# Fuzzy Systems

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# Logic [RUS95]

| **Jenis *logic*** | **Apa yang ada di dunia nyata** | **Apa yang dipercaya *Agent* tentang fakta** |
|---|---|---|
| *Propositional logic* | fakta | benar/salah /tidak diketahui |
| *First-order logic* | fakta, objek, relasi | benar/salah /tidak diketahui |
| *Temporal logic* | fakta, objek, relasi, waktu | benar/salah /tidak diketahui |
| *Probability theory* | fakta | derajat kepercayaan [0,1] |
| *Fuzzy logic* | derajat kebenaran | derajat kepercayaan [0,1] |

**Peringatan**:

1 dari 50 botol ini berisi cairan kimia mematikan yang warna dan rasanya sama dengan air mineral. Anda akan mati seketika jika meminumnya.

**Probability**

1

**Peringatan:**

Satu plastik cairan kimia mematikan dicampurkan ke dalam 50 botol ini secara tidak merata. Anda tidak akan mati jika cuma minum satu botol, tetapi anda akan menderita pusing ringan/berat.

**Fuzziness**

2

# Fuzziness & Probability

- Banyak peneliti berbeda pendapat tentang teori *fuzzy* dan teori probabilitas
- Sebenarnya, kedua teori tersebut memang sama-sama untuk menangani masalah ketidakpastian
- Tetapi, perbedaannya adalah pada jenis ketidakpastian yang ditangani

# *Fuzzy Systems*

- Ide dasar *fuzzy systems* adalah *fuzzy logic* dan *fuzzy sets*
- *Fuzzy logic* sudah lama dipikirkan oleh para filsuf Yunani kuno
- Plato: filsuf pertama yang meletakkan fondasi *fuzzy logic*
- Plato: "Terdapat area ketiga selain Benar dan Salah"
- Rumi: "Jauh di balik benar dan salah, ada sebuah padang terbuka. Kutemui kau di sana."
- *Fuzzy logic* menghilang selama 2 milenium
- Muncul kembali pada era 1960-an
- Konsep *fuzzy logic* yang sangat sistematis pertama kali diusulkan oleh Lotfi A. Zadeh, the University of California, Berkeley, Amerika Serikat

# *Classical Sets*

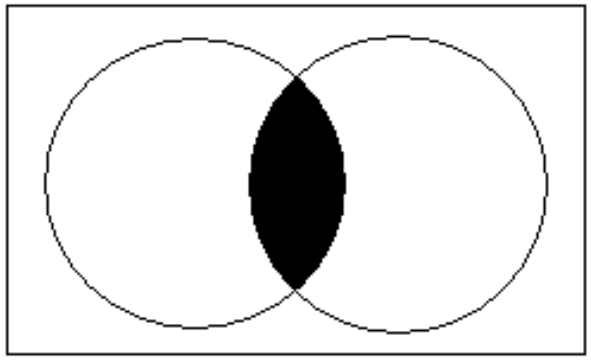
- Teori himpunan klasik: suatu himpunan secara intuitif adalah setiap kumpulan elemen-elemen
- Himpunan klasik dikenal juga sebagai ***crisp set***
- *Crisp = clear and distinct* [OXF95]
- *Crisp set* : himpunan yang membedakan anggota dan non anggotanya dengan batasan yang jelas

# Contoh

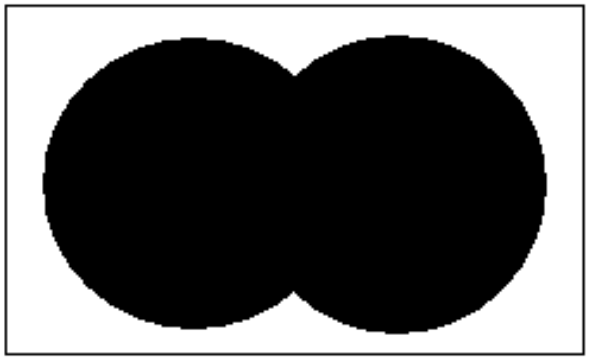
$$A = \{x \mid x \text{ bilangan bulat}, x > 6\}$$

Anggota himpunan *A* adalah 7, 8, 9, ...
Bukan anggota *A* adalah 6, 5, 4, ...

# *Intersection, union, complement, difference*

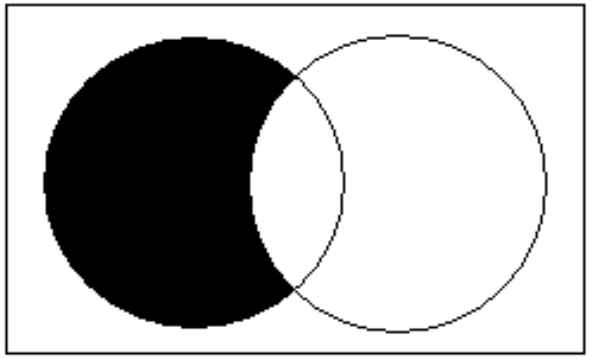


(a)



(b)

(c)



(d)

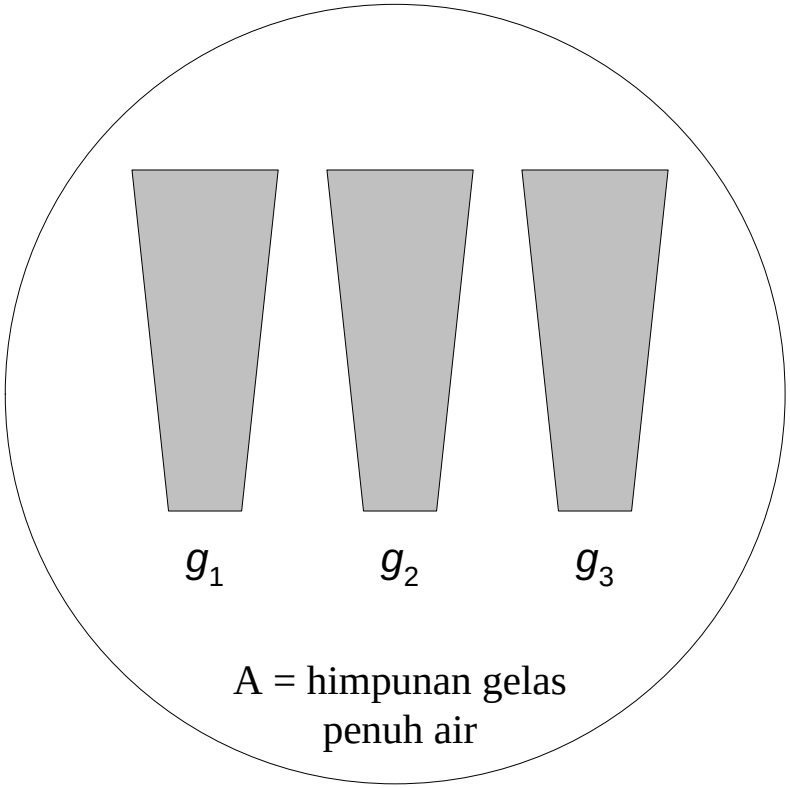
# *Excluded Middle Laws*

$$A \cup \overline{A} = U$$

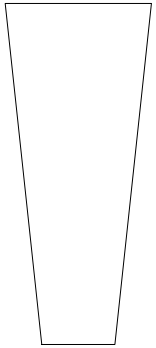
# *Law of Contradiction*

$$A \cap \overline{A} = \phi$$

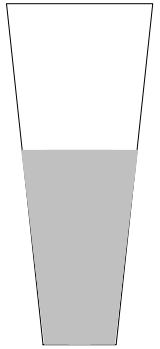
**Semesta *U***




A = himpunan gelas penuh air




Gelas kosong termasuk $\overline{A}$




**= ?**

Gelas yang berisi air setengah bagian tidak termasuk $A$ maupun $\overline{A}$

Aku adalah pembohong.
Jangan percaya padaku.

Pernyataan $P$ dan negasinya sama-sama benar. $T(P) = T(\overline{P})$

# Fungsi Karakteristik

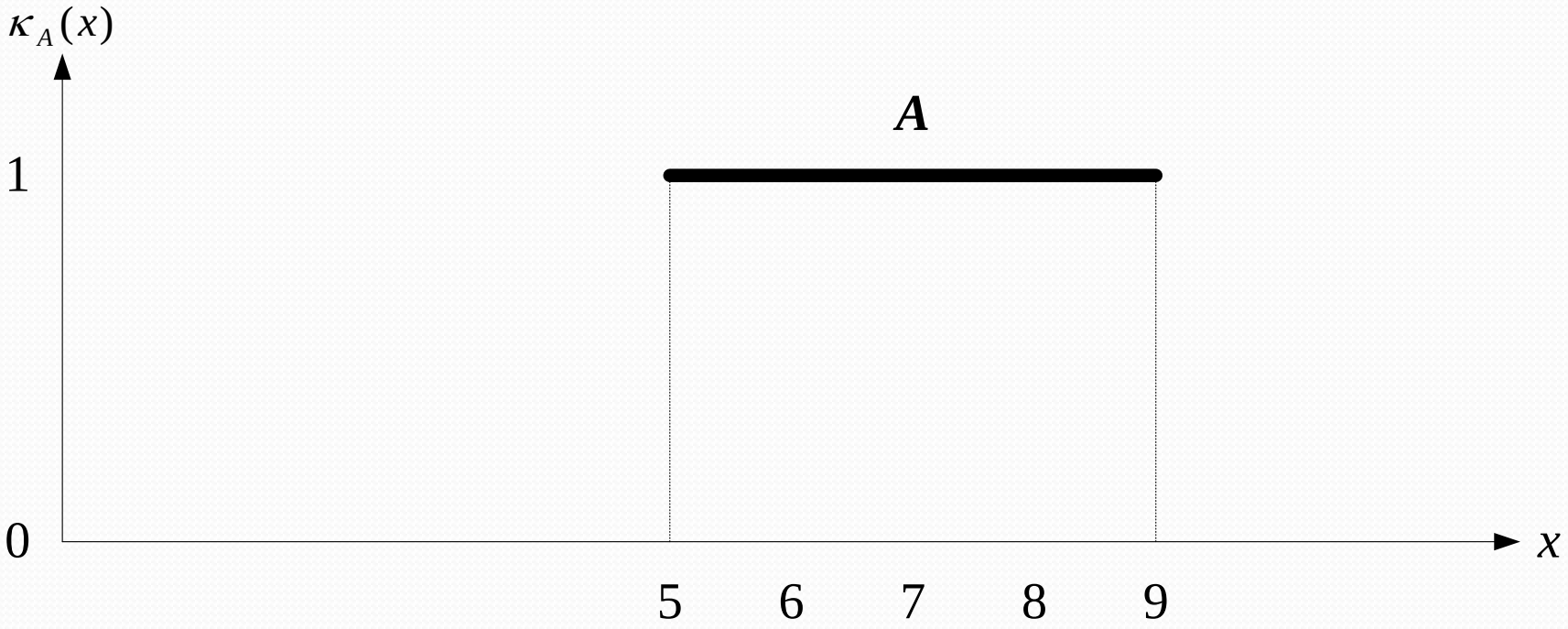
Fungsi karakteristik dari himpunan A adalah suatu pemetaan

$$\kappa_A : U \to \{0,1\}$$

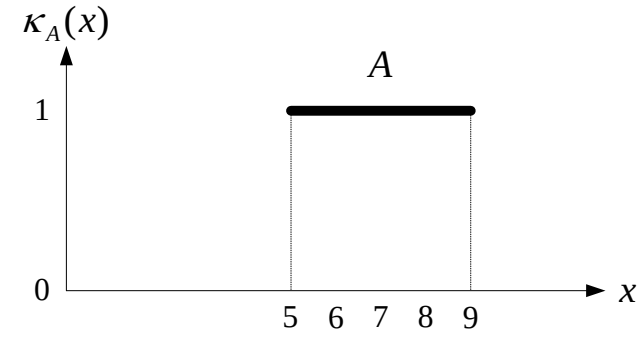
sedemikian hingga, untuk semua $x$,

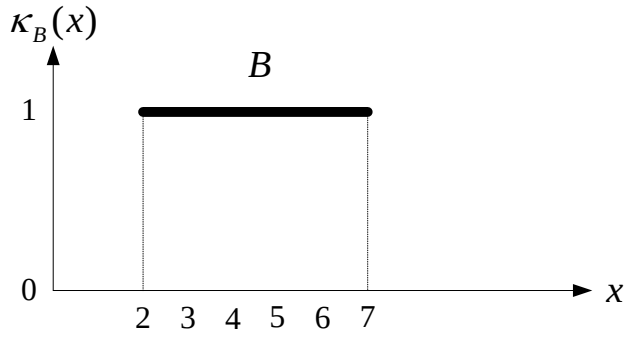
$$\kappa_A(x) = \begin{cases} 1, & \text{jika } x \in A; \\ 0 & \text{untuk kasus lainnya.} \end{cases}$$

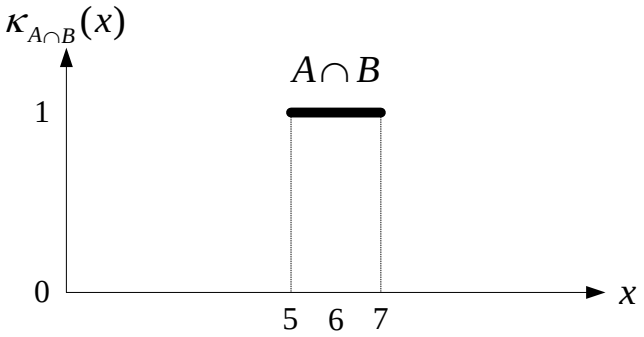
# Fungsi Karakteristik *Classical Set*



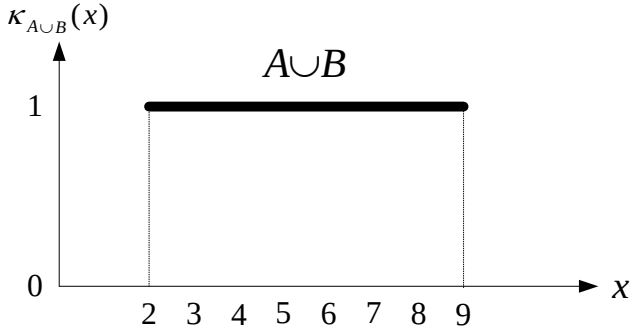

A = himpunan klasik semua bilangan bulat positif lebih dari 4 dan dan kurang dari 10 atau {5, 6, …, 9}.



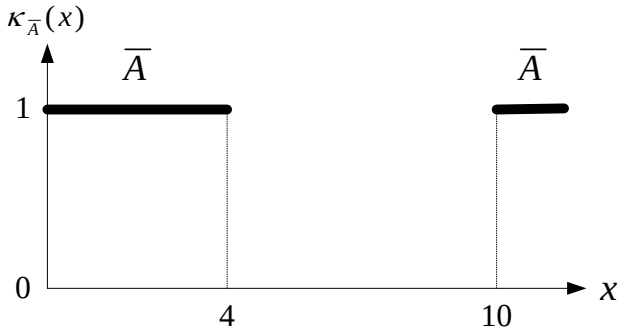



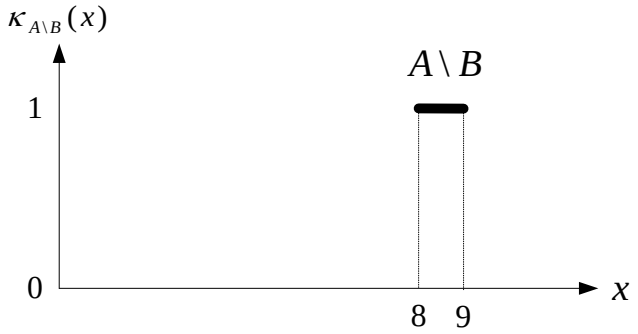

***Intersection***




***Union***




***Complement***




***Difference***

# Kasus 1: Pemberian Beasiswa

| Mahasiswa | IPK | Gaji Ortu (Rp/bulan) |
|---|---|---|
| A | 3,00 | 10 juta |
| B | 2,99 | 1 juta |

if $IPK \geq 3{,}00$ and $Gaji \leq 10$ juta

then Dapat Beasiswa

# *Fuzzy Sets*

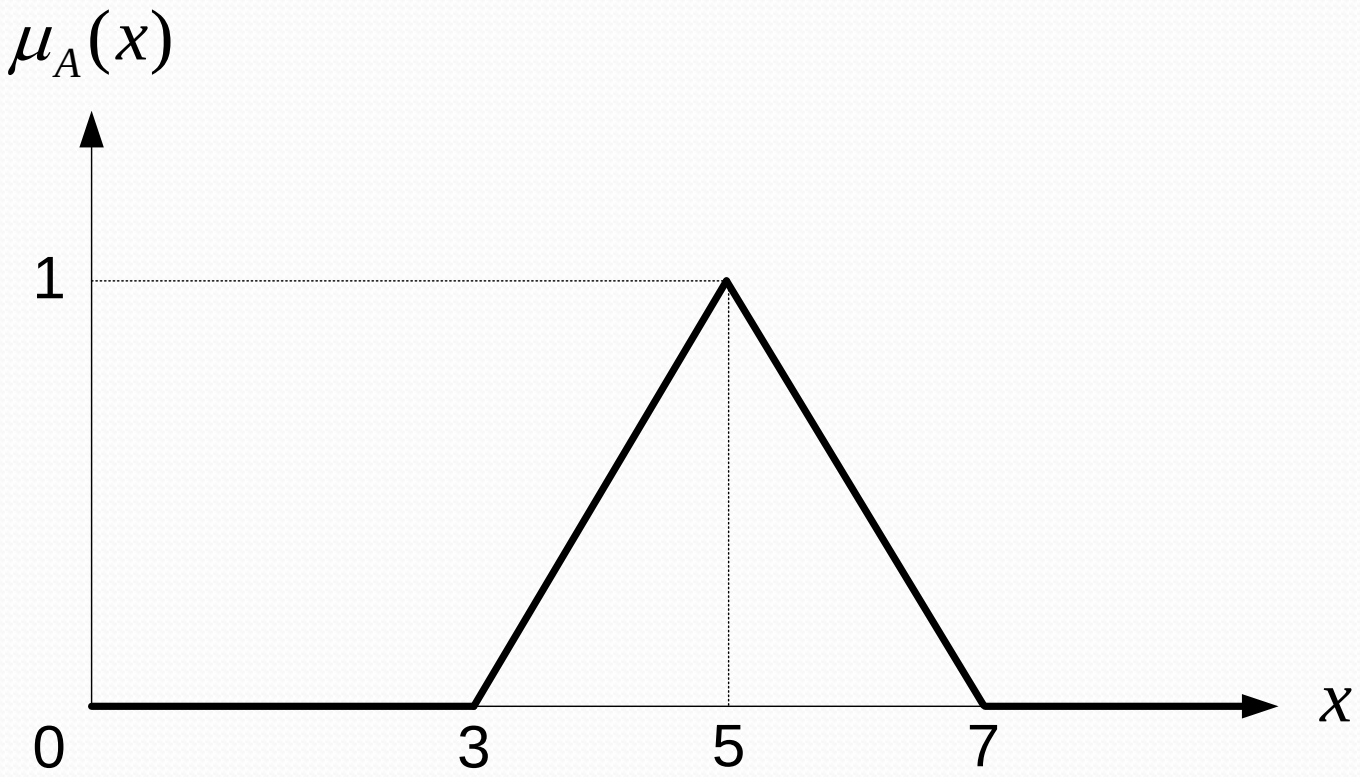
- *D*igunakan untuk penalaran yang lebih manusiawi.
- Misalkan *U* adalah *universe of discourse* (semesta pembicaraan) dan *x* adalah anggota *U*.
- Suatu *fuzzy set A* di dalam *U* didefinisikan sebagai suatu *membership function* atau fungsi keanggotaan, yang memetakan setiap objek di *U* menjadi suatu nilai real dalam interval [0, 1].
- Nilai-nilai menyatakan derajat keanggotaan *x* di dalam *A*.

