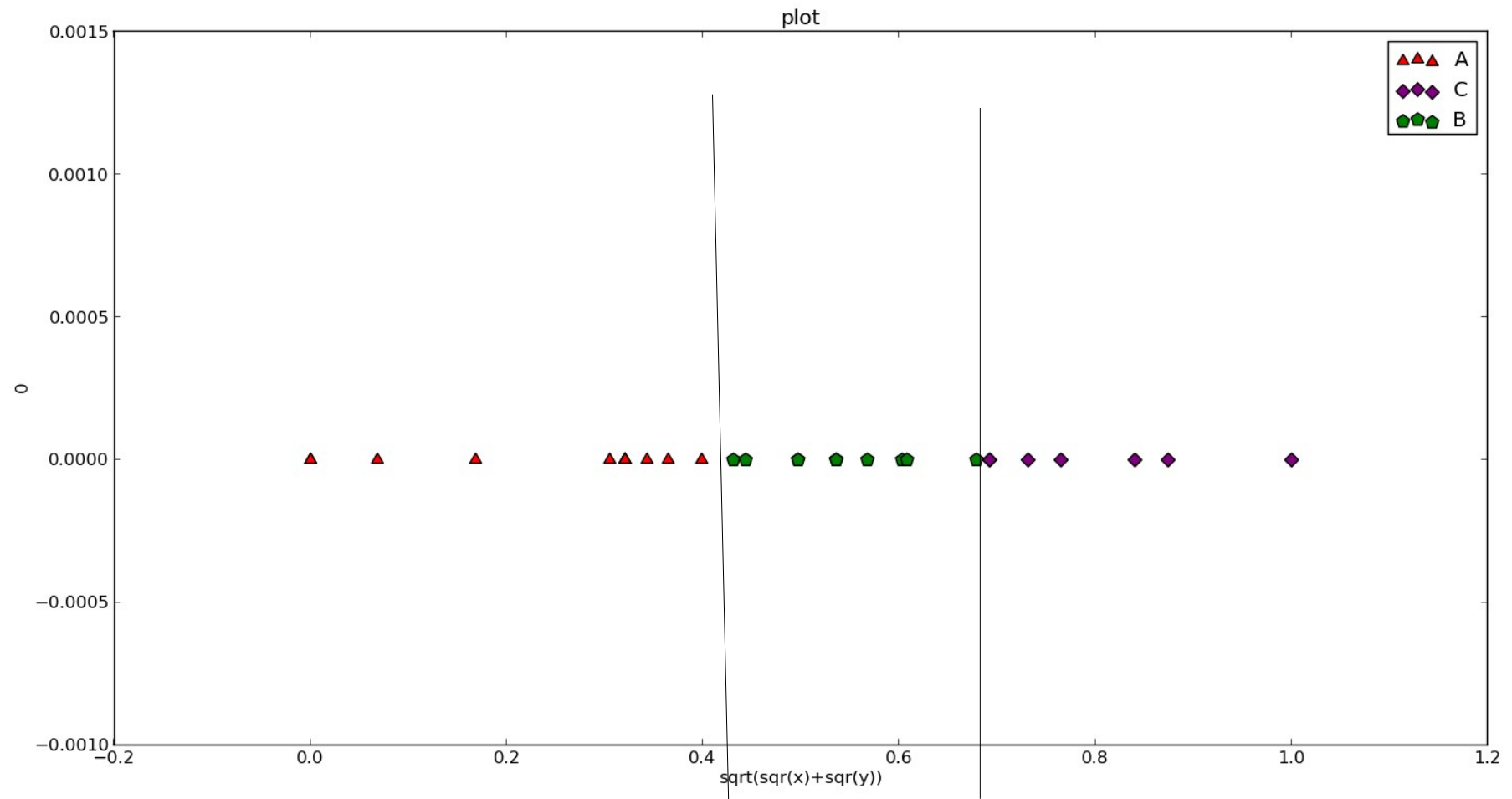
Go Frendi Gunawan (5111201033)

# Ruang Fitur

x	y	kelas
0.3	0.5	A
0.4	0.9	B
0.6	0.2	A
0.9	1.0	C
...	...	...
1.0	0.3	C
0.8	0.2	B