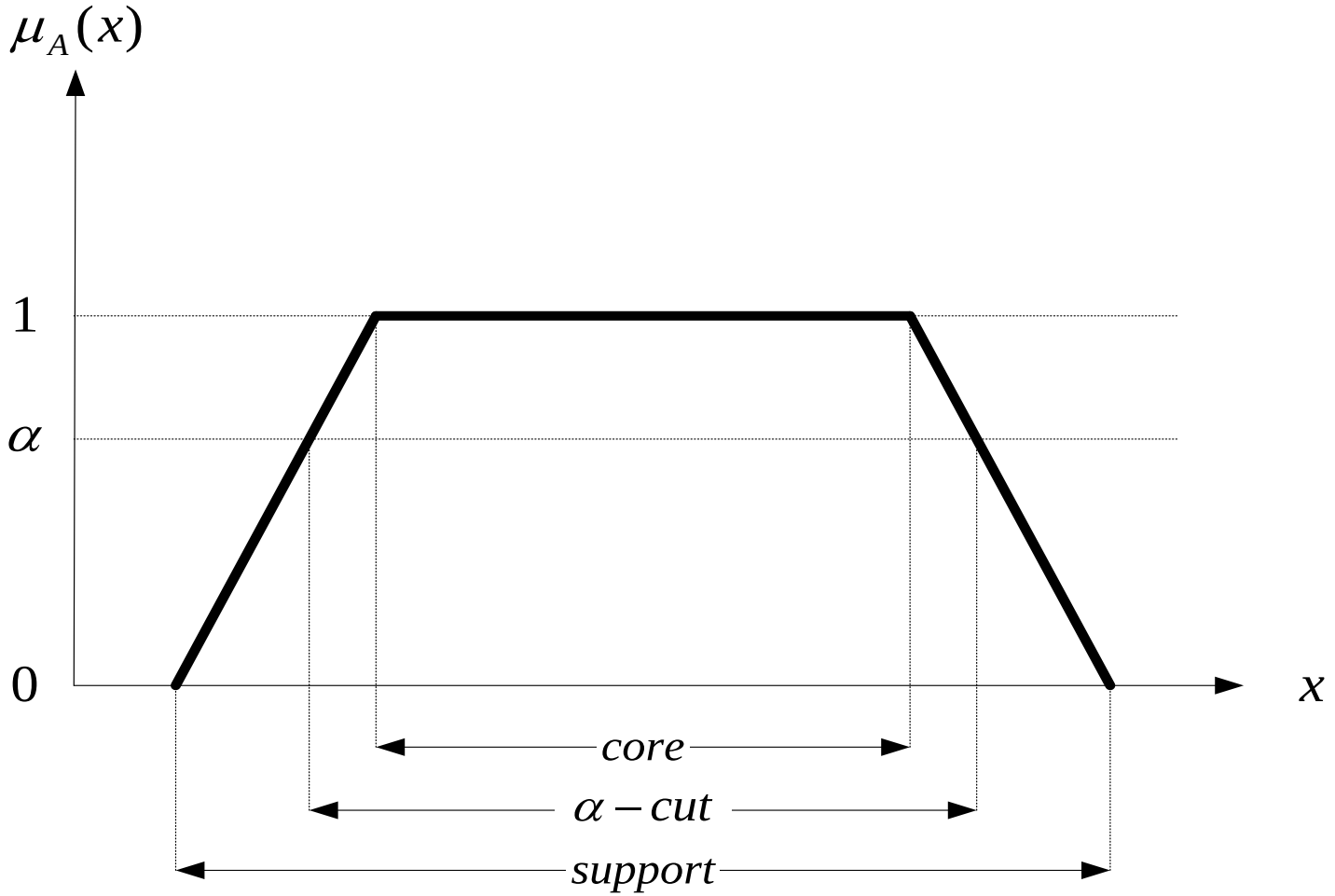
| Suhu ($^0$ C) | Dingin | Hangat | Panas |
|---|---|---|---|
| 5 | 1 | 0,1 | 0 |
| 15 | 0,9 | 0,8 | 0 |
| 25 | 0,5 | 1 | 0,6 |
| 35 | 0,1 | 0,6 | 0,9 |
| 45 | 0 | 0,2 | 1 |

# *Fuzzy Set*

- Dingin = {5, 15, 25, 35} dan derajat keanggotaannya dinyatakan oleh $\mu_{Dingin}$ = {1; 0,9; 0,5; 0,1}
- Hangat = {5, 15, 25, 35, 45} dan derajat keanggotaannya dinyatakan oleh $\mu_{Hangat}$ = {0,1; 0,8; 1; 0,6; 0,2}
- Panas = {25, 35, 45} dan derajat keanggotaannya dinyatakan oleh $\mu_{Panas}$ = {0,6; 0,9; 1}

# Graphical Representation

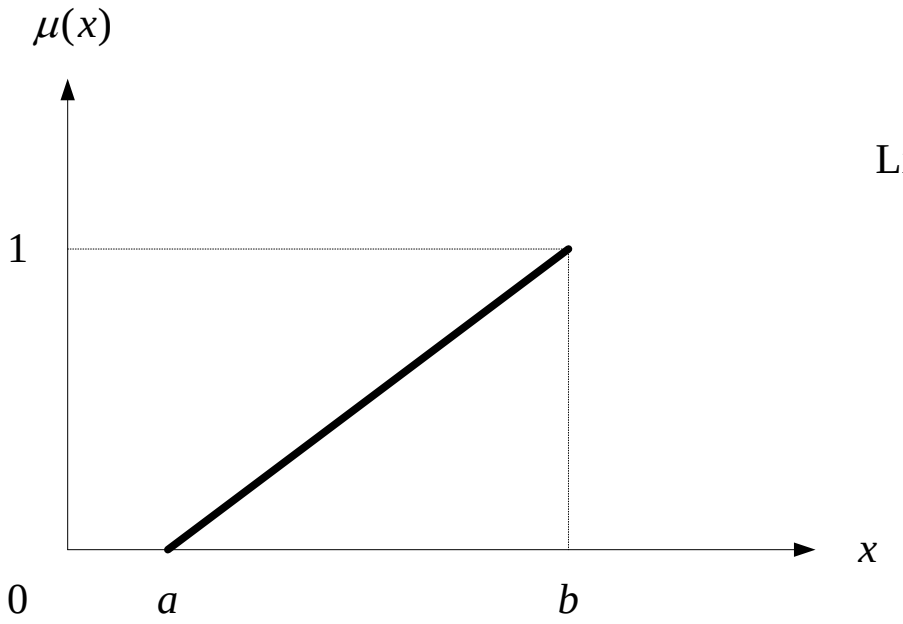




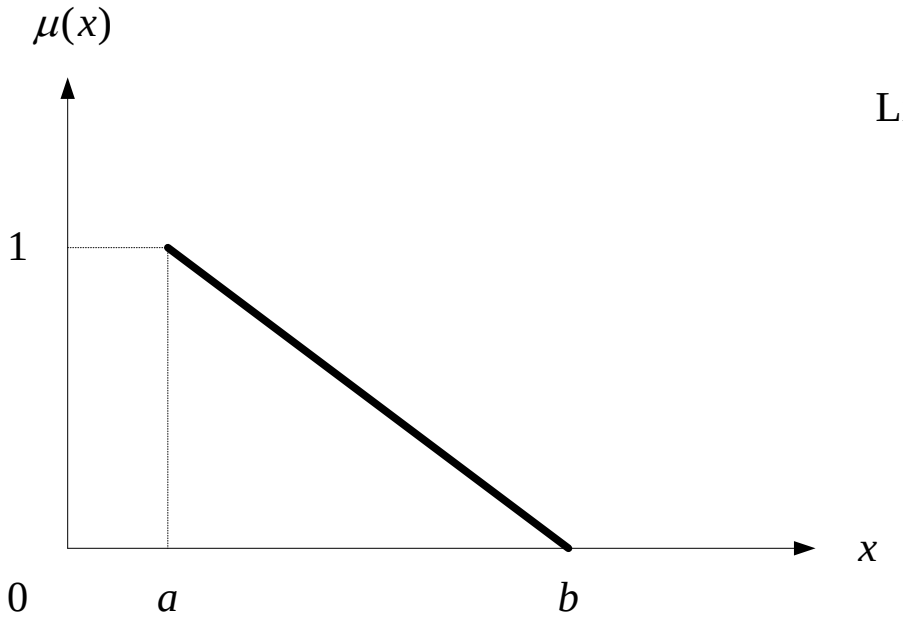

Fungsi keanggotaan $\mu_A$ dengan *core*, $\alpha - cut$ dan *support*

# Bentuk Fungsi Keanggotaan

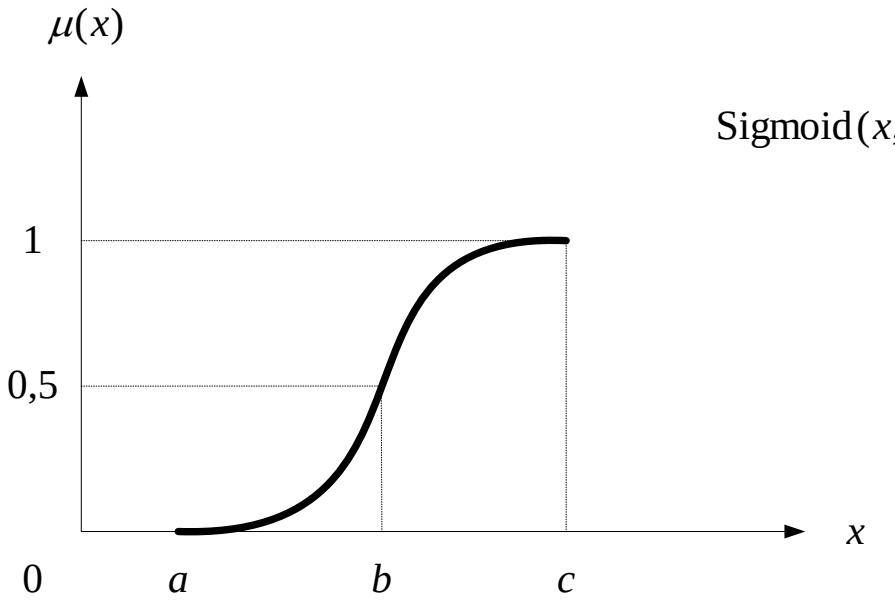
- Fungsi Linier
- Fungsi *Sigmoid*
- Fungsi Segitiga
- Fungsi Trapesium
- Fungsi Berbentuk *Bell*:
  - *Phi*
  - *Beta*
  - *Gauss*



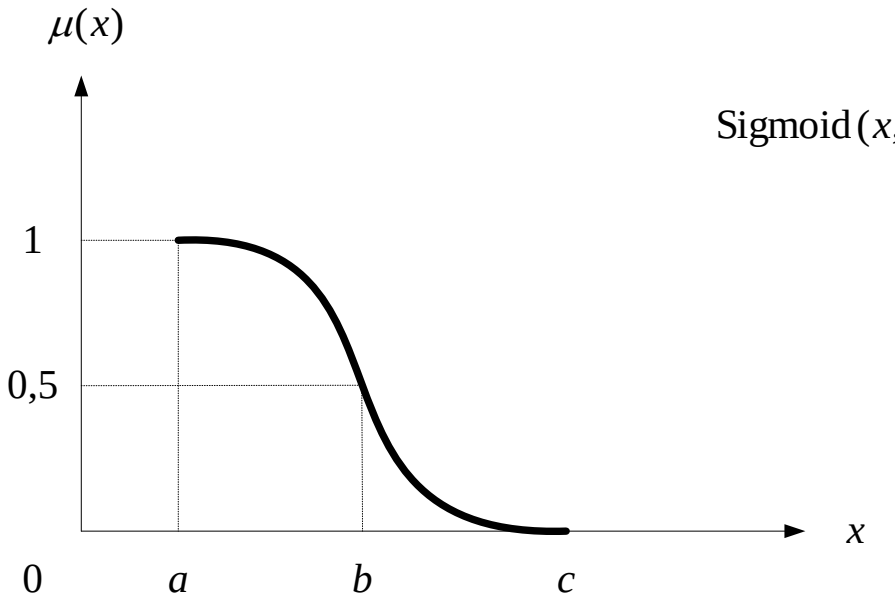

$$\text{LinierNaik}(x,a,b) = \begin{cases} 0, & x \le a \\ (x-a)/(b-a), & a < x \le b \end{cases}$$



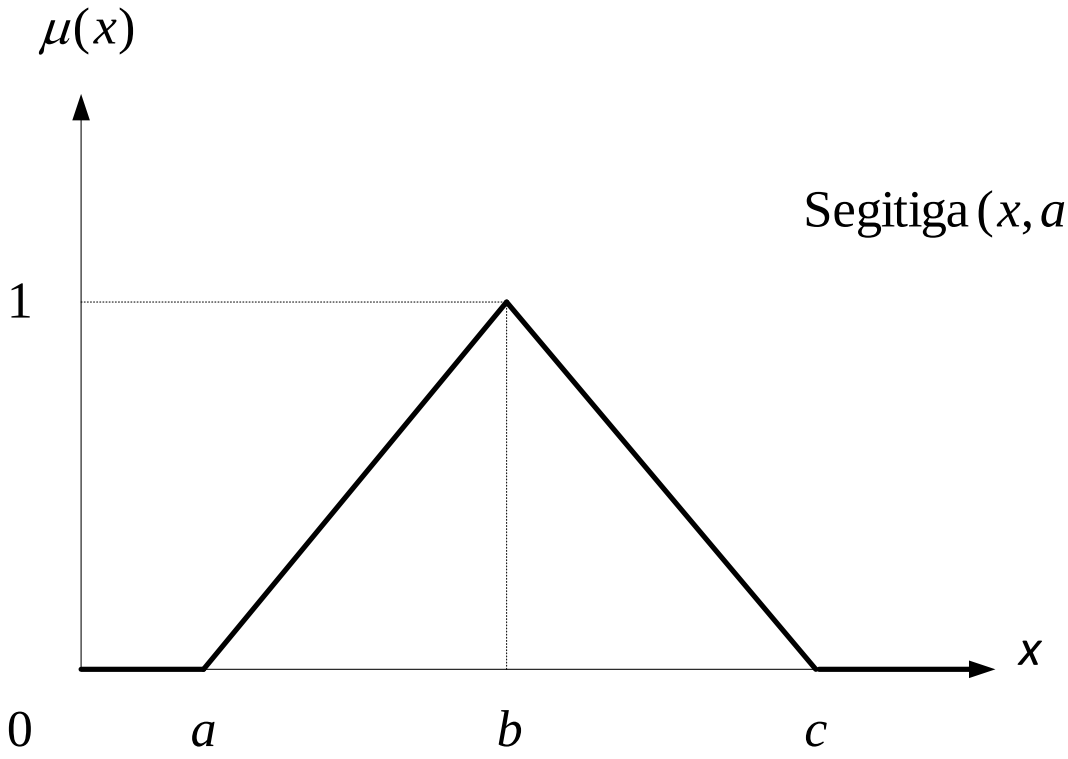

$$\text{LinierTurun}(x,a,b) = \begin{cases} (b-x)/(b-a), & a \le x < b \\ 0, & x \ge b \end{cases}$$



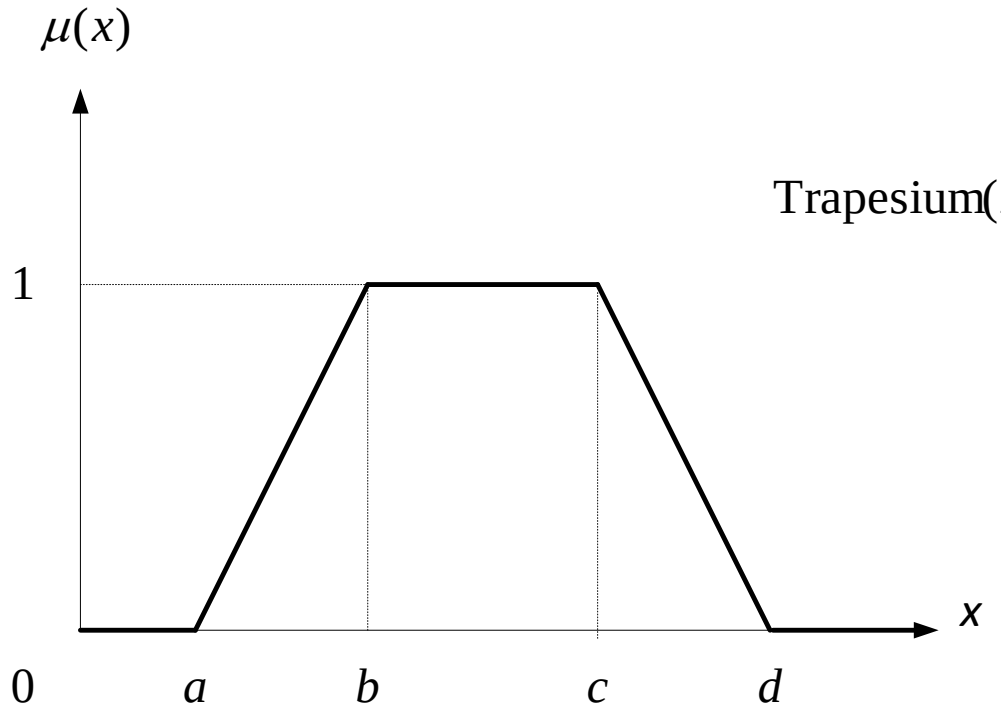

$$\text{Sigmoid}(x,a,b,c)=\begin{cases}0, & x\le a\\ 2((x-a)/(c-a))^2, & a<x\le b\\ 1-2((c-x)/(c-a))^2, & b<x<c\\ 1, & c\le x\end{cases}$$



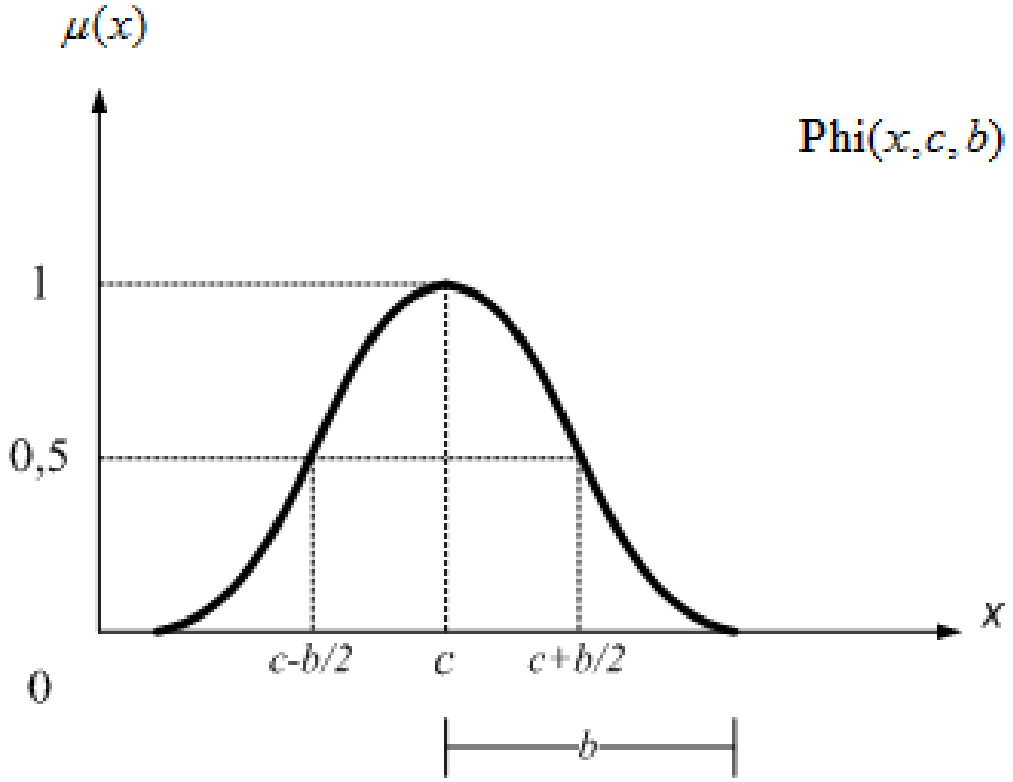

$$\text{Sigmoid}(x,a,b,c)=\begin{cases}1, & x\le a\\ 1-2((x-a)/(c-a))^2, & a<x\le b\\ 2((c-x)/(c-a))^2, & b<x<c\\ 0, & x\ge c\end{cases}$$



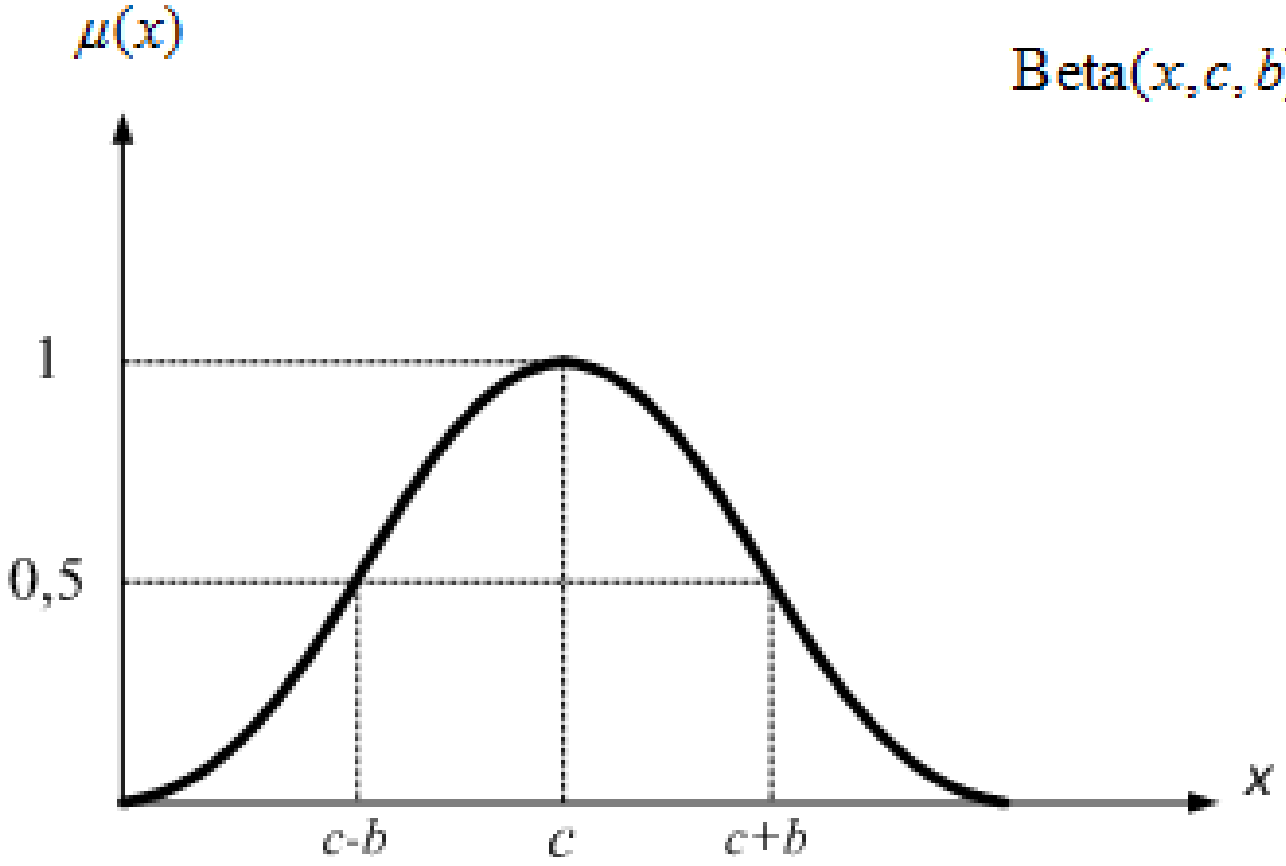

$$\text{Segitiga}(x,a,b,c)=\begin{cases}0, x \le a, x \ge c \\ (x-a)/(b-a),\ a < x \le b \\ -(x-c)/(c-b), b < x \le c\end{cases}$$




$$\text{Trapesium}(x,a,b,c,d) = \begin{cases} 0, x \le a, x \ge d \\ (x-a)/(b-a), a < x < b \\ 1, b \le x \le c \\ -(x-d)/(d-c), c < x \le d \end{cases}$$

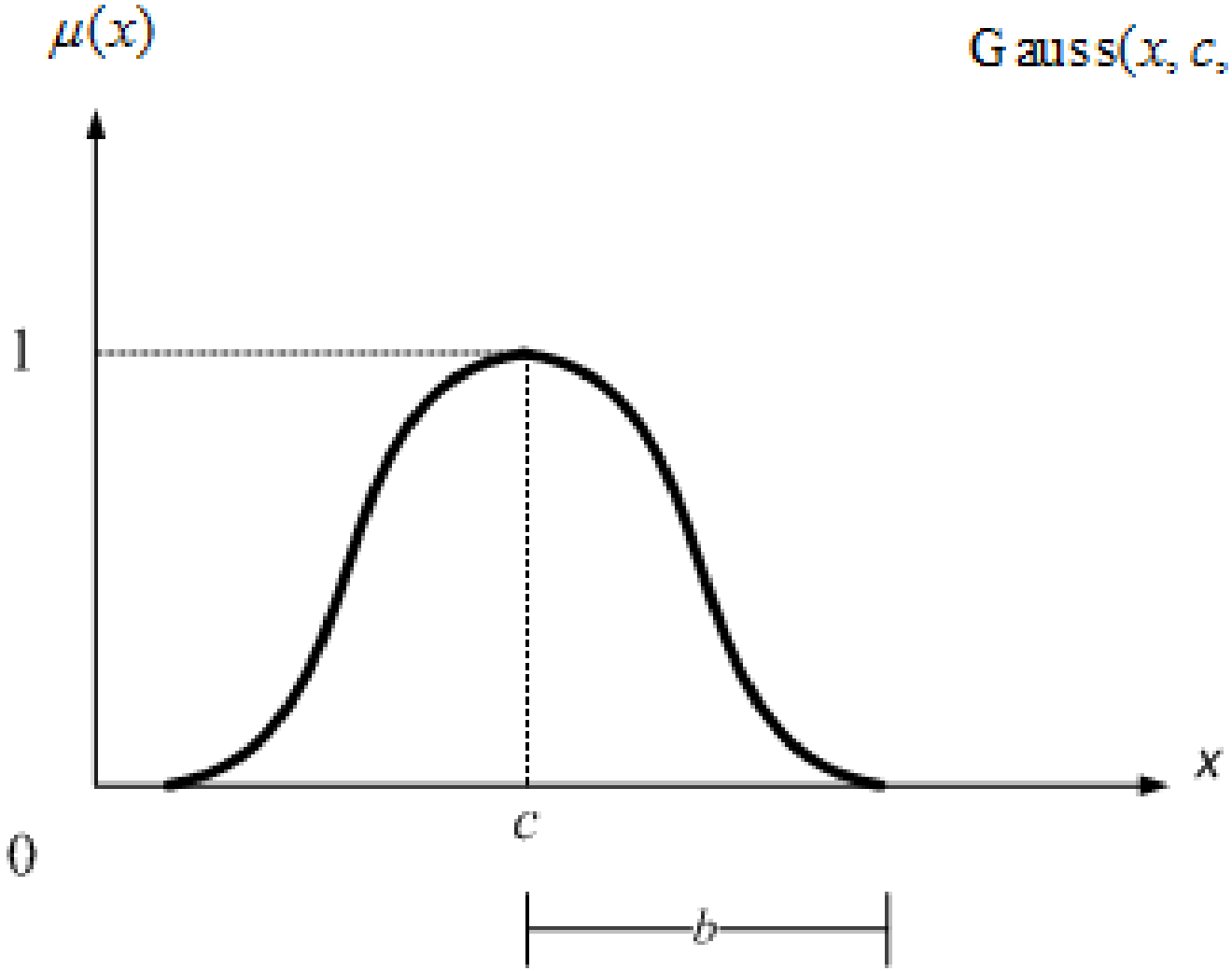



$$\mathrm{Phi}(x,c,b)=\begin{cases}\mathrm{Sigmoid}\left(x,c-b,c-\frac{b}{2},c\right), & x\le c\\ 1-\mathrm{Sigmoid}\left(x,c,c+\frac{b}{2},c+b\right), & x>c\end{cases}$$

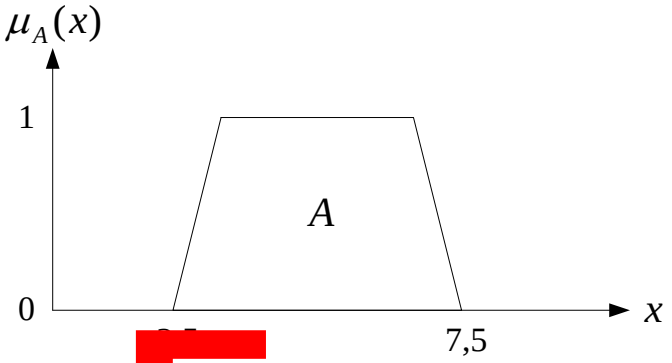



$$\mathrm{Beta}(x,c,b)=\frac{1}{\left(1+\left|\frac{x-c}{b}\right|^{2}\right)}$$

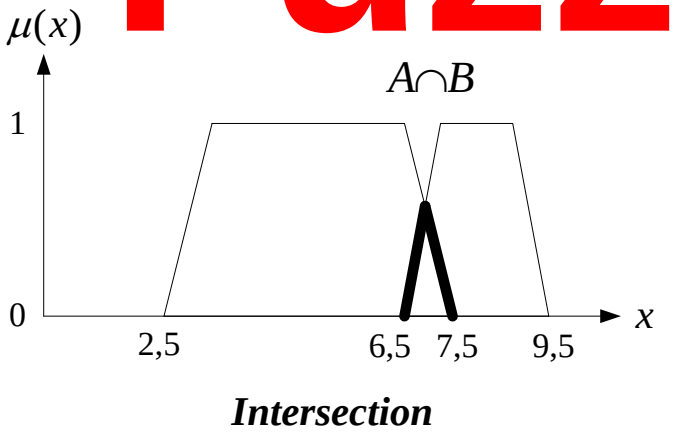
$$\mathrm{Gauss}(x, c, b) = e^{-b(c-x)^2}$$



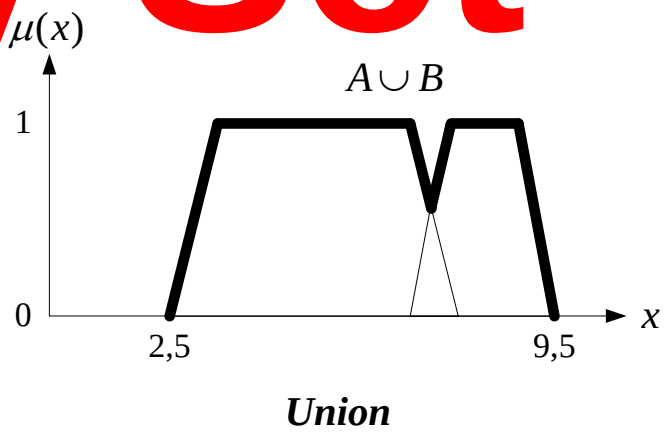
# Fuzzy Set



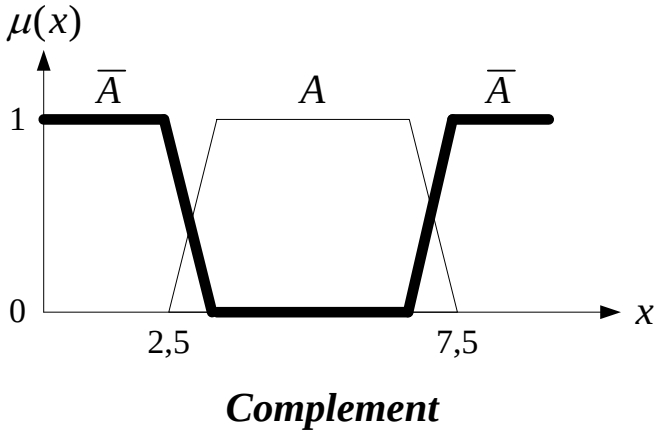




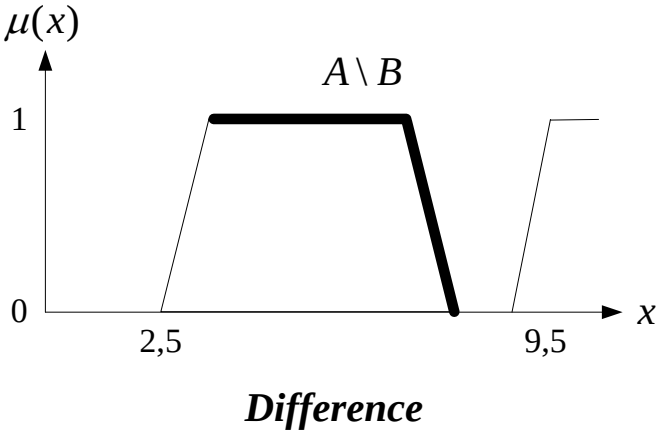

***Intersection***




***Union***

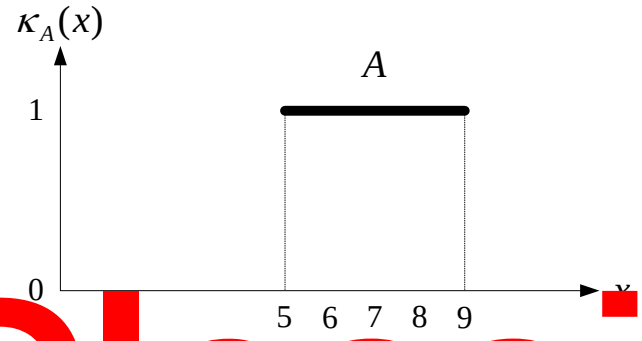


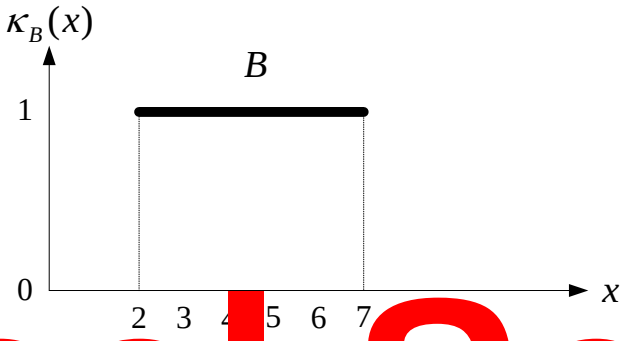

***Complement***

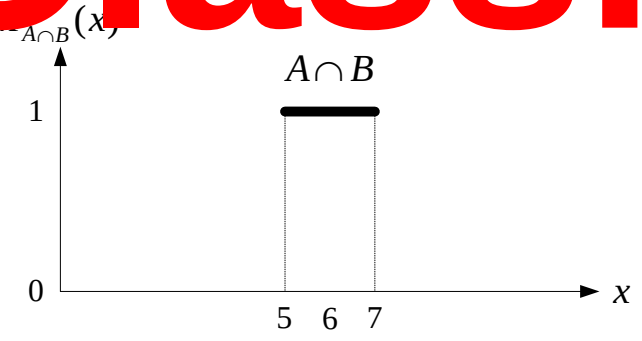



***Difference***

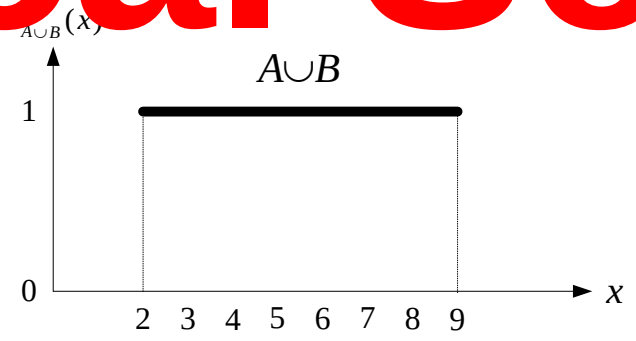
# Classical Set



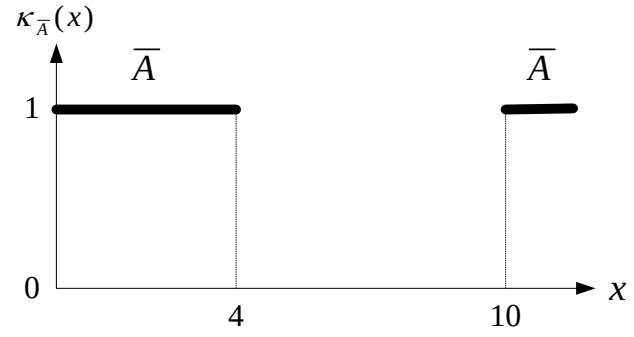



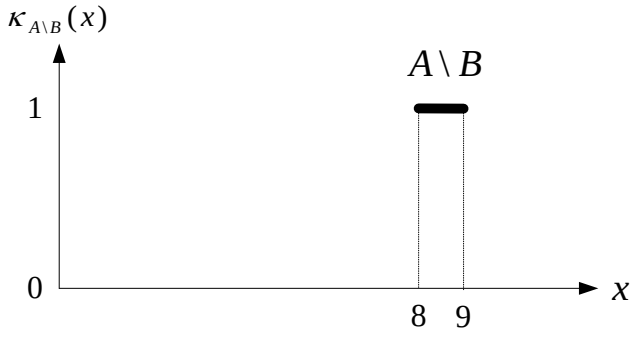

***Intersection***




***Union***




***Complement***




***Difference***

# Logical connectives & Implication

- Dalam bahasa manusia, banyak percakapan yang menggunakan kalimat yang tidak pasti kebenarannya
  - ’**Hampir semua** orang suka permen’
  - ’**Sepertinya** dia anak yang pintar’
- Misalkan *P* adalah suatu *fuzzy logic proposition*
- Nilai kebenaran *P* adalah [0, 1].
  - Nilai 0 menyatakan bahwa *P* adalah salah
  - Nilai 1 menyatakan bahwa P adalah benar

# Logical connectives & Implication

$$T : P \rightarrow [0,1]$$

*T* adalah fungsi kebenaran yang memetakan *P* ke suatu nilai dalam interval [0, 1].

# Logical Connectives

- *Negation* $T(\neg P) = 1 - T(P)$
- *Disjunction* $T(P \vee Q) = \max\{T(P), T(Q)\}$
- *Conjunction* $T(P \wedge Q) = \min\{T(P), T(Q)\}$

# *Approximate Reasoning*

A : 'Apakah dia anak yang **pintar**?'

B : '**Sepertinya begitu.**'

A : 'Apakah Indeks Prestasi dan hasil tes psikologinya **bagus**?'

B : 'Ya, keduanya **sangat bagus**.'

A : 'Apakah dia layak mendapatkan beasiswa?'

B : 'Ya, **sepertinya** itu adalah keputusan yang **baik**.'

# *Approximate Reasoning*

$P_1$ : Sebagian besar mahasiswa suka membaca

$P_2$ : Dani adalah mahasiswa

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$P_3$ : Sepertinya Dani suka membaca

# *Reasoning* yang Pasti

$P_1$ : Semua manusia pasti akan mati

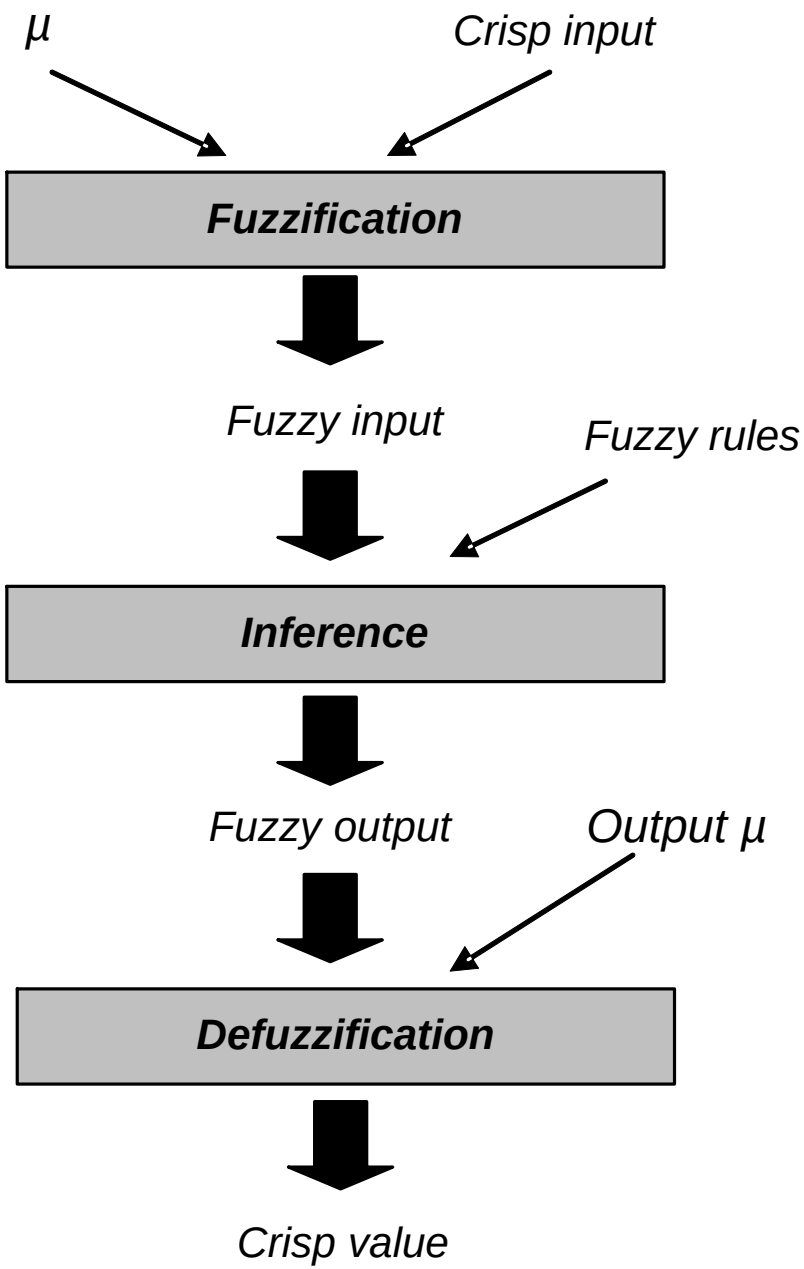
$P_2$ : Dani adalah manusia

---

$P_3$ : Dani pasti akan mati

# *Fuzzy Inference Systems*

- Variabel linguistik adalah suatu interval numerik dan mempunyai nilai-nilai linguistik, yang semantiknya didefinisikan oleh fungsi keanggotaannya.
- Misalnya, *Suhu* adalah suatu variabel linguistik yang bisa didefinisikan pada interval [-10°C, 40°C].
- Variabel tersebut bisa memiliki nilai-nilai linguistik seperti 'Dingin', 'Hangat', 'Panas' yang semantiknya didefinisikan oleh fungsi-fungsi keanggotaan tertentu.