# Ekstraksi Fitur

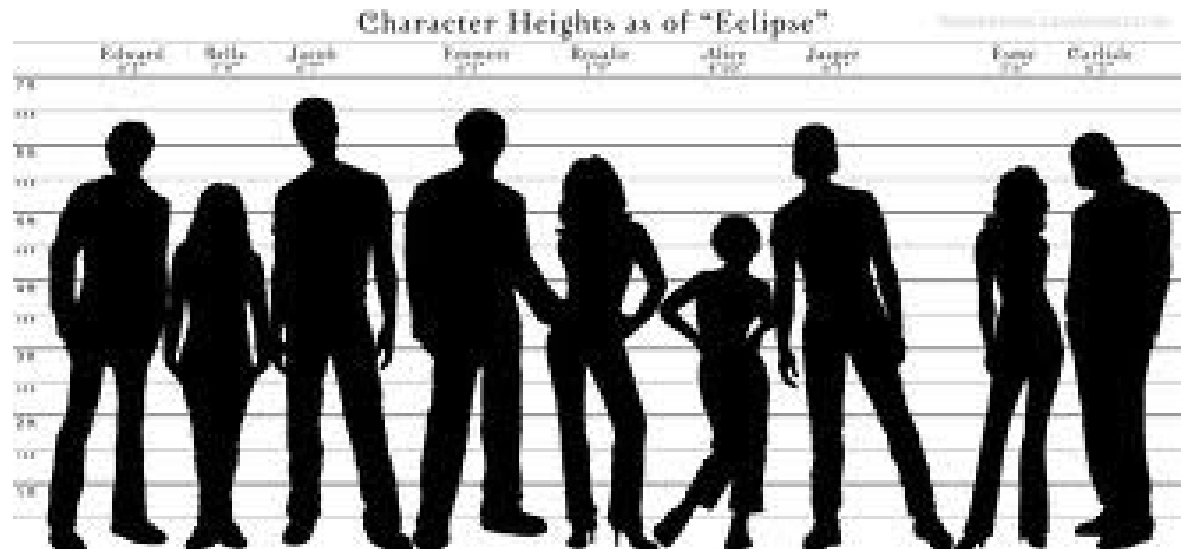


# Penelitian Sebelumnya

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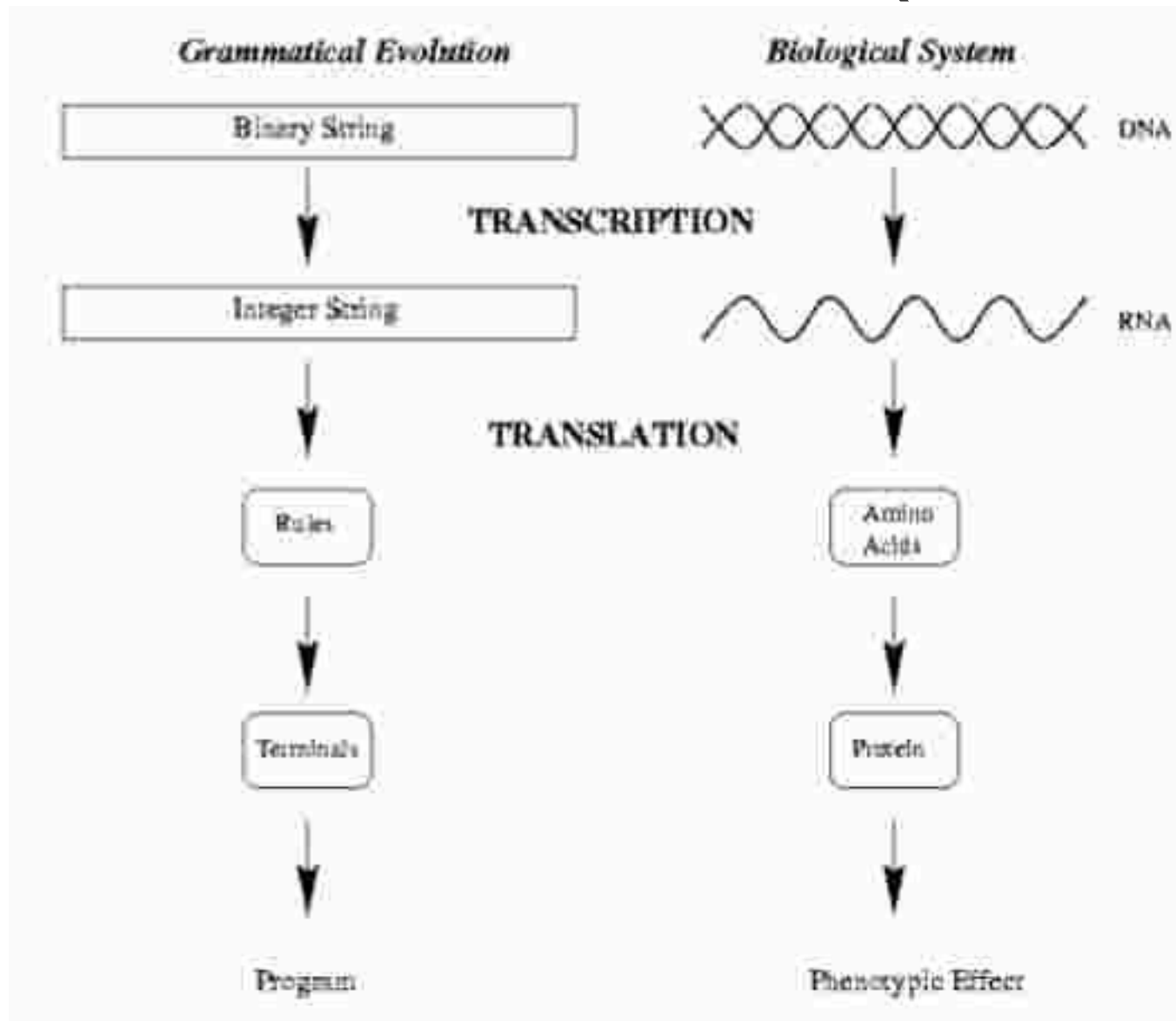
# Penelitian yang Dilakukan

- Classifier: Decision Tree
- 5 Feature Extractor untuk dibandingkan:
  - GA Select
  - GE Gavrilis
  - GE Global
  - **GE Multi**
  - **GE Tatami**



GA : Genetics Algorithm  
GE : Grammatical Evolution

# Grammatical Evolution (Overview)



# Grammatical Evolution (Detail)

- Given the individual

220	203	51	123	2	45
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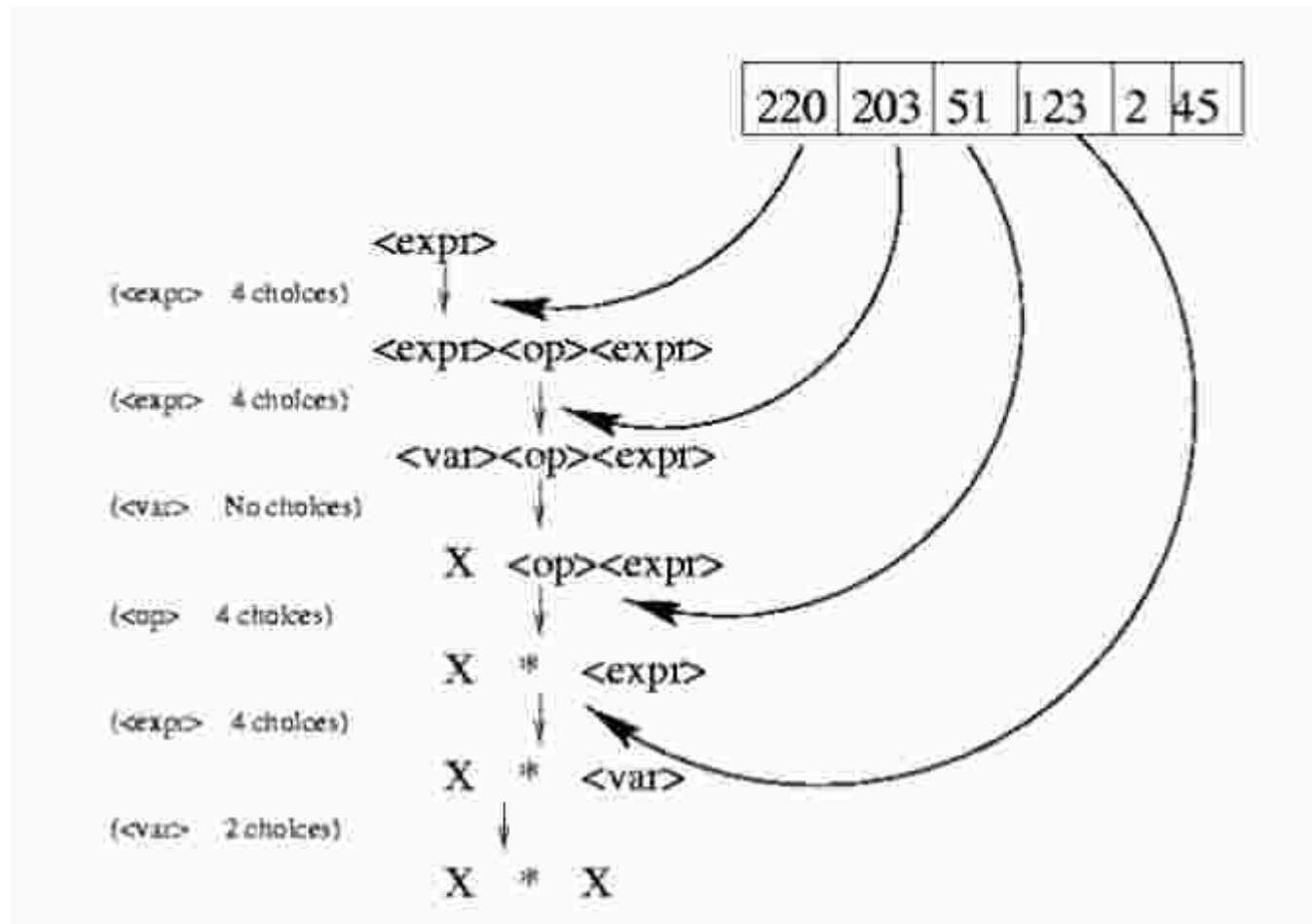
 ....what will happen?

- $\langle \text{expr} \rangle$  has 4 production rules to choose from

(1)  $\langle \text{expr} \rangle ::= \langle \text{expr} \rangle \langle \text{op} \rangle \langle \text{expr} \rangle$  (A)  
          |  $( \langle \text{expr} \rangle \langle \text{op} \rangle \langle \text{expr} \rangle )$  (B)  
          |  $\langle \text{pre-op} \rangle ( \langle \text{expr} \rangle )$  (C)  
          |  $\langle \text{var} \rangle$  (D)

- Taking first codon 220 we get  $220 \text{ MOD } 4 = 0$
  - Gives  $\langle \text{expr} \rangle \langle \text{op} \rangle \langle \text{expr} \rangle$
- Next choice for the first  $\langle \text{expr} \rangle$ 
  - Taking next codon 203 we get  $203 \text{ MOD } 4 = 3$
  - Gives  $\langle \text{var} \rangle \langle \text{op} \rangle \langle \text{expr} \rangle$

# Grammatical Evolution (Detail)





# GA Select

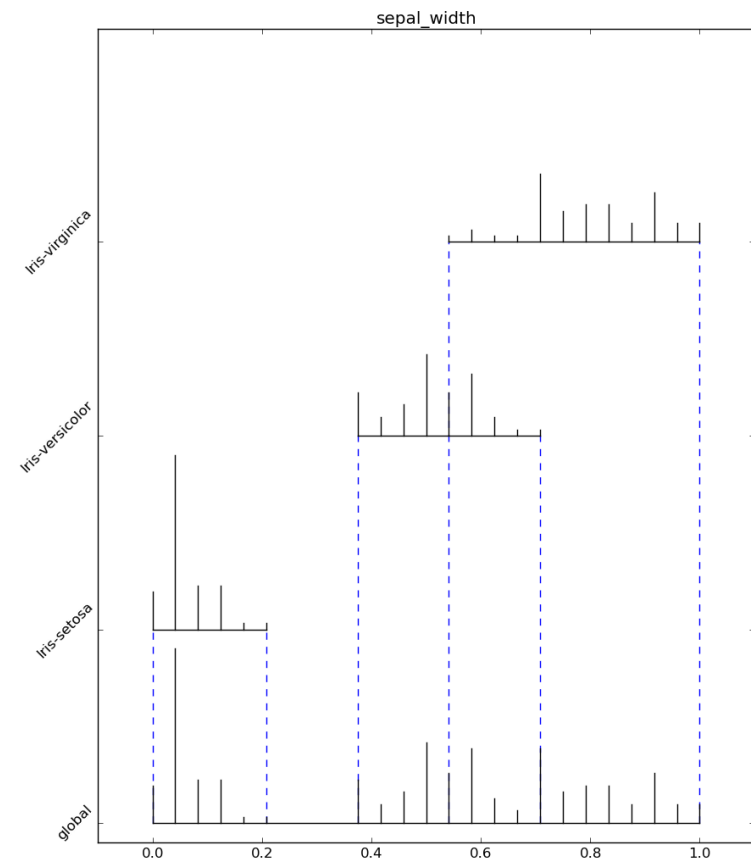
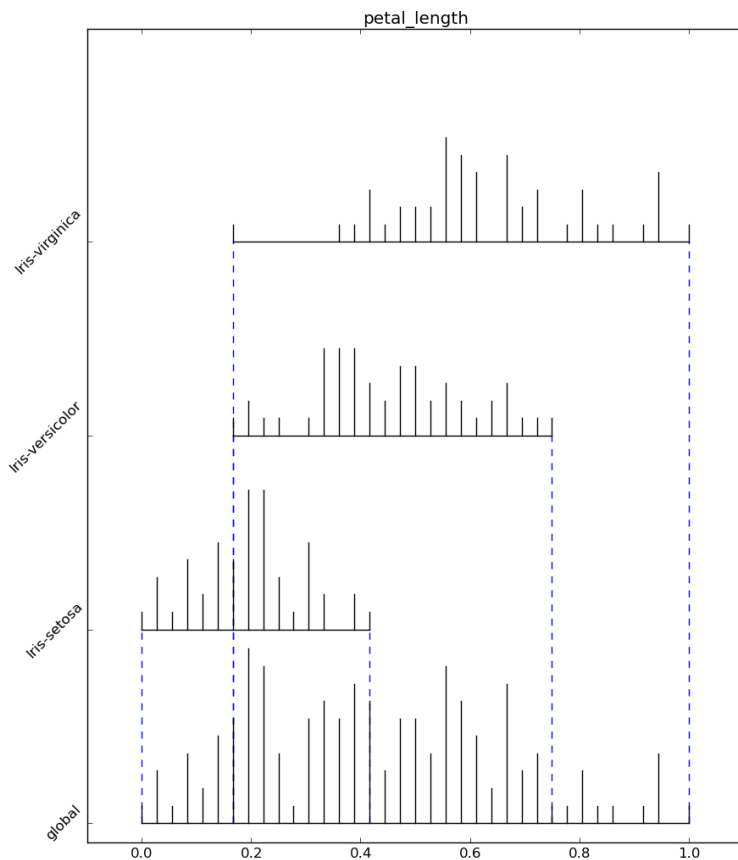
- Algoritma Genetik
- Individu di-evolusikan menjadi **subset fitur original**
- Fitness Value = Akurasi Classifier menggunakan subset fitur original
- Menilai keakuratan subset fitur tanpa modifikasi.
  - Misal: Fitur original =  $\{x,y,z\}$
  - Subset fitur yang dihasilkan:
    - $\{x\}$
    - $\{x,y\}$
    - $\{x,z\}$
    - $\{y\}$
    - $\{y,z\}$
    - $\{z\}$



# Fitur yang Dihasilkan GA Select

- **Fitur original(4)** : sepal\_length, sepal\_width, petal\_length, petal\_width
- **Fitur yang dihasilkan (2)** : petal\_length, sepal\_width