μ
Crisp input
Fuzzification
Fuzzy input
Fuzzy rules
Inference
Fuzzy output
Output μ
Defuzzification
Crisp value

# Model Inferensi

- Mamdani → *Intuitive*
- Sugeno → *Control*

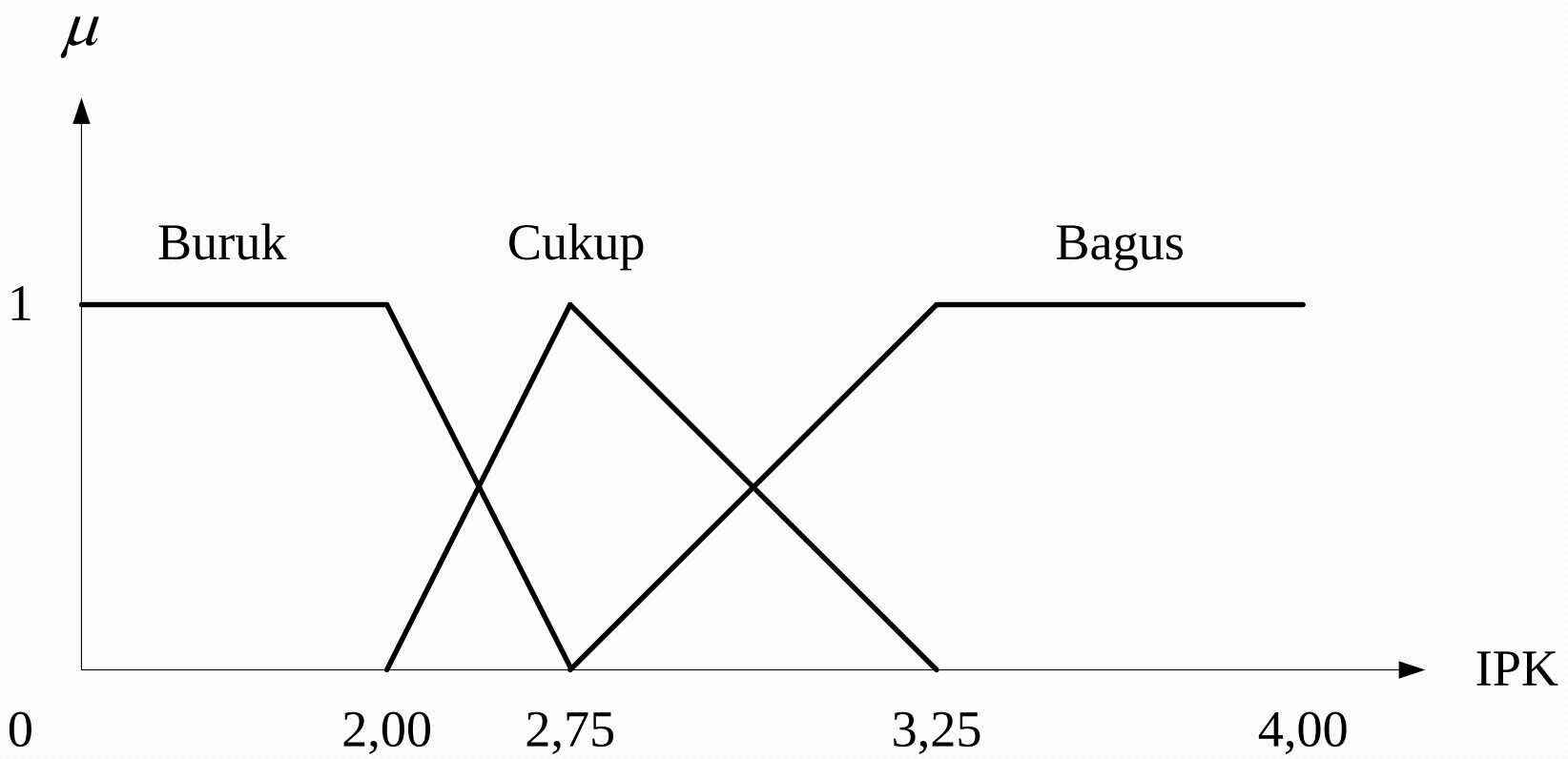
# Kasus 1: Pemberian Beasiswa

| Mahasiswa | IPK | Gaji Ortu (Rp/bulan) |
|---|---|---|
| A | 3,00 | 10 juta |
| B | 2,99 | 1 juta |

# Model Mamdani

- Untuk membangun sistem yang penalarannya menyerupai perasaan manusia
- Perhitungannya kompleks sehingga membutuhkan waktu relatif lama
- Ketelitiannya tinggi

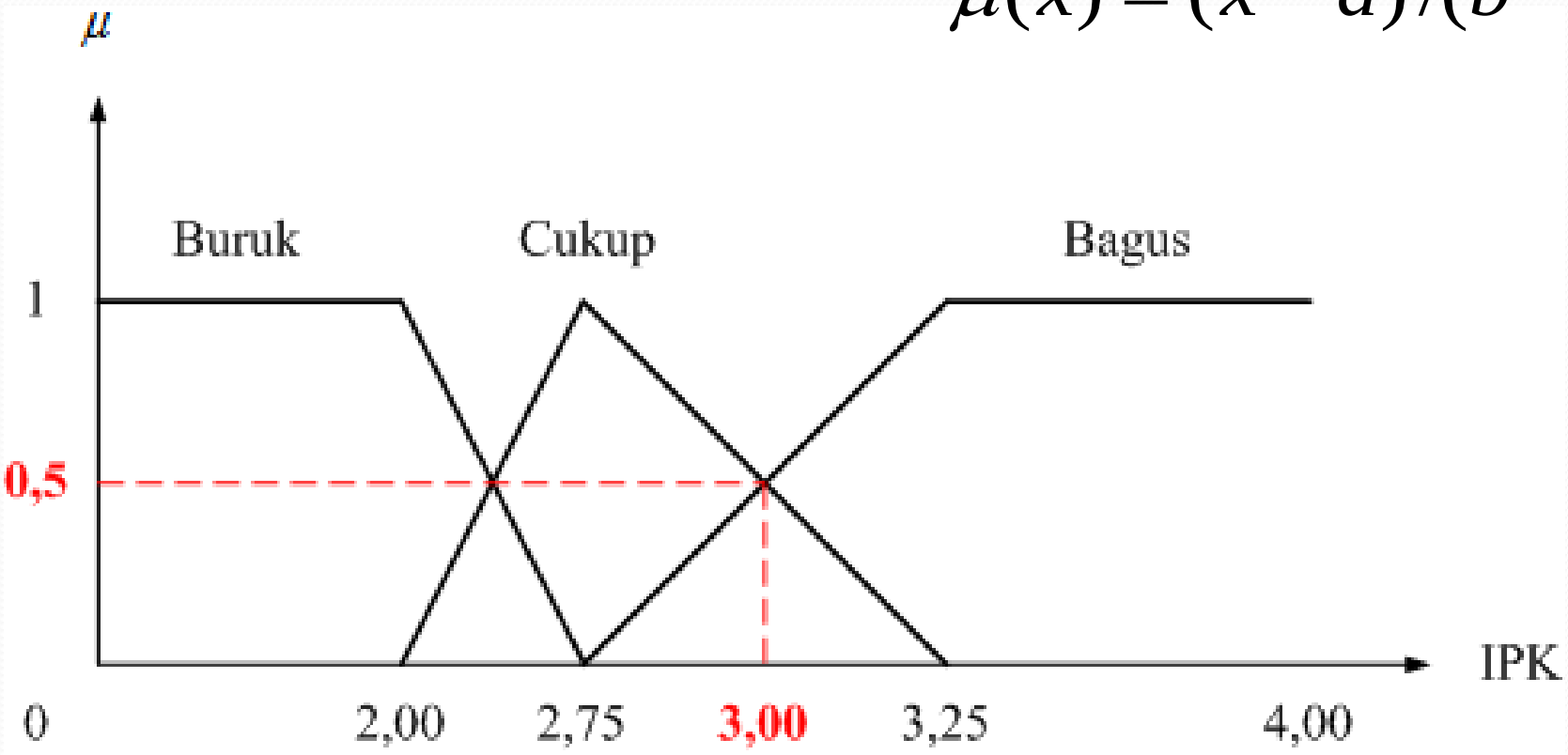
# FK untuk IPK



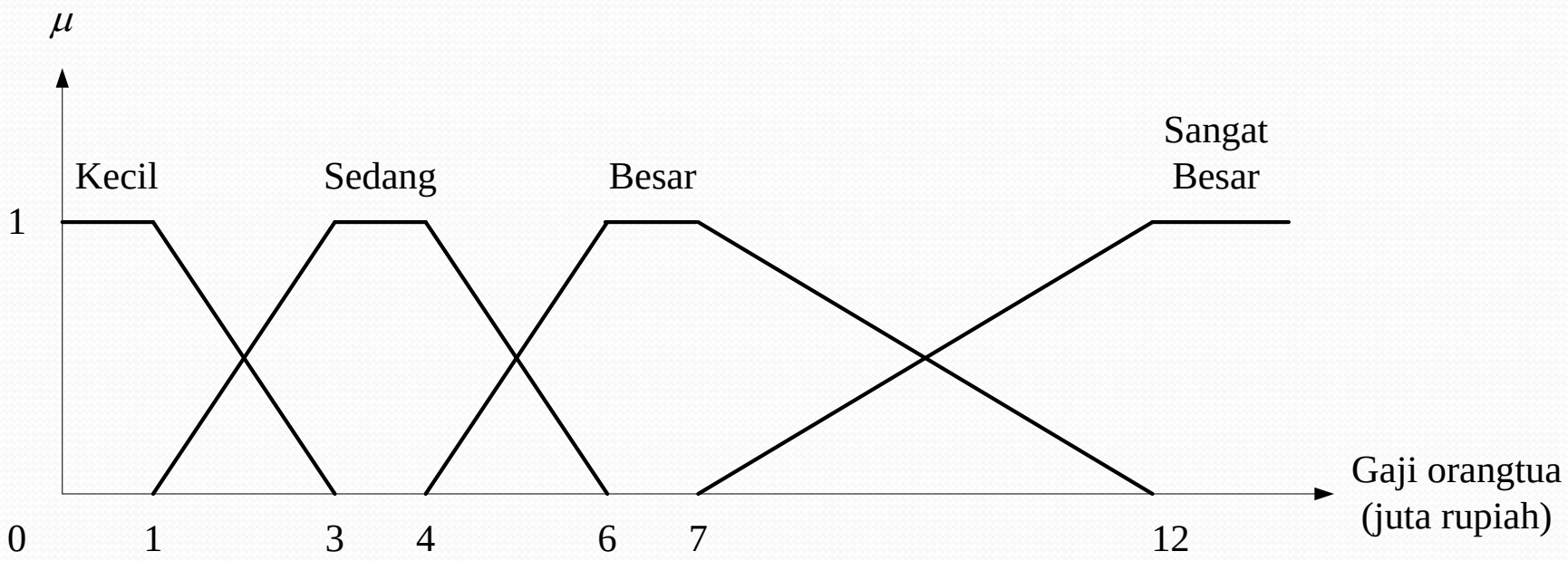
# IPK mahasiswa A

$$\mu(x) = -(x-c)/(c-b)$$

$$\mu(x) = (x-a)/(b-a)$$



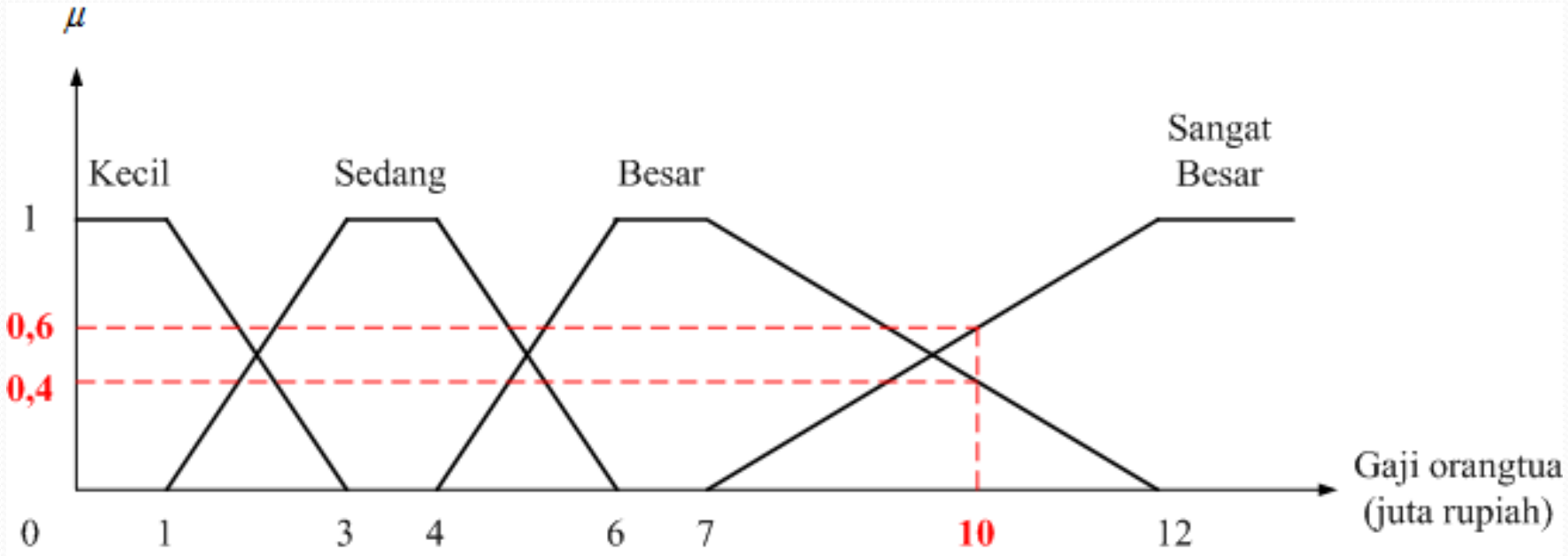
# FK Gaji Orangtua



# Gaji Ortu mhs A

$$\mu(x) = -(x-d)/(d-c), c < x \leq d$$

$$\mu(x) = (x-a)/(b-a), a < x < b$$

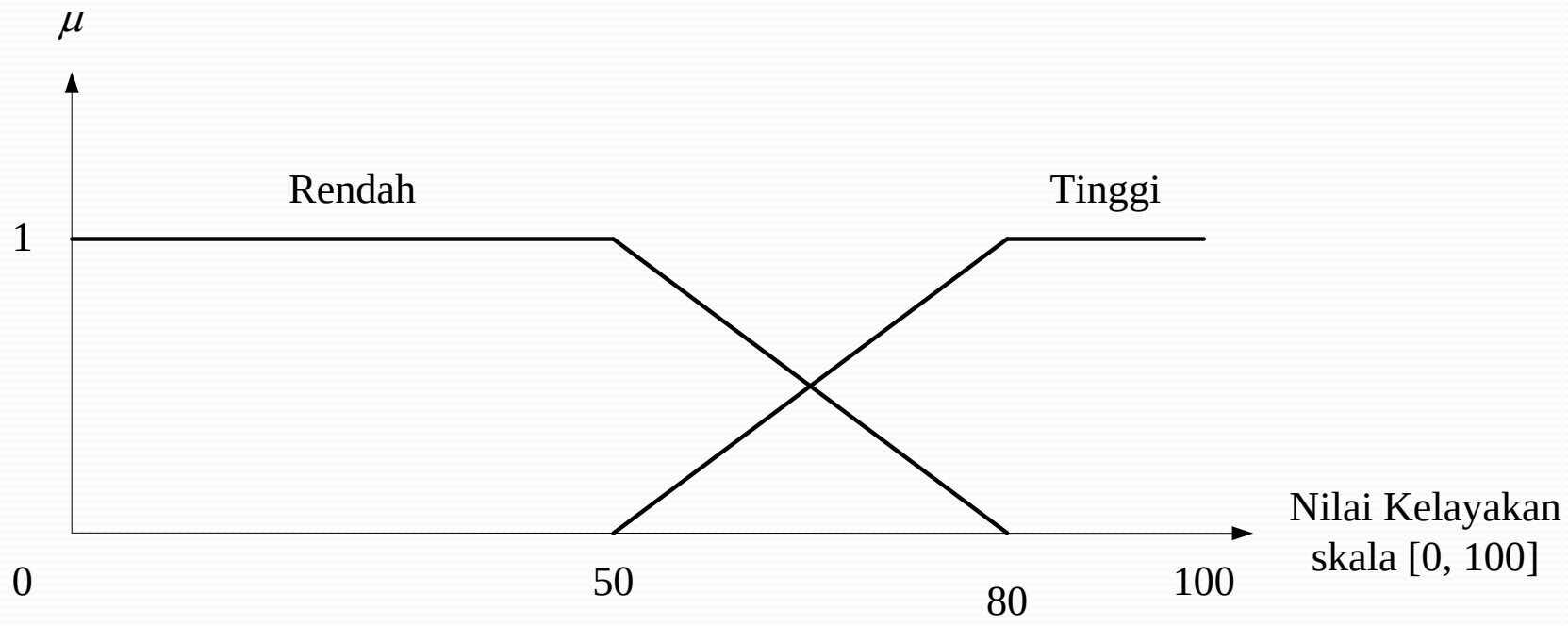


# *Fuzzification* untuk mhs A

IPK = 3,00
Gaji Orangtua = 10 juta/bulan

IPK = **Cukup** (0,5)
IPK = **Bagus** (0,5)
Gaji Orangtua = **Besar** (0,4)
Gaji Orangtua = **Sangat Besar** (0,6)

# Fungsi Keanggotaan Nilai Kelayakan

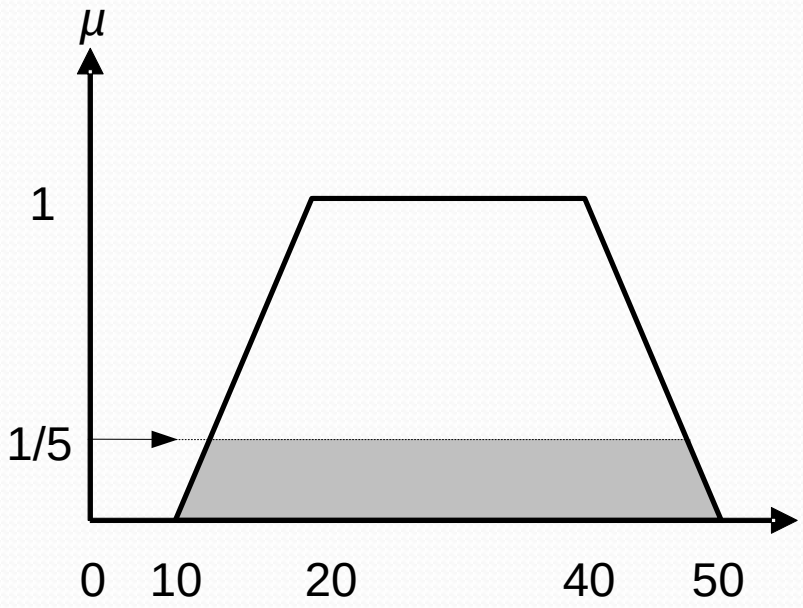


# Aturan Fuzzy untuk Nilai Kelayakan

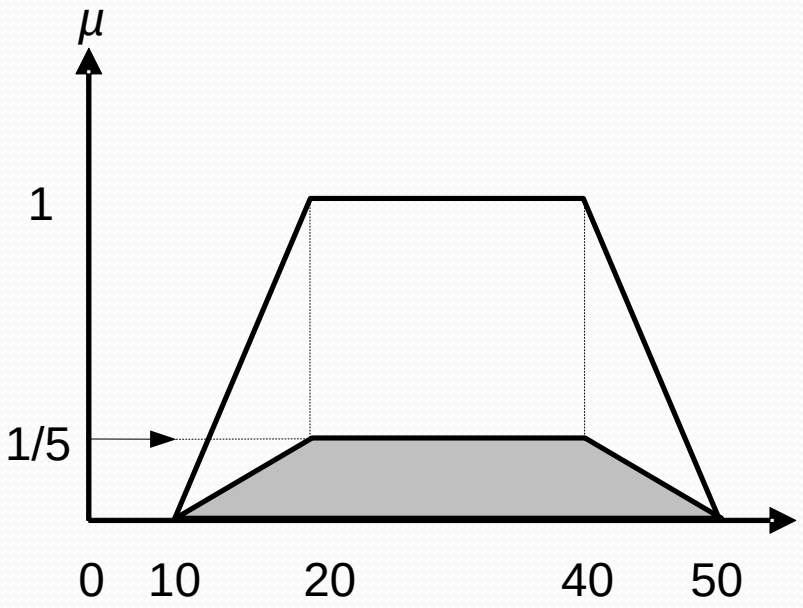
| IPK \ Gaji | Kecil | Sedang | Besar | Sangat Besar |
|---|---|---|---|---|
| Buruk | Rendah | Rendah | Rendah | Rendah |
| Cukup | Tinggi | Rendah | Rendah | Rendah |
| Bagus | Tinggi | Tinggi | Tinggi | Rendah |

1. IF $IPK$ = Buruk AND $Gaji$ = Kecil THEN $NK$ = Rendah
2. IF $IPK$ = Buruk AND $Gaji$ = Sedang THEN $NK$ = Rendah
3. IF $IPK$ = Buruk AND $Gaji$ = Besar THEN $NK$ = Rendah
4. IF $IPK$ = Buruk AND $Gaji$ = Sangat Besar THEN $NK$ = Rendah
5. IF $IPK$ = Cukup AND $Gaji$ = Kecil THEN $NK$ = Tinggi
6. IF $IPK$ = Cukup AND $Gaji$ = Sedang THEN $NK$ = Rendah
7. IF $IPK$ = Cukup AND $Gaji$ = Besar THEN $NK$ = Rendah
8. IF $IPK$ = Cukup AND $Gaji$ = Sangat Besar THEN $NK$ = Rendah
9. IF $IPK$ = Bagus AND $Gaji$ = Kecil THEN $NK$ = Tinggi
10. IF $IPK$ = Bagus AND $Gaji$ = Sedang THEN $NK$ = Tinggi
11. IF $IPK$ = Bagus AND $Gaji$ = Besar THEN $NK$ = Tinggi
12. IF $IPK$ = Bagus AND $Gaji$ = Sangat Besar THEN $NK$ = Rendah