Feature Projection



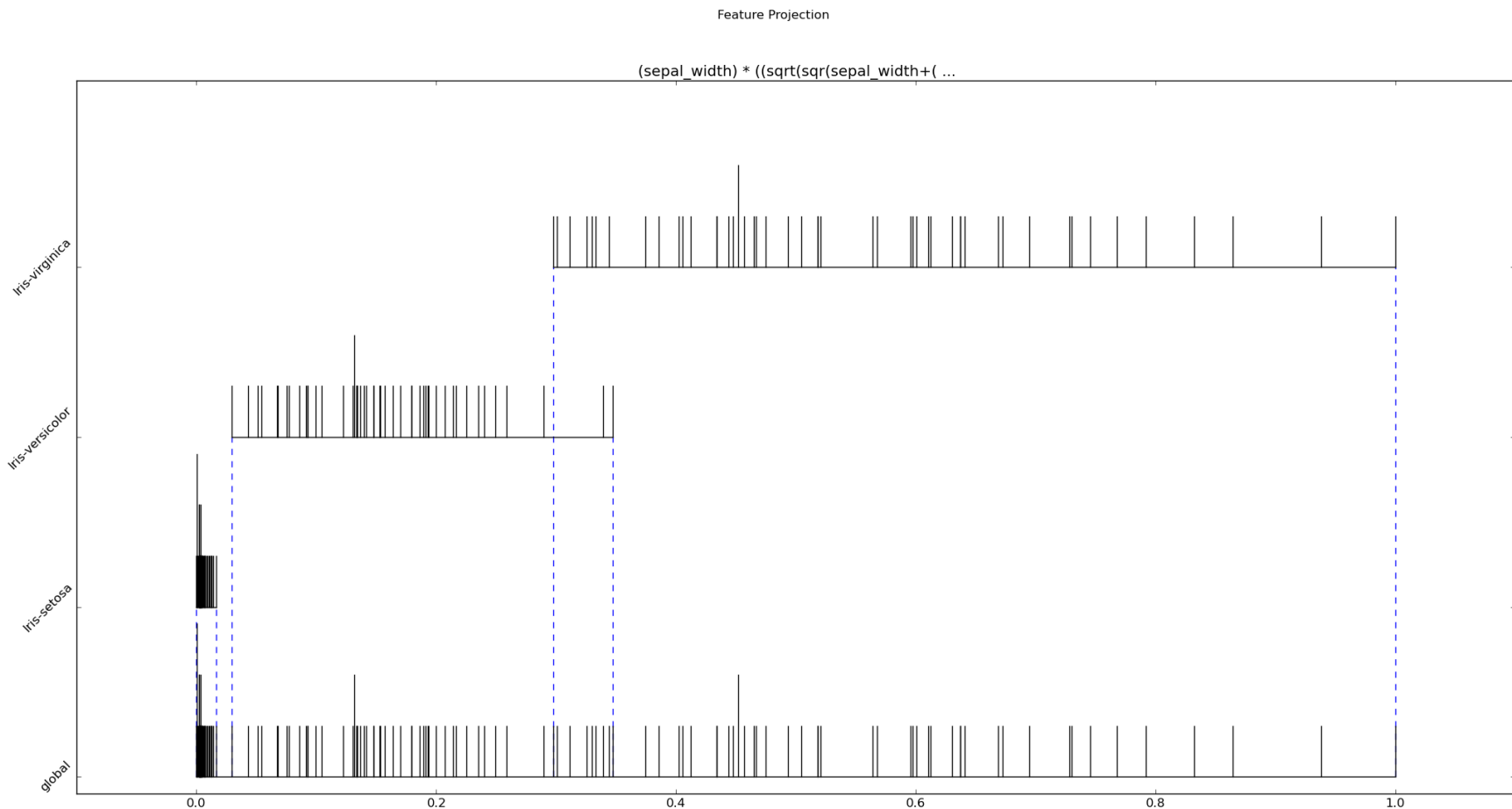
# GE Gavrilis

- Grammatical Evolution
- Individu di-evolusikan menjadi **1 set fitur baru**
- Dihasilkan sejumlah fitur secara acak, namun tidak semuanya relevan
- Fitness Value = Akurasi Classifier menggunakan set fitur baru
- Gavrilis D., et al. (2005)



# Contoh Fitur yang dihasilkan GE Gavrilis

- **Fitur original (4):** sepal\_length, sepal\_width, petal\_length, petal\_width
- **Fitur yang dihasilkan (1):**  $(\text{sepal\_width}) * ((\sqrt{\text{sepal\_width} + (\text{sepal\_length} * ((\text{sepal\_width} / (\text{sepal\_width}))) / 2)) * (\text{abs}(((\text{sepal\_length}) - (\text{petal\_length})) + (\text{sepal\_length}))))))$



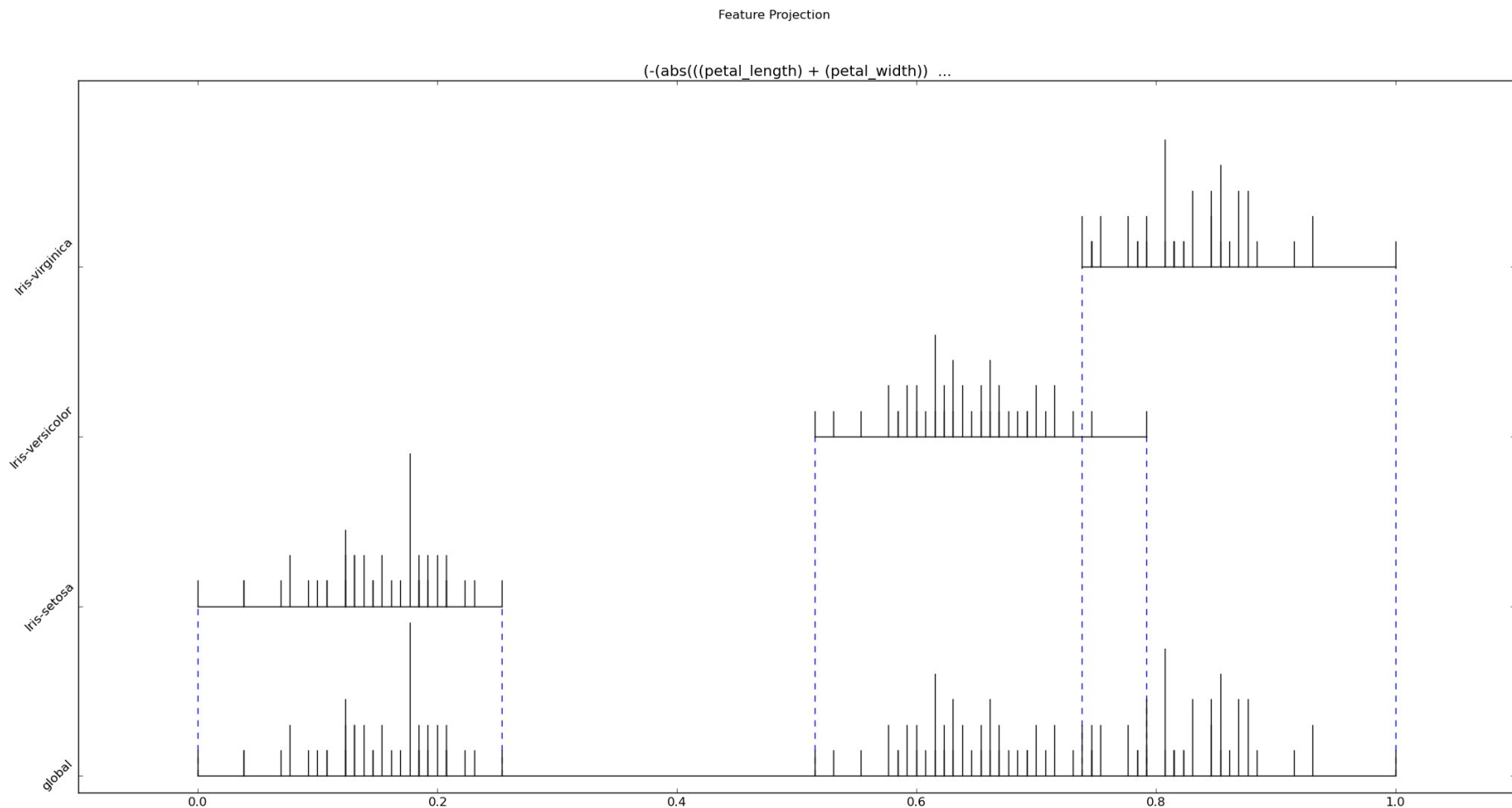
# GE Global

- Grammatical Evolution
- Menghasilkan **1 fitur baru**
- Fitness Value = Akurasi Classifier menggunakan 1 fitur baru



# Contoh Fitur yang dihasilkan GE Global

- **Fitur original** : sepal\_length, sepal\_width, petal\_length, petal\_width
- **Fitur yang dihasilkan (1)**:  $(-(\text{abs}(((\text{petal\_length}) + (\text{petal\_width})) - (\text{sepal\_width})))) + ((\text{sepal\_length}) + (\text{sepal\_length}))$



# GE Multi

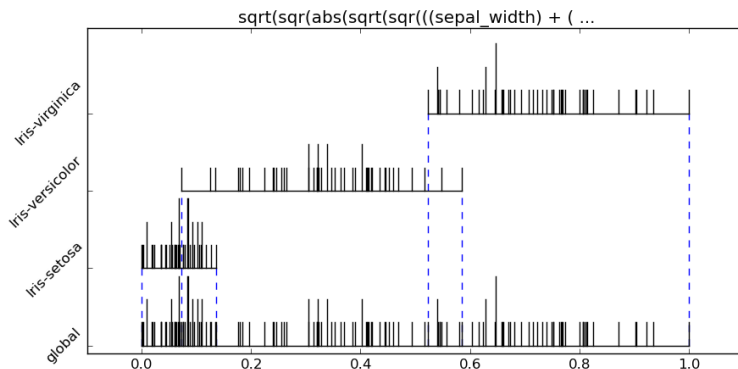
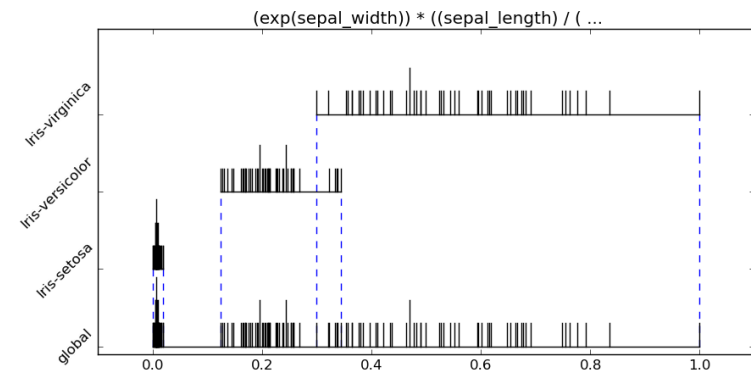
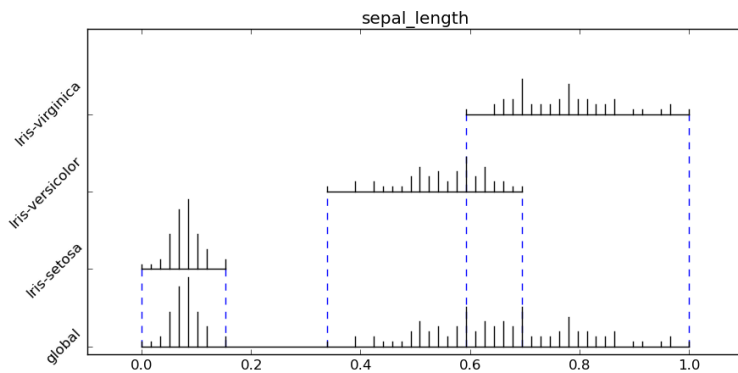
- Grammatical Evolution
- Menghasilkan **n fitur baru**,  $n$  = jumlah kelas
- Fitness Value = Akurasi Classifier menggunakan  $n$  fitur baru



# Contoh Fitur yang dihasilkan GE Multi

- **Fitur original** : sepal\_length, sepal\_width, petal\_length, petal\_width
- **Fitur yang dihasilkan (3)**: sepal\_length,  $(\exp(\text{sepal\_width})) * ((\text{sepal\_length}) / (\text{petal\_width}))$ ,  $\sqrt{\sqrt{(\text{sepal\_width}) + ((\text{sepal\_width}) - (\sqrt{(\text{petal\_length}) - (\text{sepal\_length}) + \text{sepal\_width})/2}))} - ((\text{petal\_width}) + \text{petal\_width})/2) + \text{sepal\_length})/2$