# Inferensi pada model Mamdani: *Clipping* dan *Scaling*




(a) *Clipping*




(b) *Scaling*

# Aturan *fuzzy* yang diaplikasikan

7. IF $IPK = \text{Cukup}$ AND $Gaji = \text{Besar}$ THEN $NK = \text{Rendah}$
8. IF $IPK = \text{Cukup}$ AND $Gaji = \text{Sangat Besar}$ THEN $NK = \text{Rendah}$
11. IF $IPK = \text{Bagus}$ AND $Gaji = \text{Besar}$ THEN $NK = \text{Tinggi}$
12. IF $IPK = \text{Bagus}$ AND $Gaji = \text{Sangat Besar}$ THEN $NK = \text{Rendah}$

# Nilai *fuzzy* untuk mhs A

IPK = 3,00
Gaji Orangtua = 10 juta/bulan

IPK = **Cukup** (0,5)
IPK = **Bagus** (0,5)
Gaji Orangtua = **Besar** (0,4)
Gaji Orangtua = **Sangat Besar** (0,6)

# *Conjunction* ($\wedge$) & *Disjunction* ($\vee$)

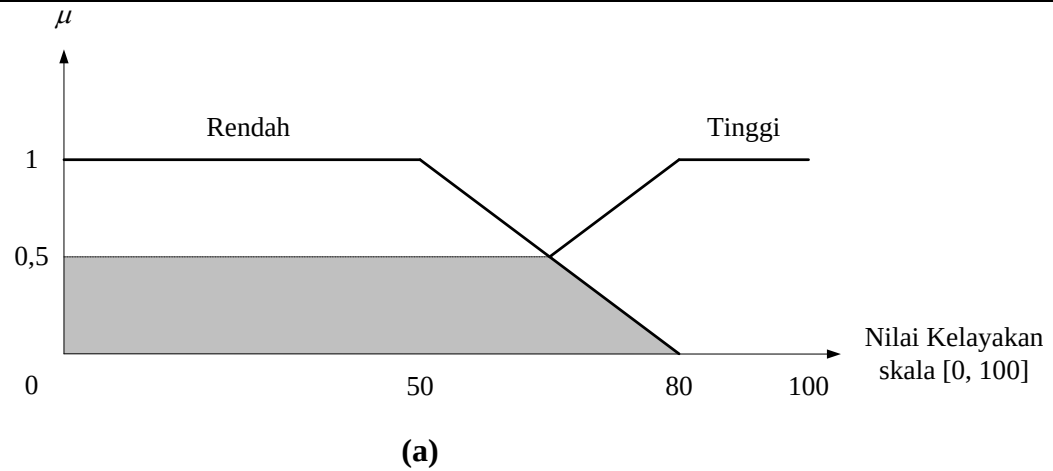
IF $IPK = \text{Cukup}(0,5)$ AND $Gaji = \text{Besar}(0,4)$ THEN $NK = \text{Rendah}(0,4)$

IF $IPK = \text{Cukup}(0,5)$ AND $Gaji = \text{Sangat Besar}(0,6)$ THEN $NK = \text{Rendah}(0,5)$

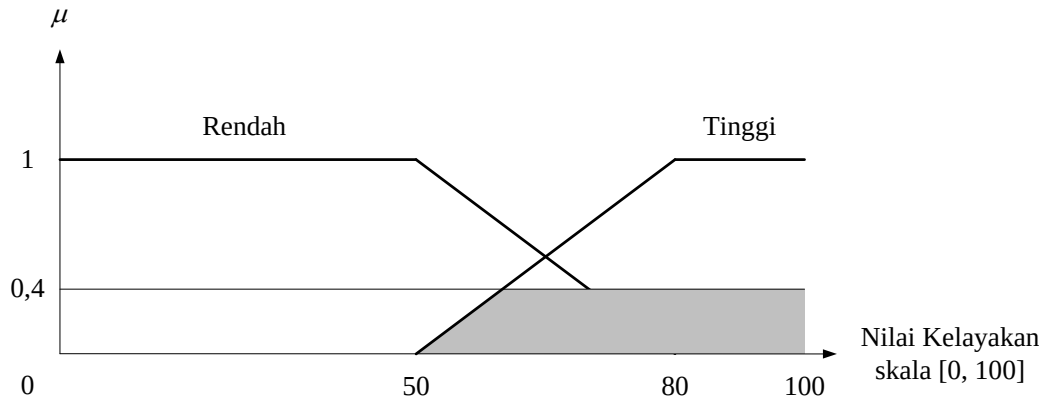
IF $IPK = \text{Bagus}(0,5)$ AND $Gaji = \text{Besar}(0,4)$ THEN $NK = \text{Tinggi}(0,4)$

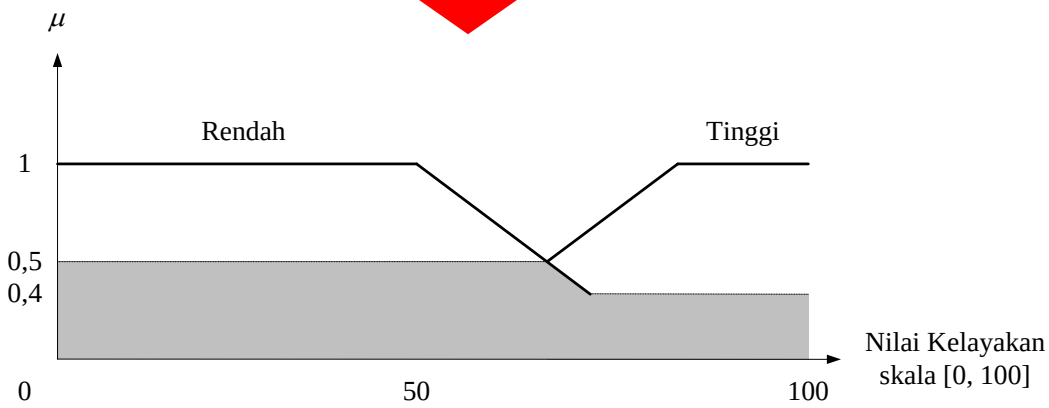
IF $IPK = \text{Bagus}(0,5)$ AND $Gaji = \text{Sangat Besar}(0,6)$ THEN $NK = \text{Rendah}(0,5)$

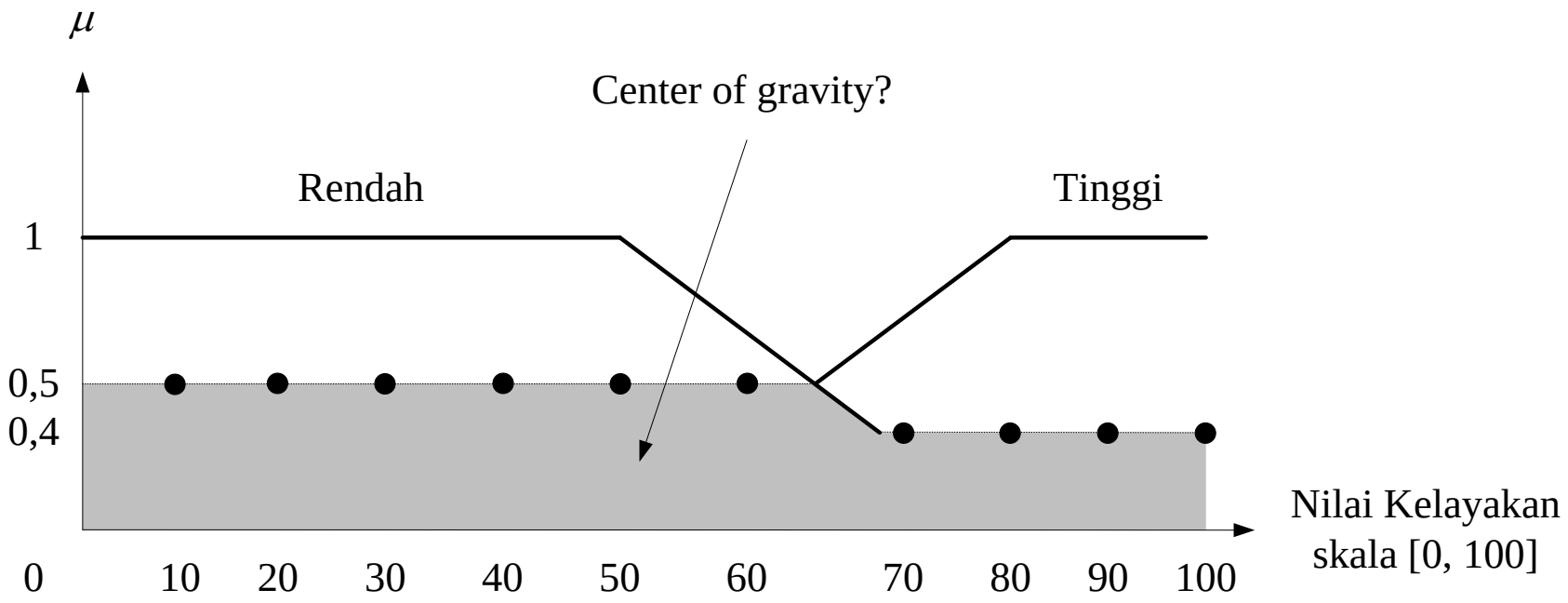
NK = Rendah (0,5)
NK = Tinggi (0,4)


μ
Rendah
Tinggi
1
0,5
0
50
80
100
Nilai Kelayakan
skala [0, 100]

**(a)**


μ
Rendah
Tinggi
1
0,4
0
50
80
100
Nilai Kelayakan
skala [0, 100]

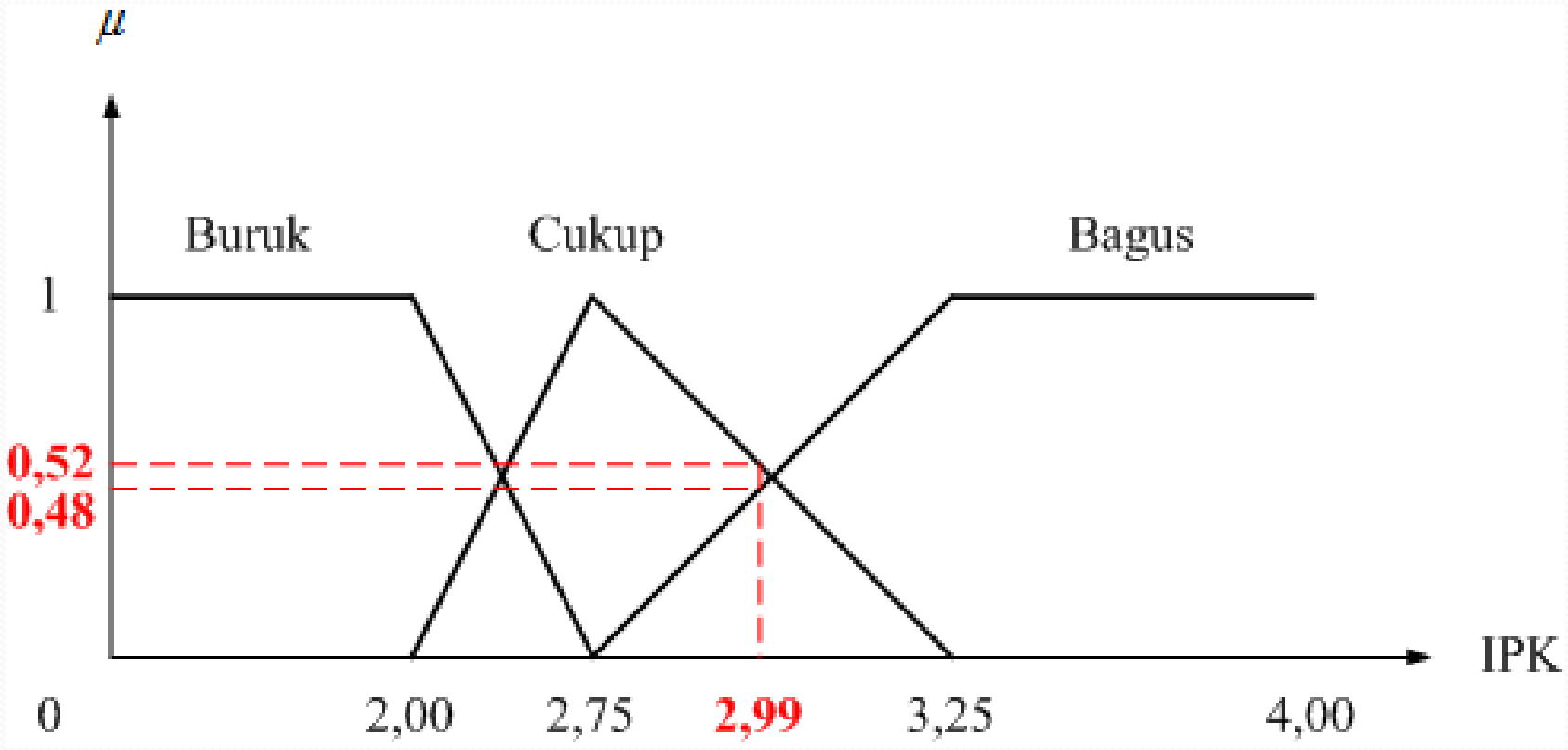

μ
Rendah
Tinggi
1
0,5
0,4
0
50
100
Nilai Kelayakan
skala [0, 100]



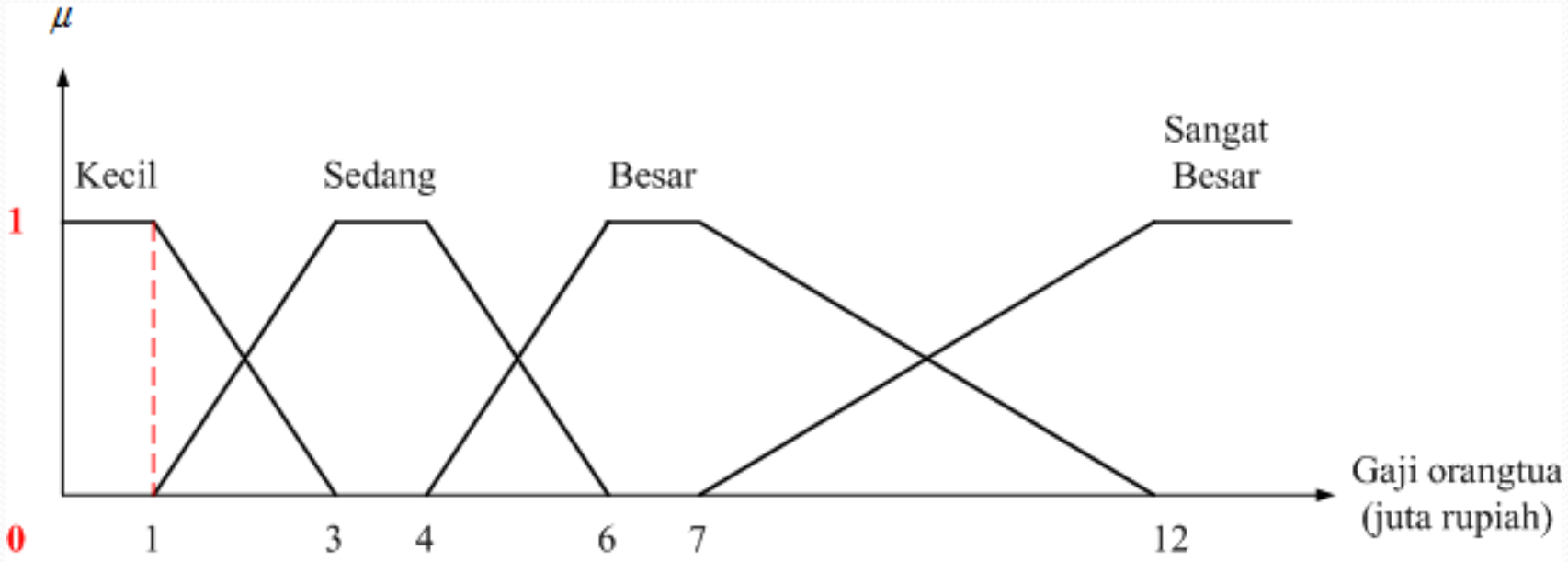

$$y^* = \frac{(10+20+30+40+50+60)0{,}5 + (70+80+90+100)0{,}4}{6(0{,}5)+4(0{,}4)}$$

$$y^* = \frac{105+136}{4{,}6} = 52{,}39$$

# IPK mahasiswa B



# Gaji Orangtua mhs B



# *Conjunction* ($\wedge$) & *Disjunction* ($\vee$)

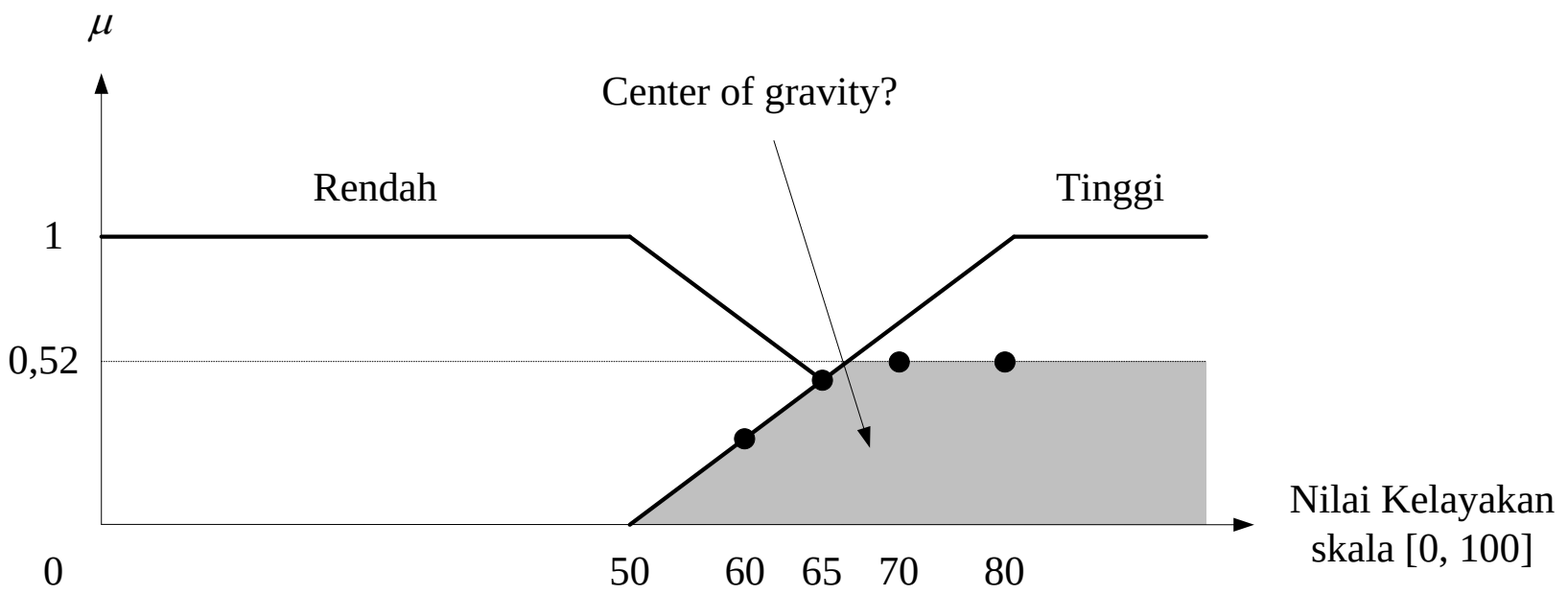
IF $IPK = \text{Cukup}(0{,}52)$ AND $Gaji = \text{Kecil}(1)$ THEN $NK = \text{Tinggi}(0{,}5\ 2)$

IF $IPK = \text{Cukup}(0{,}52)$ AND $Gaji = \text{Sedang}(0)$ THEN $NK = \text{Rendah}(0)$

IF $IPK = \text{Besar}(0{,}48)$ AND $Gaji = \text{Kecil}(1)$ THEN $NK = \text{Tinggi}(0{,}4\ 8)$

IF $IPK = \text{Besar}(0{,}48)$ AND $Gaji = \text{Sedang}(0)$ THEN $NK = \text{Tinggi}(0)$

NK = Rendah (0)
NK = Tinggi (0,52)



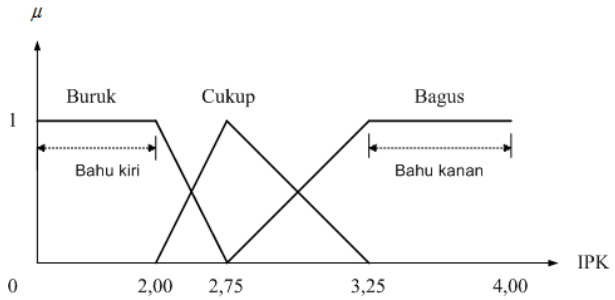

$$y^* = \frac{60(1/3) + 65(1/2) + (70+80)(0{,}52)}{(1/3) + (1/2) + (0{,}52)2}$$

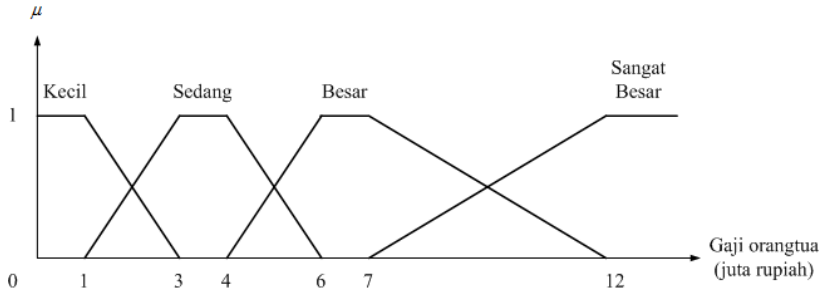
$$y^* = \frac{20 + 32{,}5 + 78}{2{,}87334} = 69{,}66$$

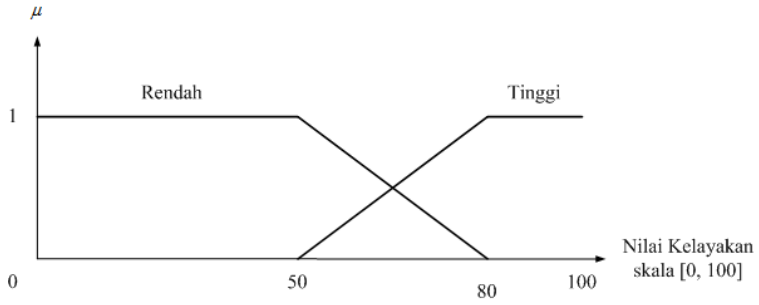
# Keputusan Model Mamdani

- Mahasiswa B dengan IPK = 2,99 dan Gaji orangtuanya sebesar 1 juta rupiah per bulan memperoleh Nilai Kelayakan sebesar **69,66**.
- Lebih besar dibandingkan dengan Nilai Kelayakan mahasiswa A yang sebesar **52,39**.
- Jadi, mahasiswa B layak mendapatkan beasiswa.