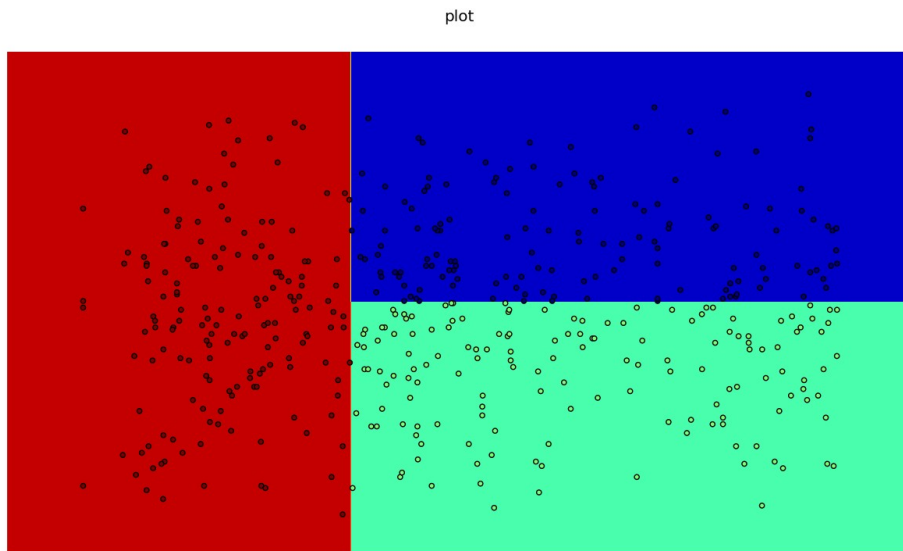
Feature Projection



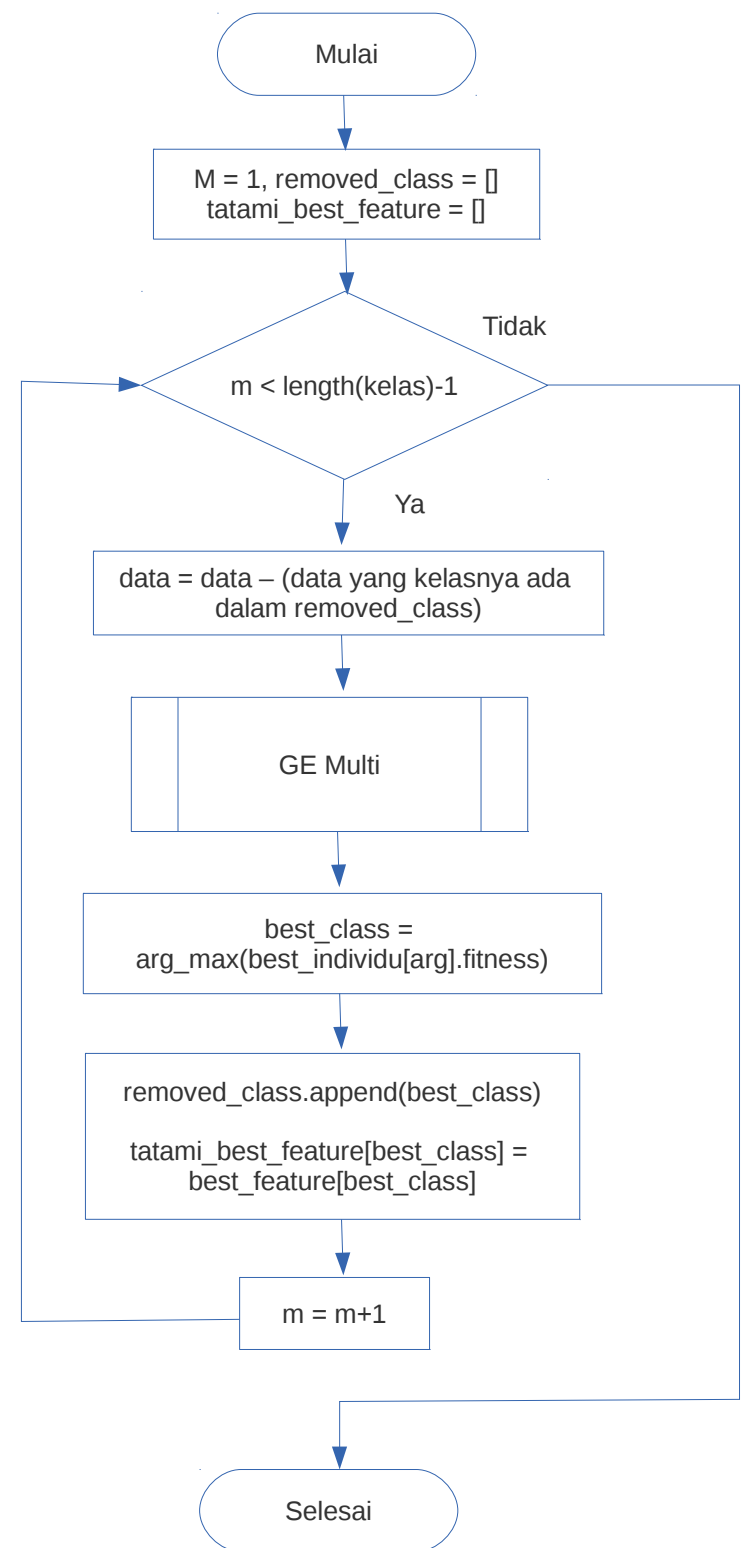


# GE Tatami

- Grammatical Evolution
- Menghasilkan **n-1 fitur baru**,  $n$  = jumlah kelas
- Fitness Value = Akurasi Classifier menggunakan  $n-1$  fitur baru



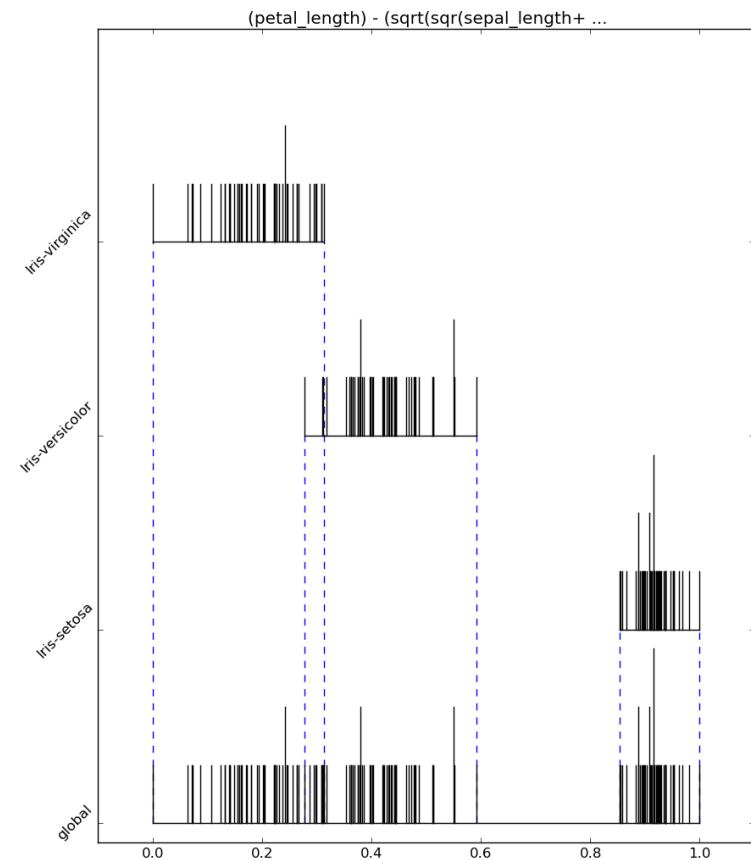
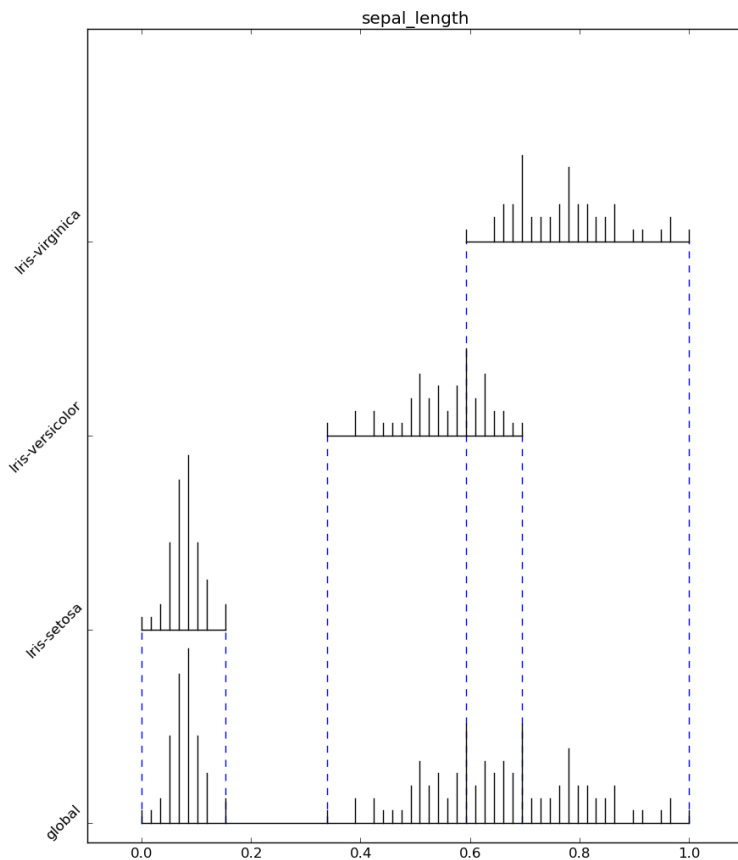
# Flowchart GE Tatami



# Contoh Fitur yang Dihasilkan GE Tatami

- **Fitur original** : sepal\_length, sepal\_width, petal\_length, petal\_width
- **Fitur yang dihasilkan (2)**:  $\text{sepal\_length} - (\sqrt{\sqrt{\text{sepal\_length} + \sqrt{\sqrt{|\text{petal\_length}| + (\sqrt{\sqrt{\text{petal\_length} + \text{petal\_width}})/2}} - (|\text{sepal\_width}| - (\text{petal\_width})))})/2})/2)$

Feature Projection



# Dataset Pengujian

- Dataset
  - Sintesis 01
  - Sintesis 02
  - Sintesis 03
  - Iris (UCI Machine Learning)
  - E Coli (UCI Machine Learning)
  - Balanced Scale (UCI Machine Learning)
- 5 Fold Cross Validation



# Data Sintesis 01

- Fitur: defense, attack, agility, stamina
- Kelas: defender, demon hunter, wizard
- Jumlah record: 460
- Penentuan kelas:  
=IF(defense/attack >= 1.4, "defender", IF(agility >= stamina, "demon hunter", "wizard"))

# Hasil Pengujian Dataset Sintesis 01

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE <u>Gavrillis</u>	
		Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features
Whole	Train	73.04	3	77.83	1	99.35	3	100.0	2	85.65	3
	Test	73.04		77.83		99.35		100.0		85.65	
	Total	73.04		77.83		99.35		100.0		85.65	
Fold 1	Train	75.95	3	78.92	1	100.0	3	100.0	2	84.59	61
	Test	67.78		35.56		76.67		81.11		83.33	
	Total	74.35		70.43		95.43		96.3		84.35	
Fold 2	Train	73.78	3	78.92	1	100.0	3	100.0	2	100.0	48
	Test	70.0		36.67		74.44		65.56		80.0	
	Total	73.04		70.65		95.0		93.26		96.09	
Fold 3	Train	71.62	3	77.57	1	100.0	3	100.0	2	85.14	3
	Test	75.56		25.56		86.67		86.67		86.67	
	Total	72.39		67.39		97.39		97.39		85.43	
Fold 4	Train	73.51	3	78.65	1	100.0	3	100.0	2	85.41	3
	Test	74.44		36.67		77.78		77.78		76.67	
	Total	73.7		70.43		95.65		95.65		83.7	
Fold 5	Train	75.68	3	81.08	1	100.0	3	100.0	2	87.03	2
	Testing	70.0		42.22		94.44		82.22		72.22	
	Total	74.57		73.48		98.91		96.52		84.13	

# Data Sintesis 02

- Fitur: defense, attack, agility, stamina
- Kelas: defender, demon hunter, monk, wizard
- Jumlah record: 613
- Penentuan kelas:  
=IF(defense/attack >= 1.6, "defender",  
IF( agility/stamina >= 1.3, "demon hunter",  
IF(stamina>attack, "monk", "wizard"))))

# Hasil Pengujian Dataset Sintesis 02

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE <u>Gavrilis</u>	
		Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res
Whole	Train	77.98	4	70.8	1	100.0	4	100.0	3	90.38	12
	Test	77.98		70.8		100.0		100.0		90.38	
	Total	77.98		70.8		100.0		100.0		90.38	
Fold 1	Train	78.66	4	73.17	1	99.39	4	100.0	3	89.84	12
	Test	76.03		33.06		46.28		62.81		72.73	
	Total	78.14		65.25		88.91		92.66		86.46	
Fold 2	Train	76.42	4	70.53	1	100.0	4	100.0	3	89.43	12
	Test	77.69		27.27		72.73		74.38		85.95	
	Total	76.67		61.99		94.62		94.94		88.74	
Fold 3	Train	79.67	4	71.75	1	99.39	3	100.0	3	90.04	12
	Test	68.6		34.71		64.46		83.47		68.6	
	Total	77.49		64.44		92.5		96.74		85.81	
Fold 4	Train	79.07	4	70.73	1	100.0	4	100.0	3	90.24	12
	Test	72.73		40.5		71.07		61.16		80.17	
	Total	77.81		64.76		94.29		92.33		88.25	
Fold 5	Train	78.05	4	71.75	1	100.0	4	100.0	3	86.99	12
	Test	73.55		32.23		83.47		94.21		70.25	
	Total	77.16		63.95		96.74		98.86		83.69	



# Data Sintesis 03

- Fitur:
  - Hidden:  $m1, m2, m3, m4$  (random)
  - Tampak:  $f1, f2, f3, f4, f5$ 
    - $f1 = \text{ROUND}(\text{RAND()}*9.9+0.1,3)$
    - $f2 = f1/m1$
    - $f3 = f2/m2$
    - $f4 = m3/f1$
    - $f5 = f4/m4$
  - Noise:  $n1, n2$  (random)
- Kelas: A, B, C, D, E
- Jumlah record: 400
- Penentuan kelas:  
 $=\text{IF}(m1<0.5, "A", \text{IF}(m2<0.5, "B", \text{IF}(m3<0.5, "C", \text{IF}(m4<0.5, "D", "E"))))$

# Hasil Pengujian Dataset Sintesis 03

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE <u>Gavrillis</u>	
		Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res
Whole	Train	72.5	6	67.0	1	98.25	5	100.0	4	80.75	6
	Test	72.5		67.0		98.25		100.0		80.75	
	Total	72.5		67.0		98.25		100.0		80.75	
Fold 1	Train	74.45	6	67.91	1	99.07	5	100.0	4	82.55	6
	Test	26.58		27.85		45.57		63.29		32.91	
	Total	65.0		60.0		88.5		92.75		72.75	
Fold 2	Train	72.9	6	66.98	1	100.0	5	100.0	4	86.29	47
	Test	62.03		27.85		68.35		94.94		69.62	
	Total	70.75		59.25		93.75		99.0		83.0	
Fold 3	Train	71.34	6	69.47	1	99.69	5	100.0	4	83.18	6
	Test	29.11		24.05		55.7		65.82		46.84	
	Total	63.0		60.5		91.0		93.25		76.0	
Fold 4	Train	72.9	4	66.98	1	98.44	5	100.0	4	73.52	2
	Test	27.85		26.58		50.63		78.48		25.32	
	Total	64.0		59.0		89.0		95.75		64.0	
Fold 5	Train	72.27	6	68.85	1	99.38	5	100.0	4	85.67	47
	Test	25.32		48.1		59.49		63.29		49.37	
	Total	63.0		64.75		91.5		92.75		78.5	