# Model Mamdani



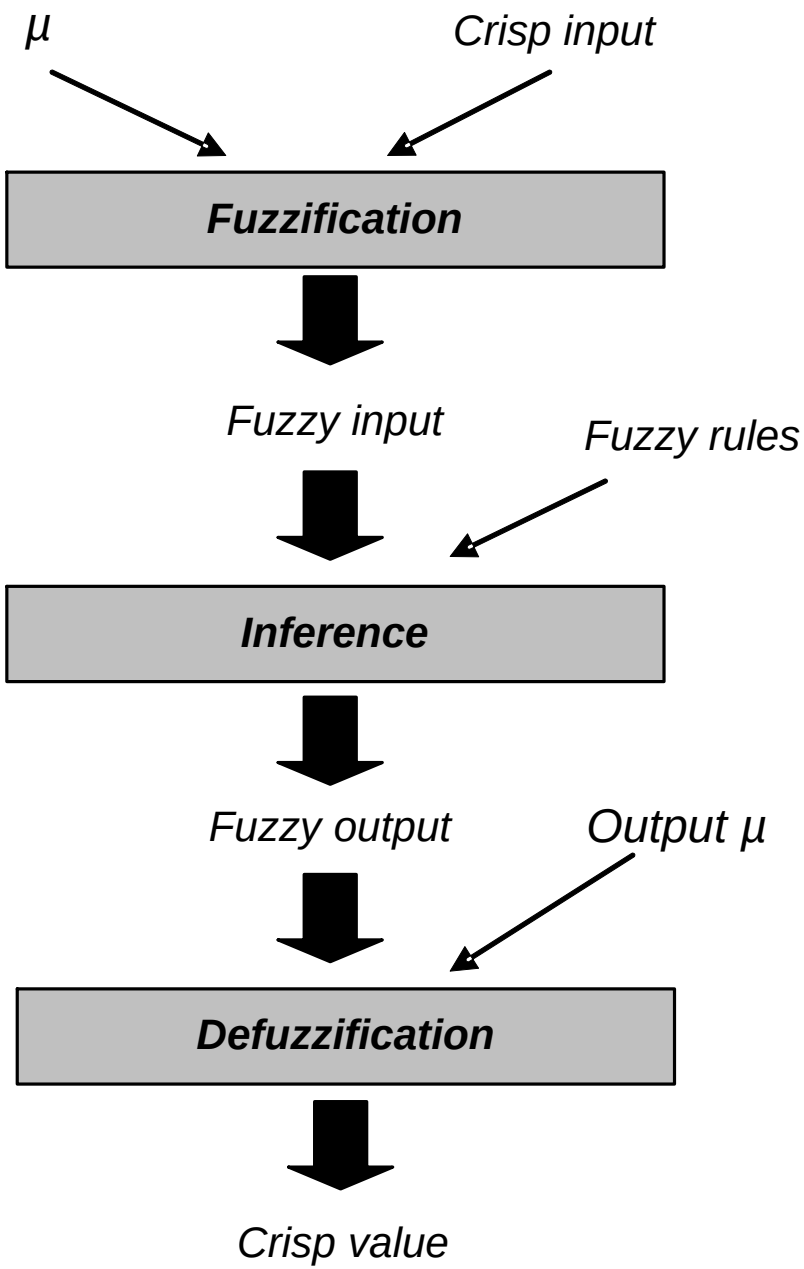

| IPK \ Gaji | Kecil | Sedang | Besar | Sangat Besar |
|---|---|---|---|---|
| Buruk | Rendah | Rendah | Rendah | Rendah |
| Cukup | Tinggi | Rendah | Rendah | Rendah |
| Bagus | Tinggi | Tinggi | Tinggi | Rendah |

# Model Sugeno

- Model ini sering digunakan untuk membangun sistem kontrol yang membutuhkan respon cepat
- Proses perhitungannya sangat sederhana sehingga membutuhkan waktu relatif cepat sehingga sangat sesuai untuk sistem kontrol
- Bagaimana jika digunakan untuk masalah pemberian beasiswa?

# Masalah: Pemberian Beasiswa

| Mahasiswa | IPK | Gaji Ortu (Rp/bulan) |
|---|---|---|
| A | 3,00 | 10 juta |
| B | 2,99 | 1 juta |


μ
Crisp input
Fuzzification
Fuzzy input
Fuzzy rules
Inference
Fuzzy output
Output μ
Defuzzification
Crisp value

# *Fuzzification & Rule Evaluation*

- Misalkan proses *fuzzification*-nya sama persis dengan model Mamdani.
- Misalkan *Rule* yang digunakan juga sama persis dengan model Mamdani.

# Mahasiswa A

IF $IPK = \text{Cukup}(0,5)$ AND $Gaji = \text{Besar}(0,4)$ THEN $NK = \text{Rendah}(0,4)$

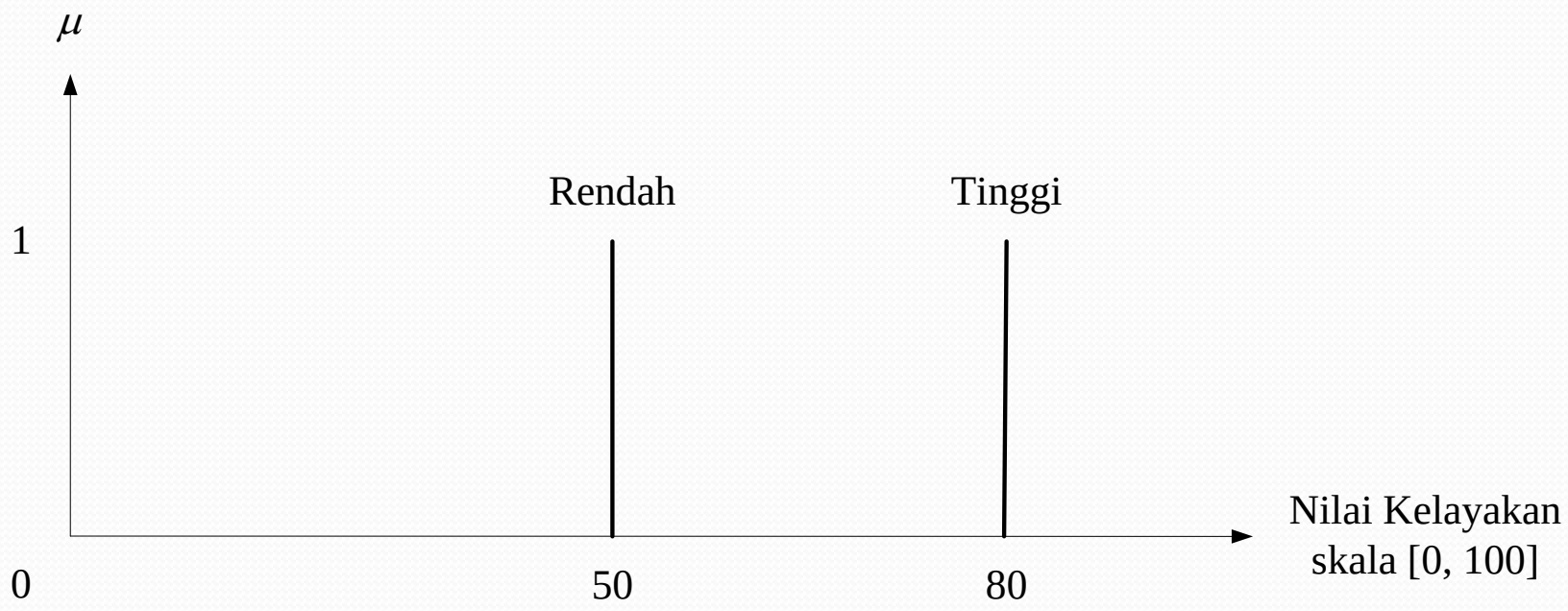
IF $IPK = \text{Cukup}(0,5)$ AND $Gaji = \text{Sangat Besar}(0,6)$ THEN $NK = \text{Rendah}(0,5)$

IF $IPK = \text{Bagus}(0,5)$ AND $Gaji = \text{Besar}(0,4)$ THEN $NK = \text{Tinggi}(0,4)$

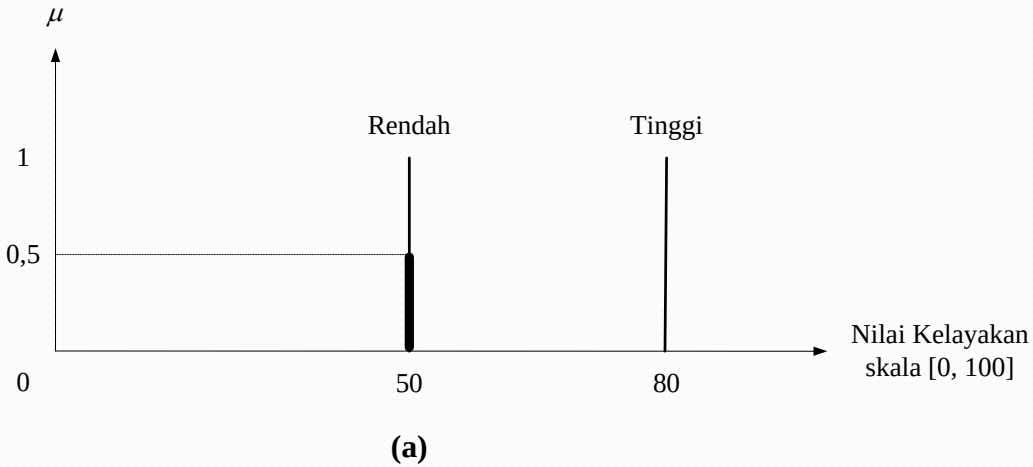
IF $IPK = \text{Bagus}(0,5)$ AND $Gaji = \text{Sangat Besar}(0,6)$ THEN $NK = \text{Rendah}(0,5)$

NK = Rendah (0,5)
NK = Tinggi (0,4)

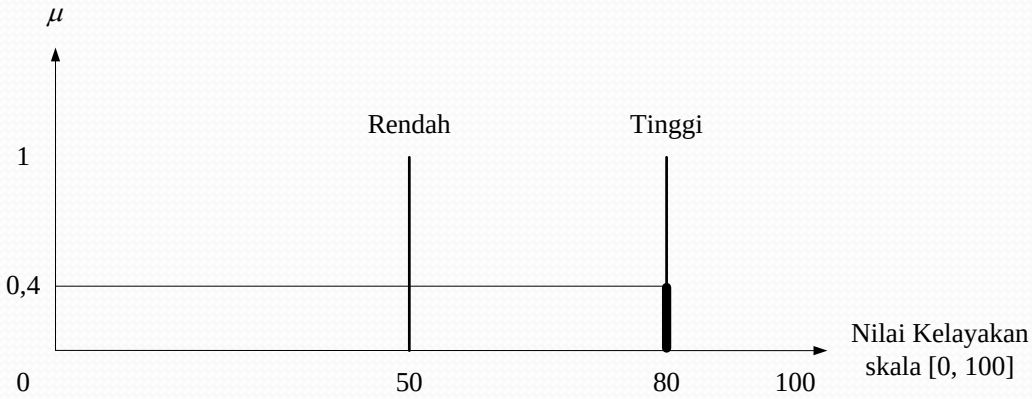
# FK *singleton* untuk Nilai Kelayakan



# Untuk mahasiswa A



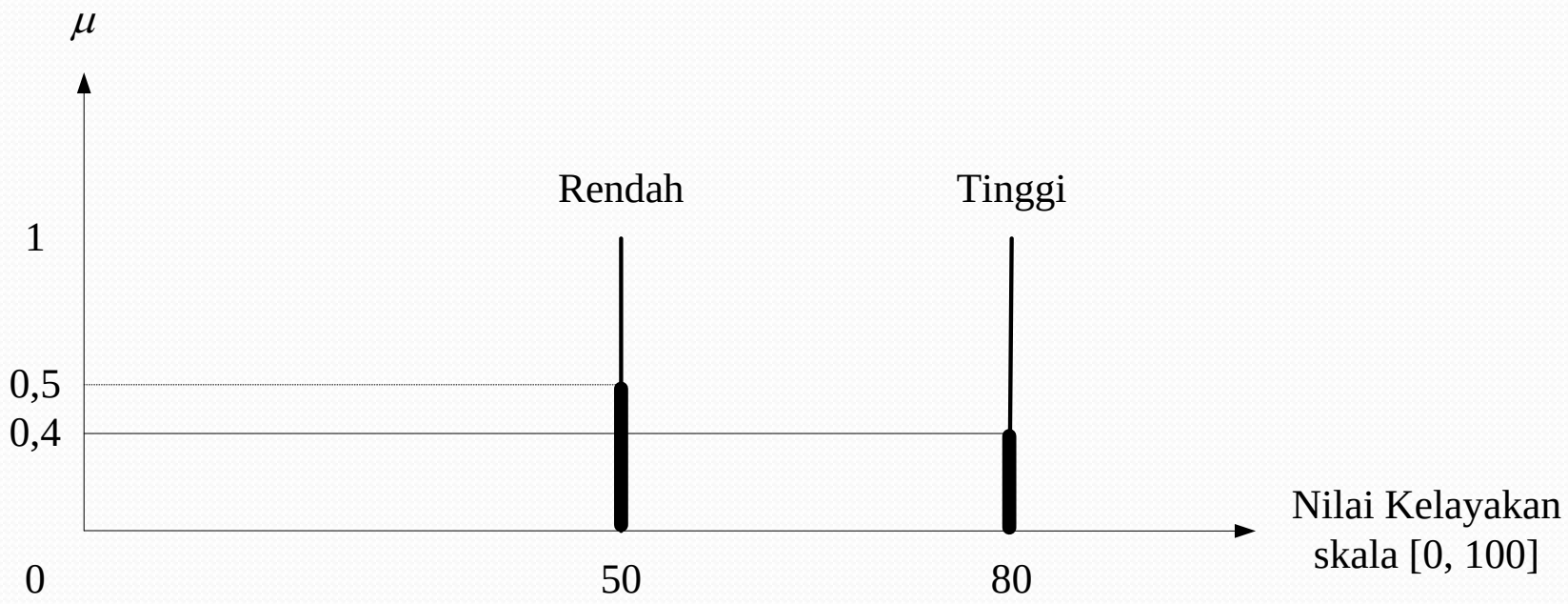

**(a)**




**(b)**

- NK = Rendah (0,5)
- NK = Tinggi (0,4)

# Proses *Composition*



# *Defuzzyfication: Weighted Average*

$$y^* = \frac{(0{,}5)50 + (0{,}4)80}{(0{,}5) + (0{,}4)} = 63{,}33$$

# Mahasiswa B

IF $IPK = \text{Cukup}(0{,}52)$ AND $Gaji = \text{Kecil}(1)$ THEN $NK = \text{Tinggi}(0{,}5\ 2)$

IF $IPK = \text{Cukup}(0{,}52)$ AND $Gaji = \text{Sedang}(0)$ THEN $NK = \text{Rendah}(0)$

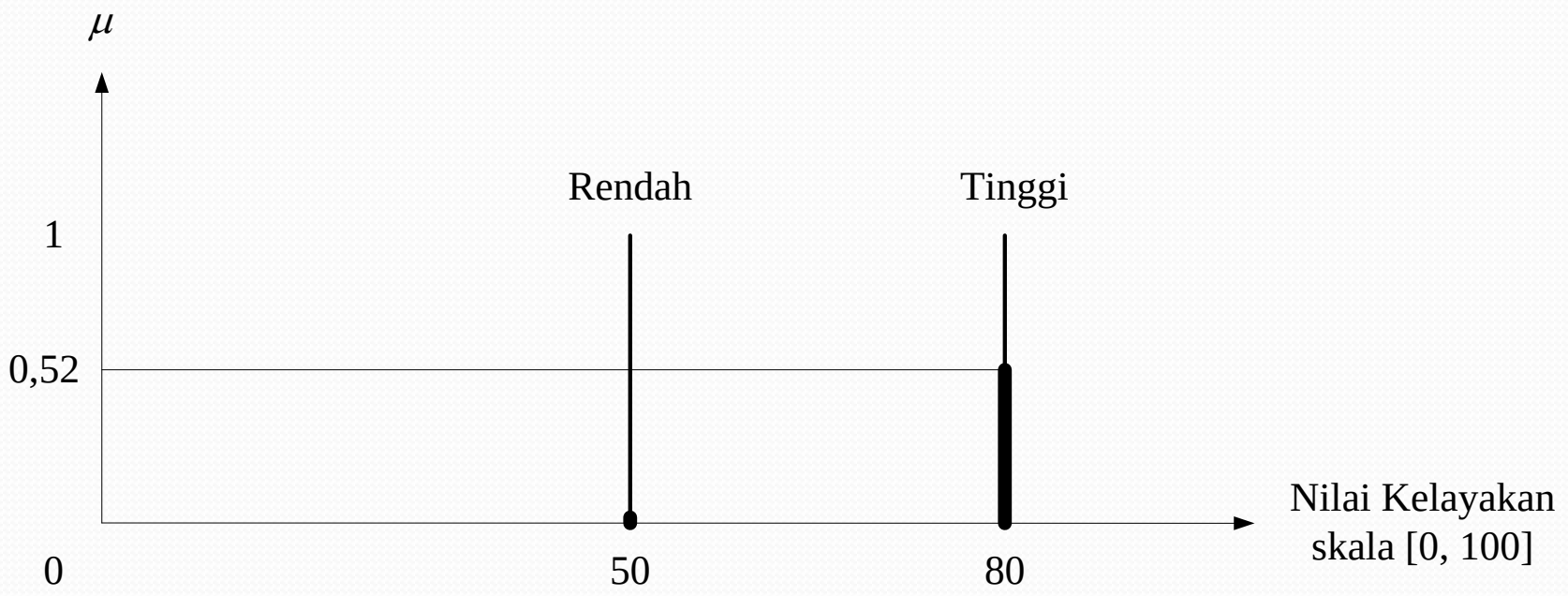
IF $IPK = \text{Besar}(0{,}48)$ AND $Gaji = \text{Kecil}(1)$ THEN $NK = \text{Tinggi}(0{,}4\ 8)$

IF $IPK = \text{Besar}(0{,}48)$ AND $Gaji = \text{Sedang}(0)$ THEN $NK = \text{Tinggi}(0)$

NK = Rendah (0)
NK = Tinggi (0,52)

# Untuk Mahasiswa B

- NK = Rendah (0)
- NK = Tinggi (0,52)



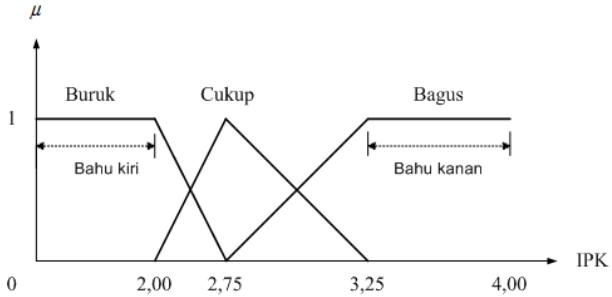
# *Defuzzyfication: Weighted Average*

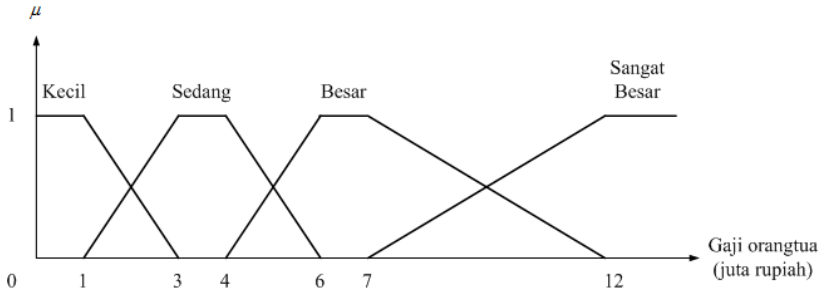
$$y^* = \frac{(0)50 + (0{,}52)80}{0 + 0{,}52} = 80$$

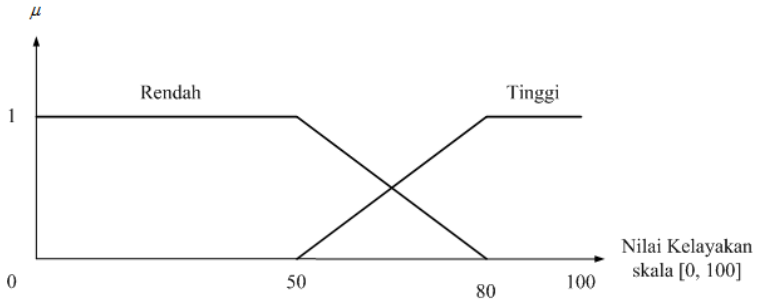
# Keputusan Model Sugeno

- Mahasiswa B dengan IPK = 2,99 dan Gaji orangtuanya sebesar Rp 1 juta per bulan memperoleh Nilai Kelayakan sebesar **80**.
- Lebih besar dibandingkan dengan Nilai Kelayakan mahasiswa A yang sebesar **63,33**.
- Jadi, mahasiswa B layak mendapatkan beasiswa.