# Hasil Pengujian Dataset Iris

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE <u>Gavrilis</u>	
		Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features
Whole	Train	96.0	2	98.67	1	98.67	3	98.67	2	98.67	1
	Test	96.0		98.67		98.67		98.67		98.67	
	Total	96.0		98.67		98.67		98.67		98.67	
Fold 1	Train	96.67	2	99.17	1	99.17	3	98.33	2	99.17	1
	Test	86.67		96.67		96.67		96.67		96.67	
	Total	94.67		98.67		98.67		98.0		98.67	
Fold 2	Train	95.83	2	100.0	1	99.17	3	99.17	2	100.0	3
	Test	96.67		96.67		83.33		66.67		96.67	
	Total	96.0		99.33		96.0		92.67		99.33	
Fold 3	Train	96.67	2	98.33	1	98.33	3	99.17	2	98.33	1
	Test	93.33		76.67		100.0		100.0		100.0	
	Total	96.0		94.0		98.67		99.33		98.67	
Fold 4	Train	95.83	2	99.17	1	99.17	3	99.17	2	99.17	1
	Test	96.67		93.33		96.67		96.67		96.67	
	Total	96.0		98.0		98.67		98.67		98.67	
Fold 5	Train	96.67	2	98.33	1	98.33	3	99.17	2	99.17	3
	Testing	93.33		93.33		93.33		96.67		96.67	
	Total	96.0		97.33		97.33		98.67		98.67	

# Hasil Pengujian Dataset E Coli

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE <u>Gavrilis</u>	
		Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res	Accu racy (%)	Featu res
Whole	Train	97.02	7	84.52	1	96.73	8	97.62	7	97.02	12
	Test	97.02		84.52		96.73		97.62		97.02	
	Total	97.02		84.52		96.73		97.62		97.02	
Fold 1	Train	97.42	6	87.45	1	98.89	8	96.31	7	97.79	12
	Test	73.85		58.46		53.85		33.85		69.23	
	Total	92.86		81.85		90.18		88.1		92.26	
Fold 2	Train	96.68	5	86.72	1	97.79	8	98.52	7	97.79	12
	Test	78.46		63.08		49.23		1.54		58.46	
	Total	93.15		82.14		88.39		79.76		90.18	
Fold 3	Train	97.79	7	89.3	1	99.26	8	97.05	7	98.52	26
	Test	70.77		53.85		80.0		69.23		53.85	
	Total	92.56		82.44		95.54		91.67		89.88	
Fold 4	Train	96.31	5	87.08	1	98.52	8	97.42	7	98.15	12
	Test	73.85		69.23		63.08		43.08		56.92	
	Total	91.96		83.63		91.67		86.9		90.18	
Fold 5	Train	97.05	4	86.72	1	98.15	8	96.31	7	98.89	18
	Test	75.38		61.54		38.46		38.46		67.69	
	Total	92.86		81.85		86.61		85.12		92.86	



# Hasil Pengujian Dataset Balanced Scale

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE <u>Gavrillis</u>	
		Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features
Whole	Train	70.88	3	84.8	1	91.68	1	91.68	2	82.56	9
	Test	70.88		84.8		91.68		91.68		82.56	
	Total	70.88		84.8		91.68		91.68		82.56	
Fold 1	Train	70.92	3	100.0	1	100.0	1	92.03	2	81.08	4
	Test	70.73		91.87		91.87		85.37		81.3	
	Total	70.88		98.4		98.4		90.72		81.12	
Fold 2	Train	71.91	3	85.46	1	92.23	1	92.63	2	83.86	9
	Test	66.67		69.92		89.43		82.93		78.86	
	Total	70.88		82.4		91.68		90.72		82.88	
Fold 3	Train	70.52	3	90.04	1	99.0	2	92.03	2	83.67	126
	Test	72.36		66.67		85.37		71.54		81.3	
	Total	70.88		85.44		96.32		88.0		83.2	
Fold 4	Train	72.51	3	86.65	1	100.0	1	91.83	2	82.27	2
	Test	68.29		78.05		73.98		91.06		77.24	
	Total	71.68		84.96		94.88		91.68		81.28	
Fold 5	Train	71.12	3	84.66	1	94.62	3	100.0	2	82.87	1
	Test	69.92		82.93		57.72		66.67		51.22	
	Total	70.88		84.32		87.36		93.44		76.64	

# Rata Rata Hasil Pengujian

Experiment		GA Select Feature		GE Global		GE Multi		GE Tatami Multi		GE Gavrilis	
		Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features	Accuracy (%)	Features
iris.data	Train	96.28	2	98.95	1	98.81	3	98.95	2	<b>99.08</b>	1
	Test	93.78		92.56		94.78		92.56		<b>97.56</b>	
	Total	95.78		97.67		98.0		97.67		<b>98.78</b>	
balance-scale.data	Train	71.31	3	88.6	1	<b>96.25</b>	1	93.37	2	82.72	25
	Test	69.81		79.04		<b>81.68</b>		81.54		75.41	
	Total	71.01		86.72		<b>93.39</b>		91.04		81.28	
ecoli.edit	Train	97.05	5	86.96	1	<b>98.22</b>	8	97.2	7	98.03	15
	Test	<b>78.22</b>		65.11		63.56		50.63		67.2	
	Total	<b>93.4</b>		82.74		91.52		88.2		92.06	
synthesis_01	Train	73.93	3	78.83	1	99.89	3	<b>100.0</b>	2	87.97	20
	Test	71.8		42.42		<b>84.89</b>		82.22		80.76	
	Total	73.52		71.7		<b>96.95</b>		96.52		86.56	
synthesis_02	Train	78.31	4	71.45	1	99.8	3	<b>100.0</b>	3	89.49	12
	Test	74.43		39.76		73.0		<b>79.34</b>		78.01	
	Total	77.54		65.2		94.51		<b>95.92</b>		87.22	
synthesis_03	Train	72.73	5	67.87	1	99.14	5	<b>100.0</b>	4	81.99	19
	Test	40.57		36.9		63.0		<b>77.64</b>		50.8	
	Total	66.38		61.75		92.0		<b>95.58</b>		75.83	
All (Average)	Train	81.6	3	82.11	1	<b>98.69</b>	3	98.25	3	89.88	15
	Test	71.43		59.3		76.82		<b>77.32</b>		74.96	
	Total	79.6		77.63		<b>94.4</b>		94.15		86.96	

# Kesimpulan

- Secara umum GE Tatami & GE Multi dapat menciptakan set fitur yang dapat meningkatkan akurasi decision tree.
- Penggunaan SVM sebagai classifier memberikan hasil yang buruk.
- GE Tatami memberikan persyaratan yang lebih mudah dipenuhi dibandingkan GE Multi & GE Global.
- Jika pada langkah pertama GE Tatami gagal mencari fitur terbaik, maka langkah selanjutnya tidak akan bisa memperbaiki akurasi.

# Saran

- Penggabungan GE Multi & GE Tatami diharapkan dapat memberikan hasil yang lebih baik.
- Optimalisasi fitness function dapat meningkatkan kecepatan komputasi



**Thank you ...**

ありがとう ...

谢谢 ...

**Terima kasih ...**