# Model Mamdani

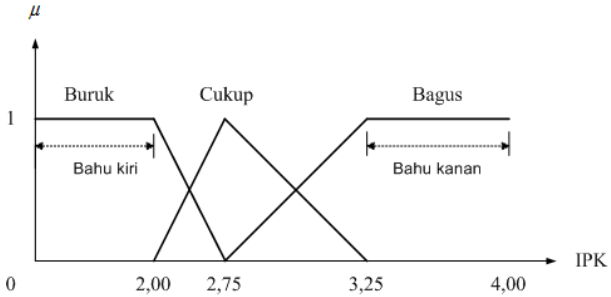


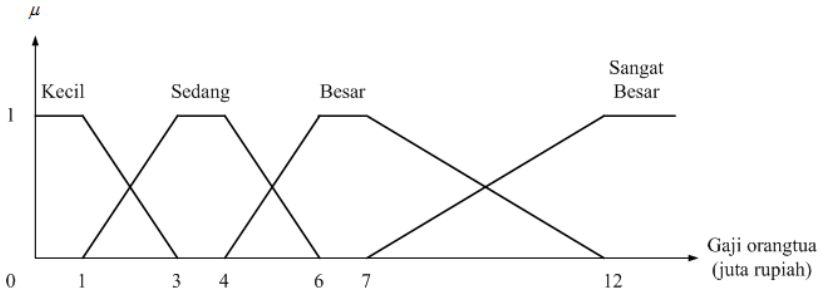



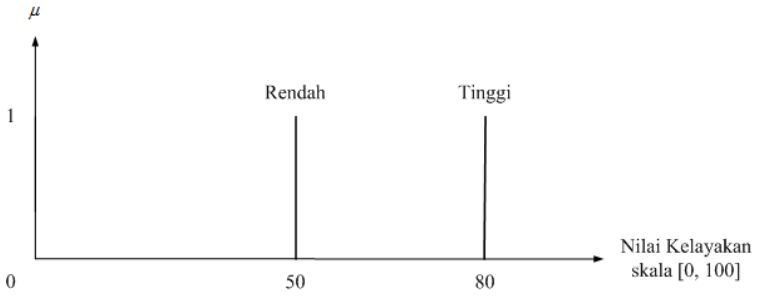




| IPK \ Gaji | Kecil | Sedang | Besar | Sangat Besar |
|---|---|---|---|---|
| Buruk | Rendah | Rendah | Rendah | Rendah |
| Cukup | Tinggi | Rendah | Rendah | Rendah |
| Bagus | Tinggi | Tinggi | Tinggi | Rendah |

# Model Sugeno




| IPK \ Gaji | Kecil | Sedang | Besar | Sangat Besar |
|---|---|---|---|---|
| Buruk | Rendah | Rendah | Rendah | Rendah |
| Cukup | Tinggi | Rendah | Rendah | Rendah |
| Bagus | Tinggi | Tinggi | Tinggi | Rendah |

# Nilai Kelayakan mahasiswa A & B

| Mahasiswa | Nilai Kelayakan mendapat beasiswa | |
|---|---|---|
| | Model Mamdani | Model Sugeno |
| A | 52,39 | 63,33 |
| B | 69,66 | 80 |
| Selisih A dan B | **17,72** | **16,67** |

# Sistem Berbasis *Crisp Sets* dan FOL

IF $IPK = 2{,}57$ AND $Gaji = 1{,}20$ juta THEN $NK = 62{,}5$

IF $IPK = 2{,}57$ AND $Gaji = 1{,}25$ juta THEN $NK = 62{,}3$

...

...

...

# Aturan FOL untuk proses inference

| IPK \ Gaji | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| P1 | 70 | 60 | 40 | 30 | 20 |
| P2 | 80 | 70 | 50 | 40 | 30 |
| P3 | 90 | 80 | 60 | 50 | 40 |
| P4 | 100 | 90 | 70 | 60 | 50 |

# Aturan FOL untuk proses inference

1. IF $Interval(IPK, P1) \wedge Interval(Gaji, G1) \Rightarrow NK = 70$
2. IF $Interval(IPK, P1) \wedge Interval(Gaji, G2) \Rightarrow NK = 60$

...

...

...

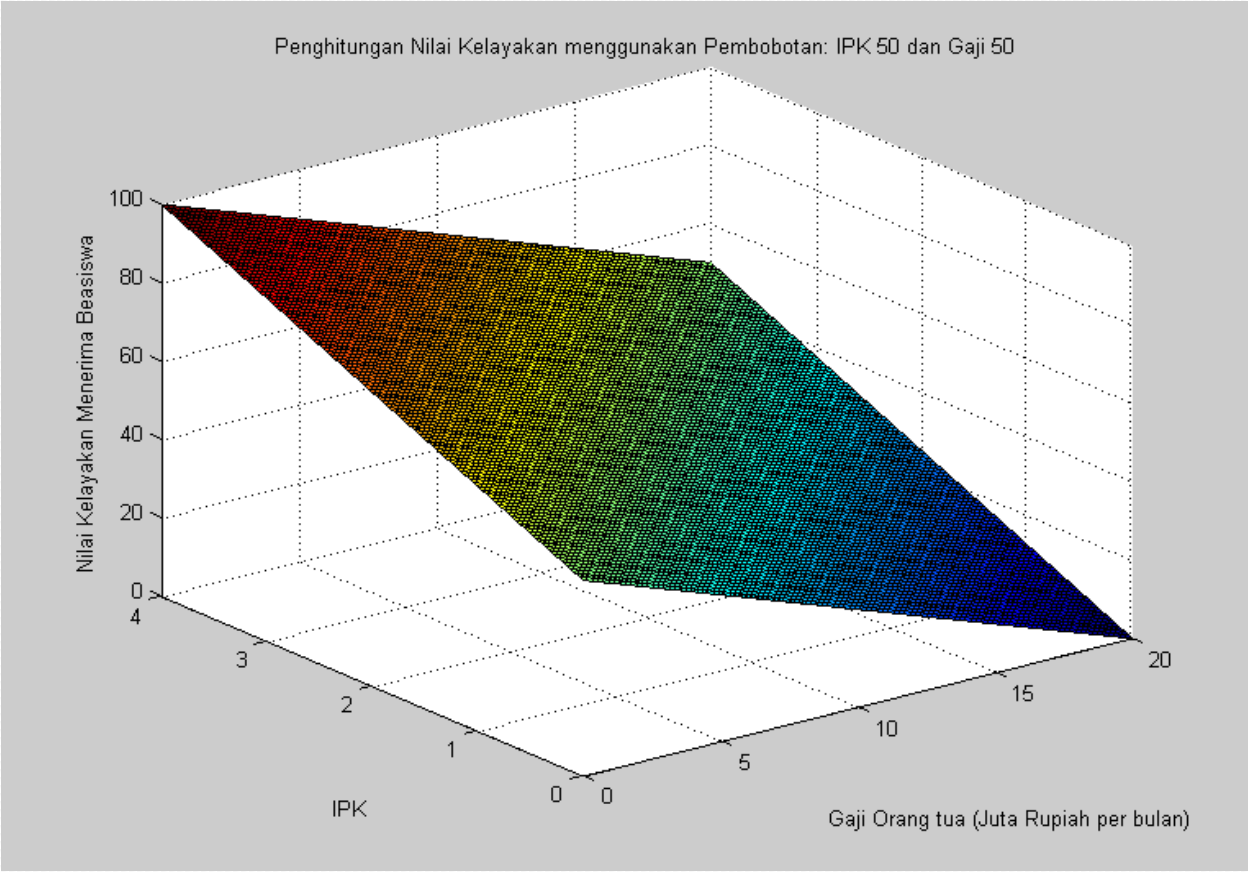
20. IF $Interval(IPK, P4) \wedge Interval(Gaji, G5) \Rightarrow NK = 50$

# Sistem yang Linier

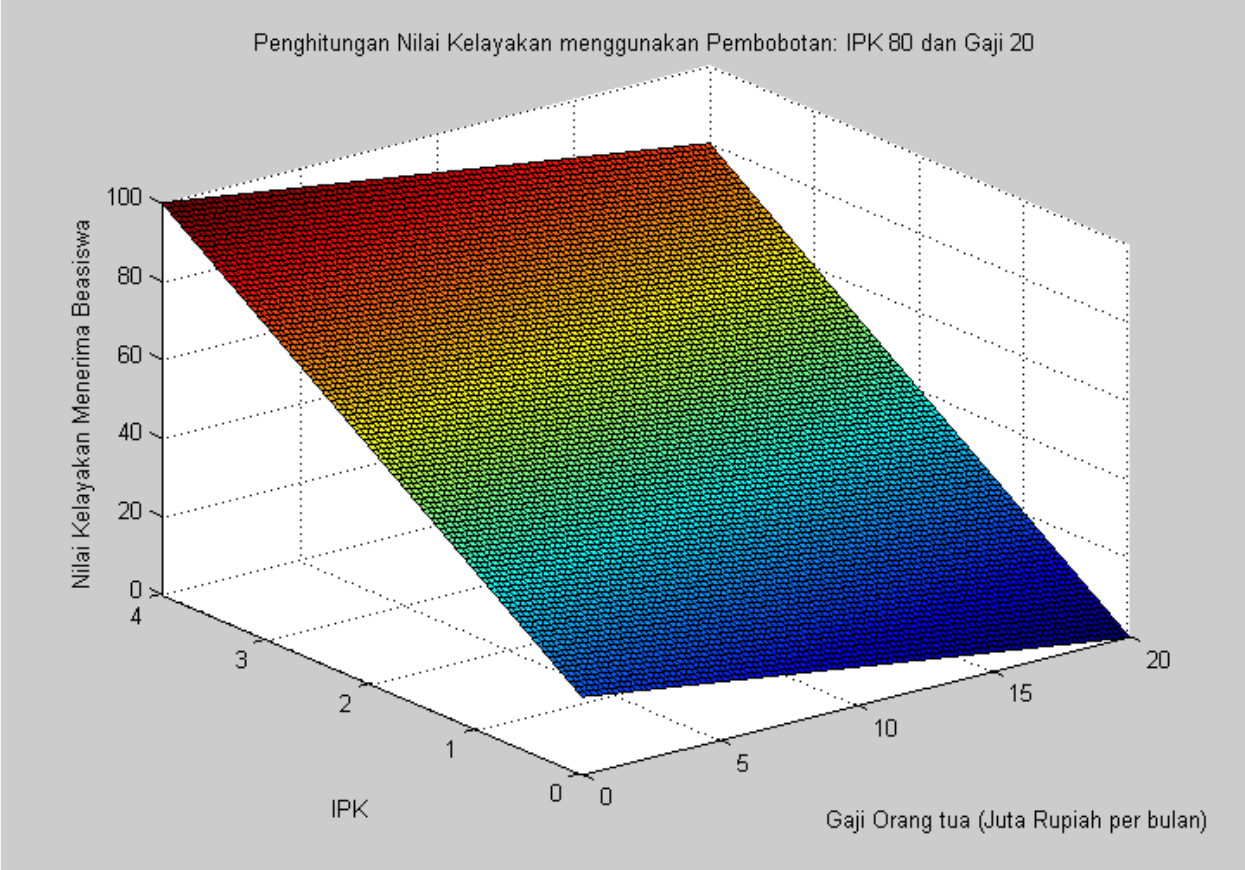
$$NK = W_1(IPK / 4) + W_2((20 - Gaji) / 20)$$

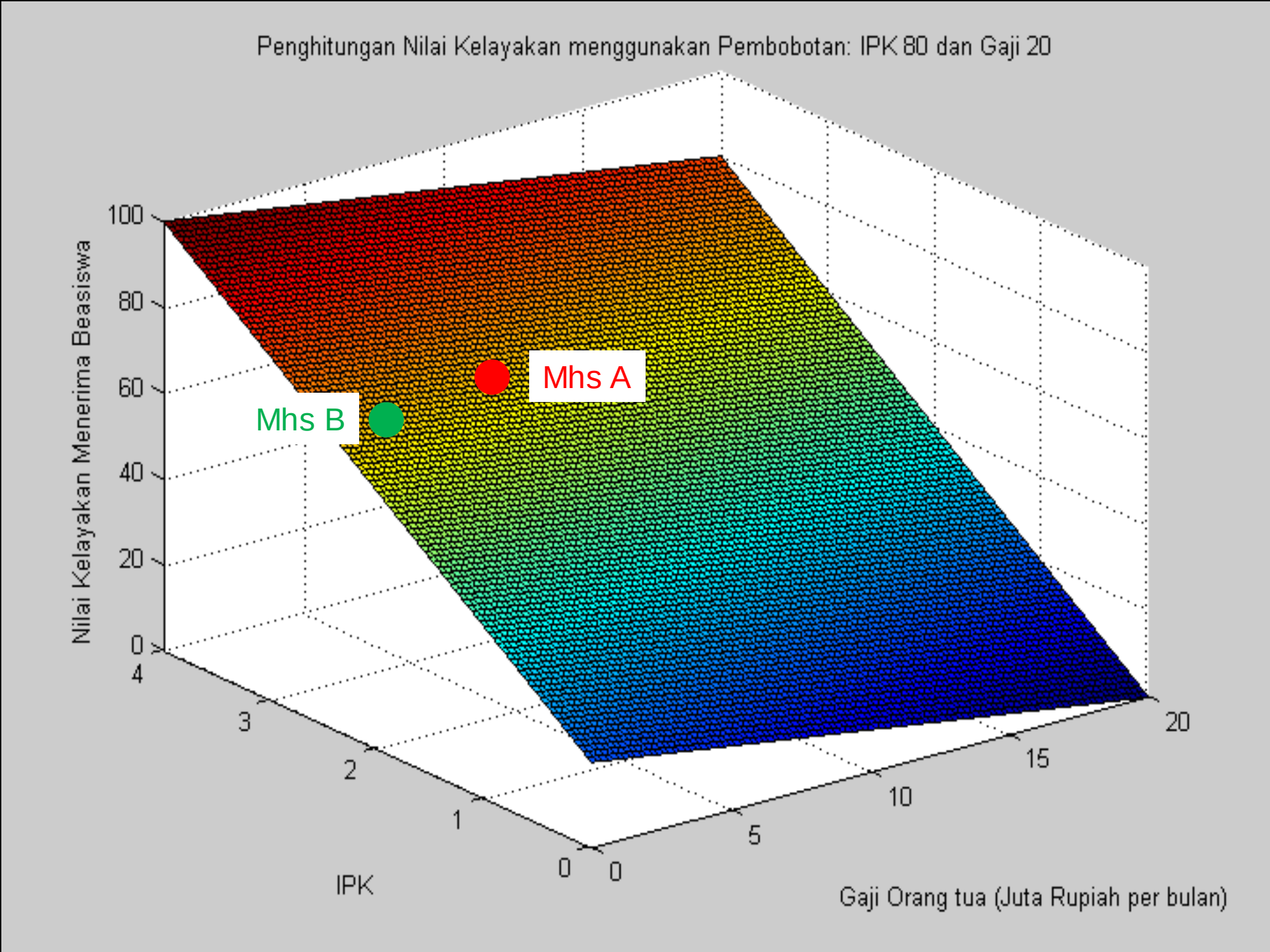
- $W_1$ adalah bobot untuk IPK, $W_2$ adalah bobot untuk Gaji.
- Asumsi: IPK maksimum adalah 4,00
- Asumsi: Gaji Orang tua maksimum adalah Rp 20 jt/bln.
- Karena skala untuk *NK* adalah [0, 100], maka $W_1 + W_2$ harus sama dengan 100.

# $W_1 = 50$ dan $W_2 = 50$

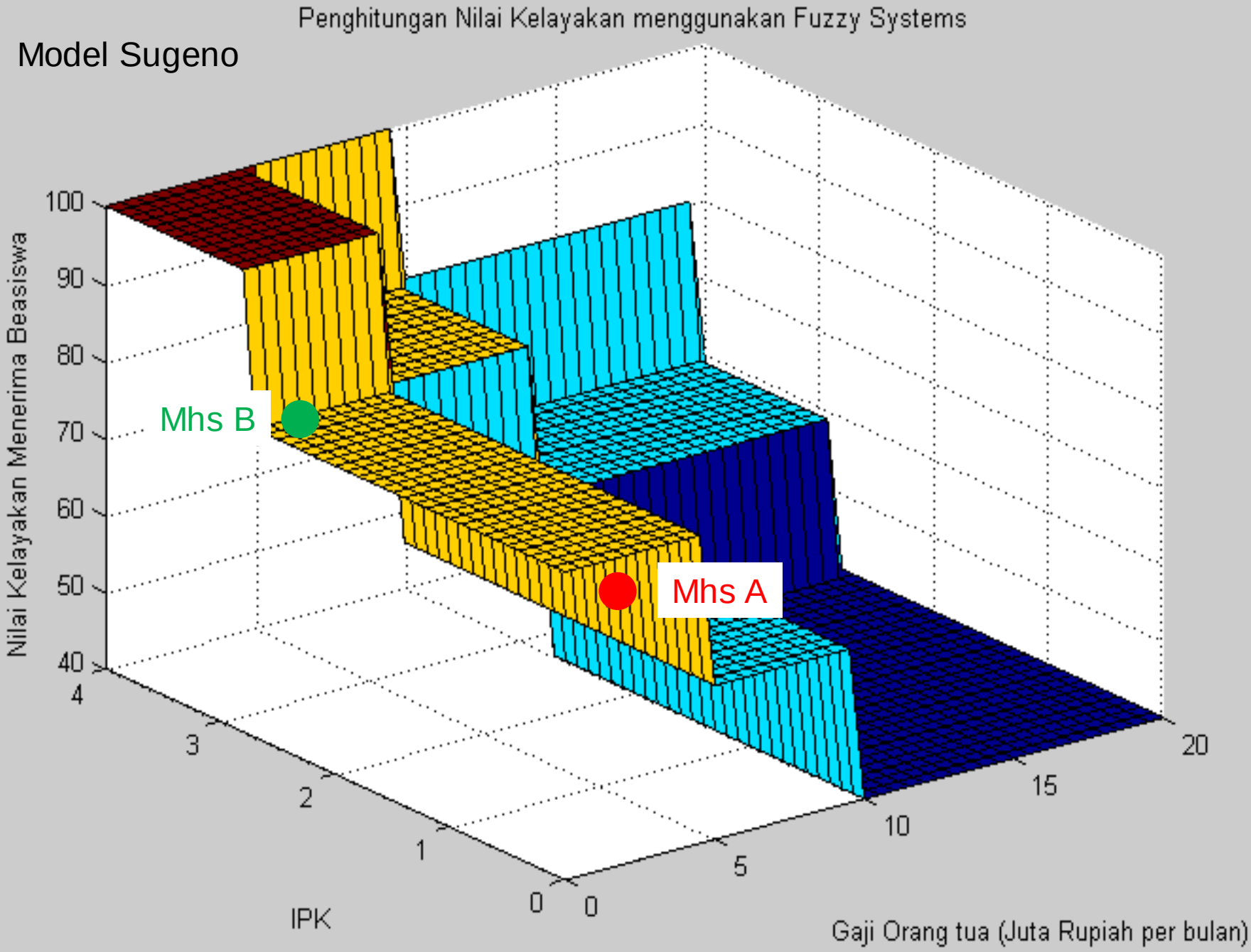


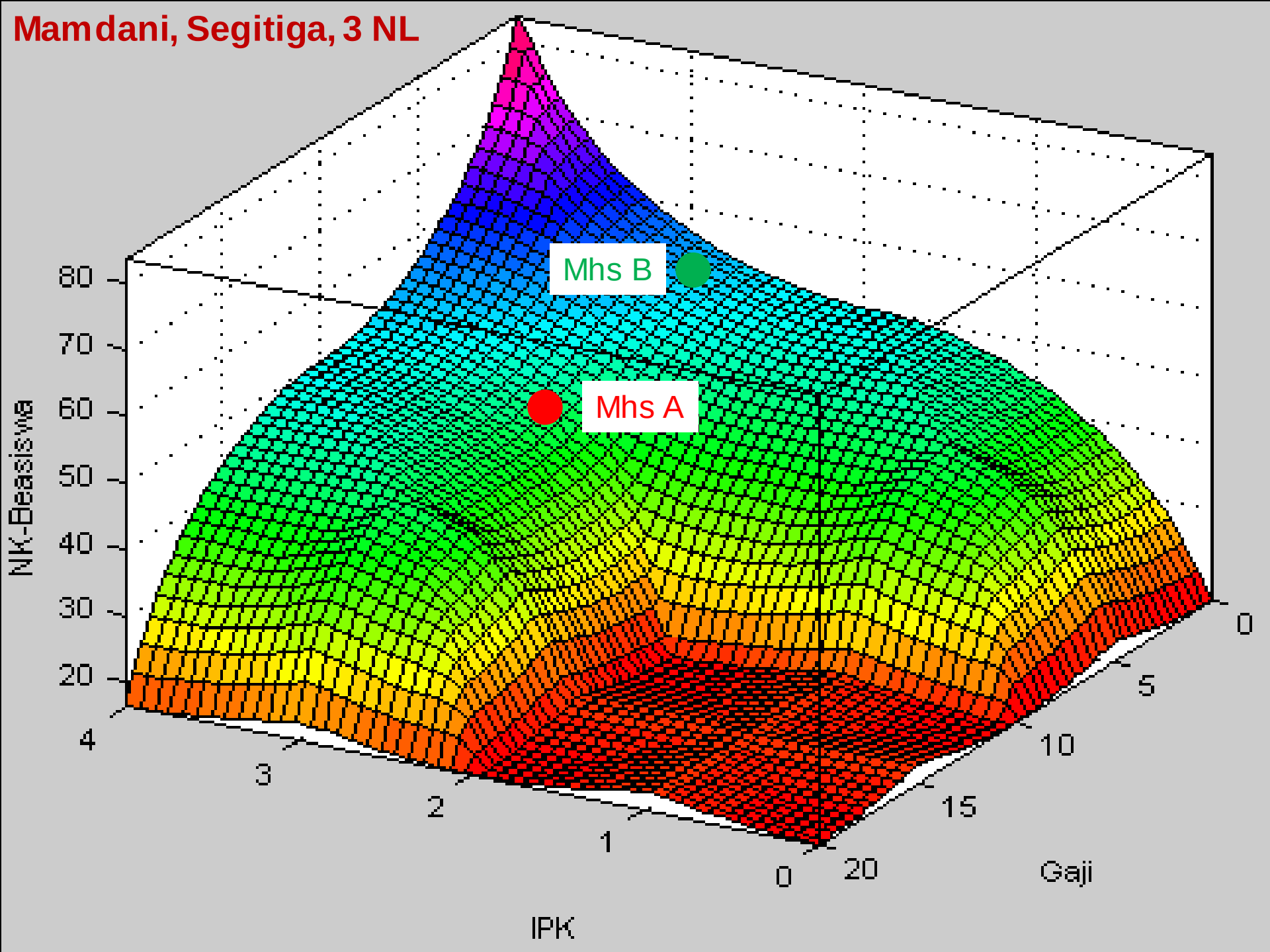
# $W_1 = 80$ dan $W_2 = 20$

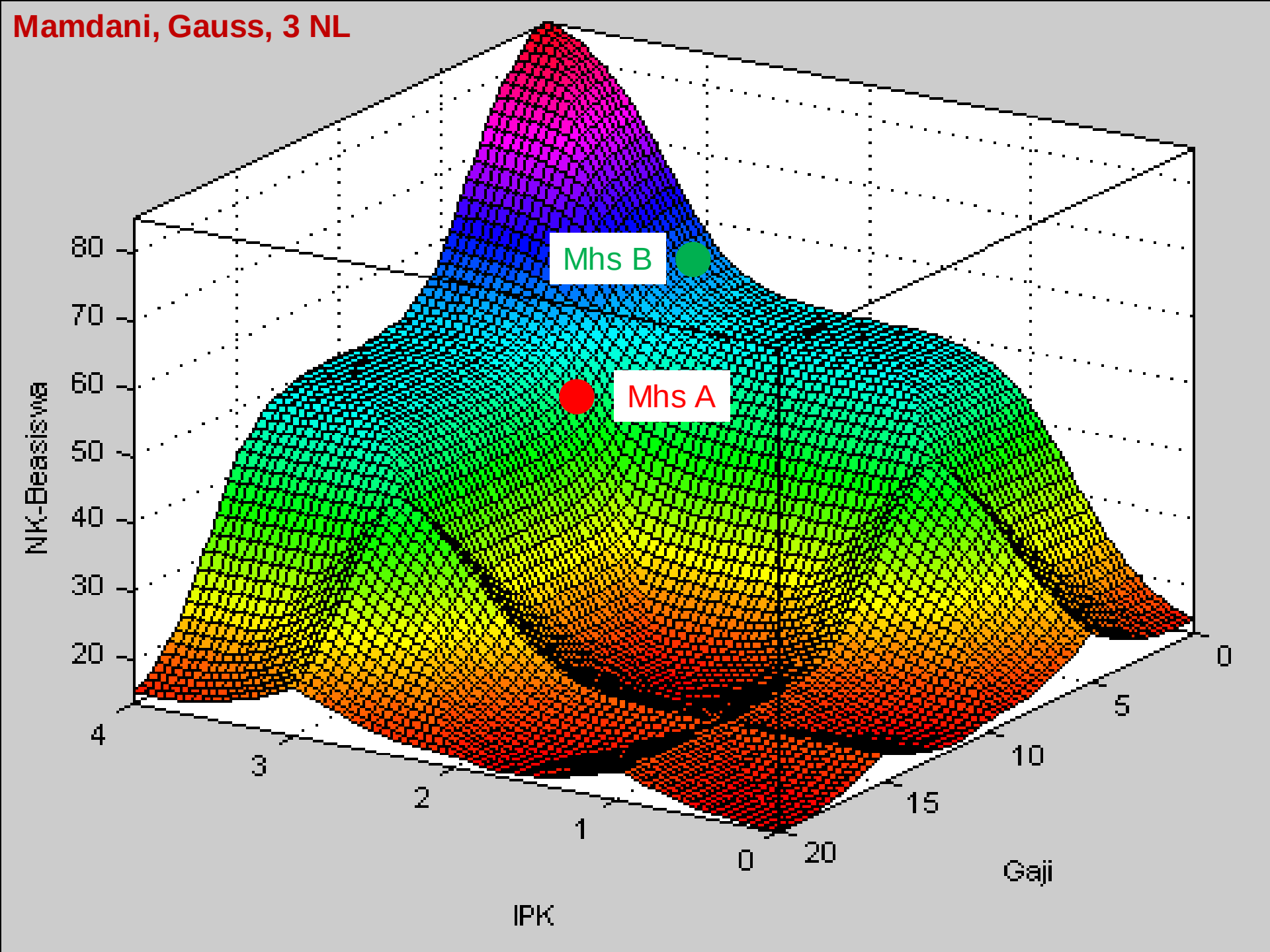


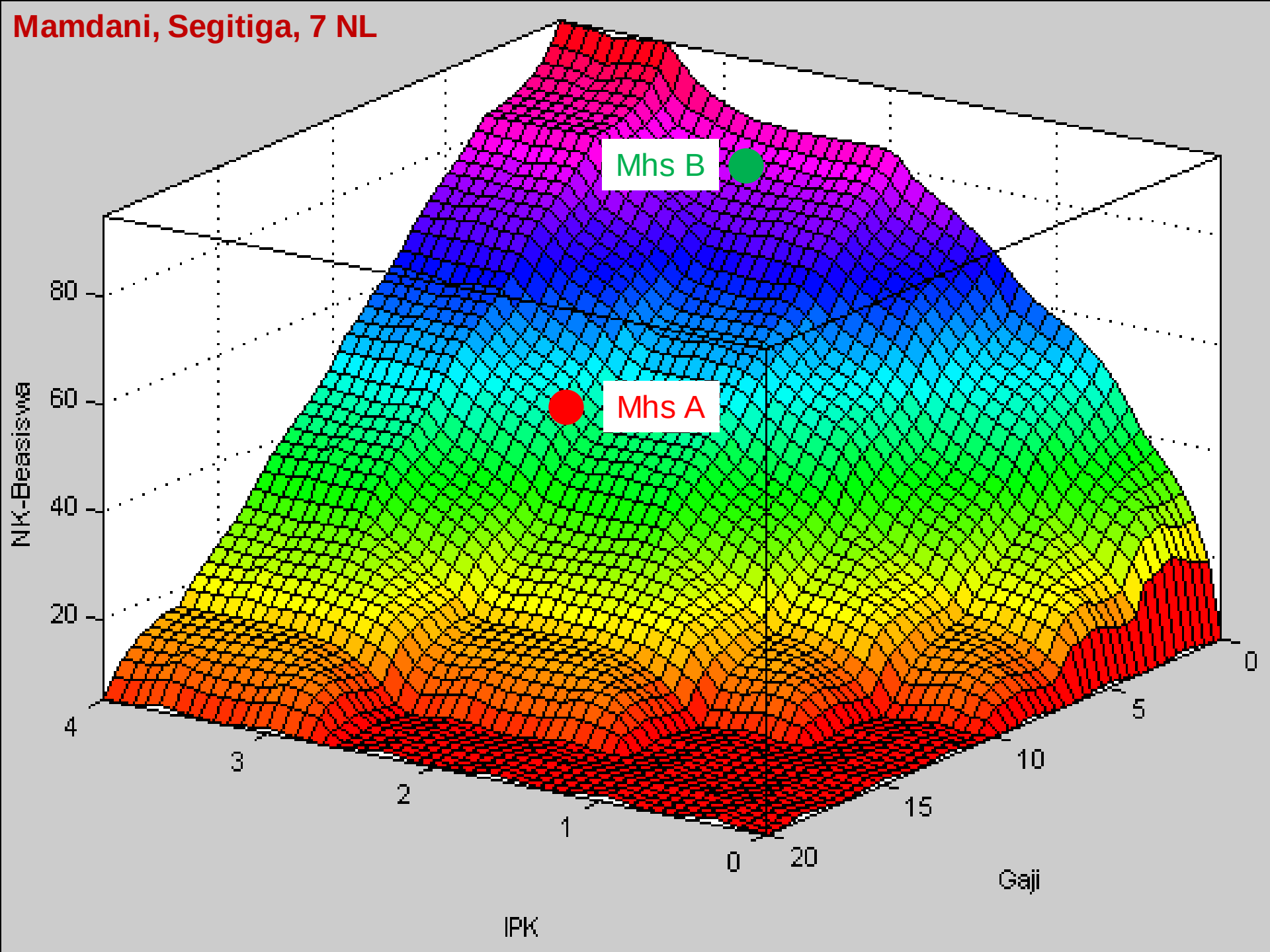

Penghitungan Nilai Kelayakan menggunakan Pembobotan: IPK 80 dan Gaji 20
Nilai Kelayakan Menerima Beasiswa
100
80
60
40
20
0
Mhs A
Mhs B
4
3
2
1
0
IPK
0
5
10
15
20
Gaji Orang tua (Juta Rupiah per bulan)

Model Sugeno

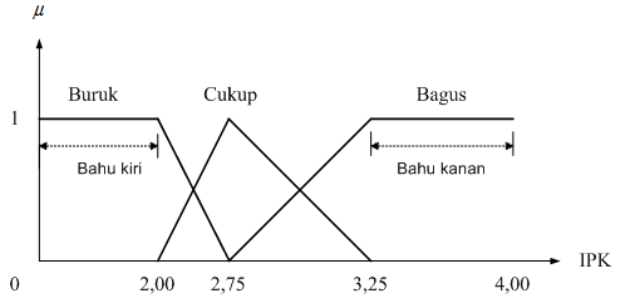


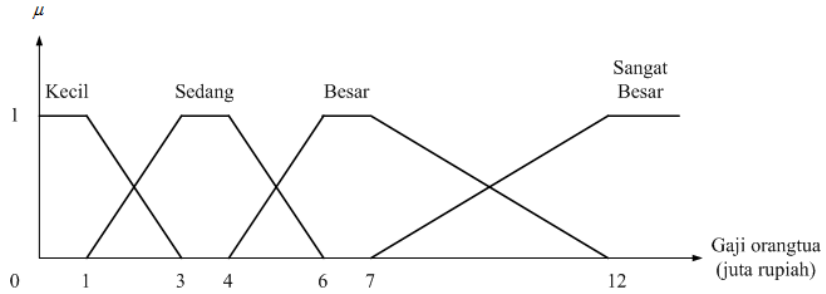

Mamdani, Segitiga, 3 NL
Mhs B
Mhs A
NK-Beasiswa
80
70
60
50
40
30
20
IPK
4
3
2
1
0
Gaji
0
5
10
15
20

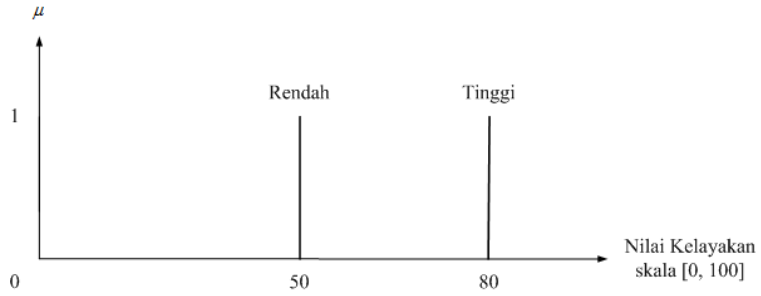

Mamdani, Gauss, 3 NL
Mhs B
Mhs A
NK-Beasiswa
80
70
60
50
40
30
20
IPK
4
3
2
1
0
Gaji
20
15
10
5
0


Mamdani, Segitiga, 7 NL
Mhs B
Mhs A
NK-Beasiswa
80
60
40
20
IPK
4
3
2
1
0
Gaji
0
5
10
15
20

# Model Sugeno

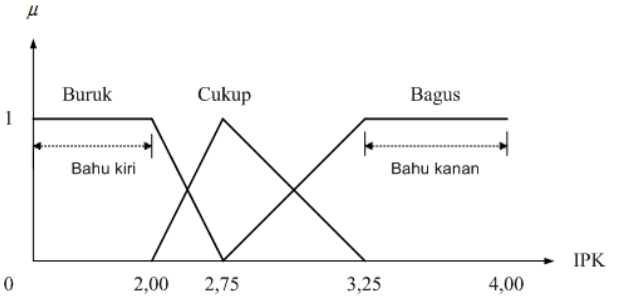


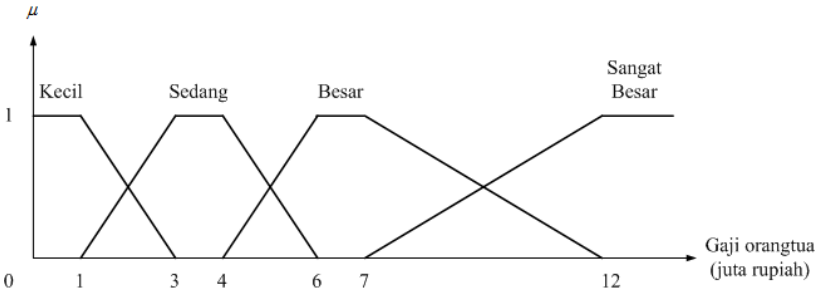



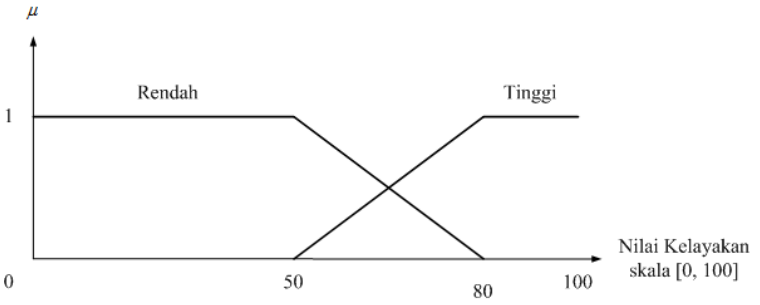




| IPK \ Gaji | Kecil | Sedang | Besar | Sangat Besar |
|---|---|---|---|---|
| Buruk | Rendah | Rendah | Rendah | Rendah |
| Cukup | Tinggi | Rendah | Rendah | Rendah |
| Bagus | Tinggi | Tinggi | Tinggi | Rendah |

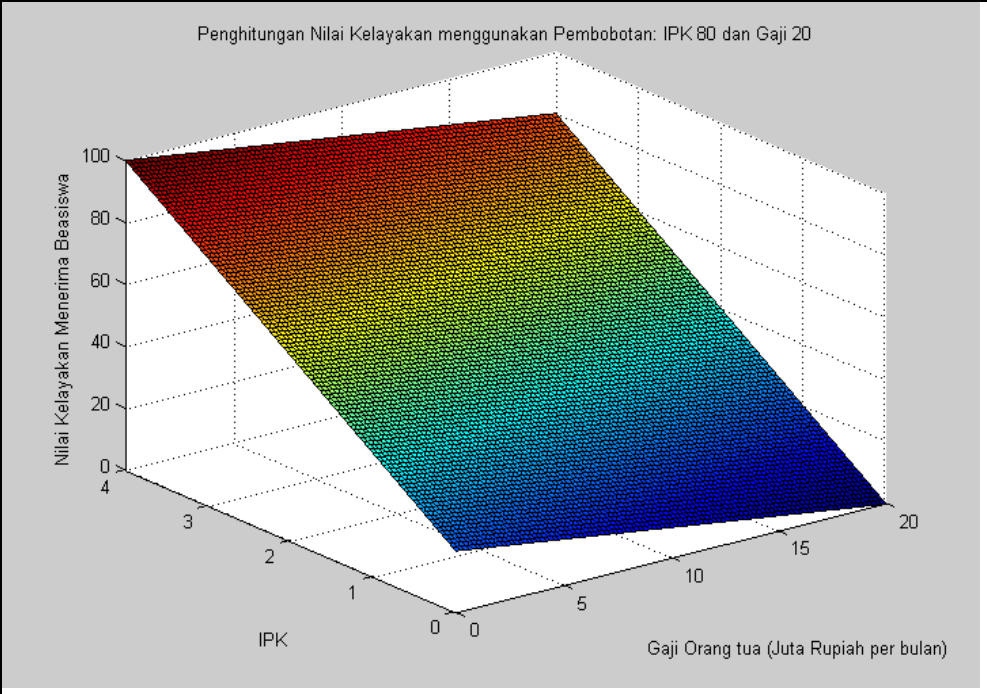
# Model Mamdani

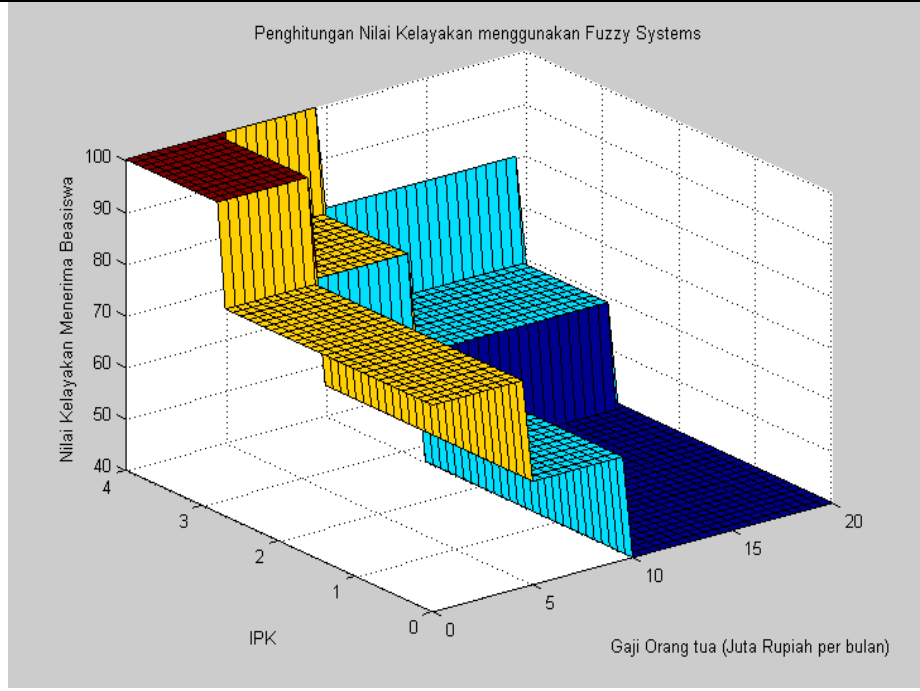


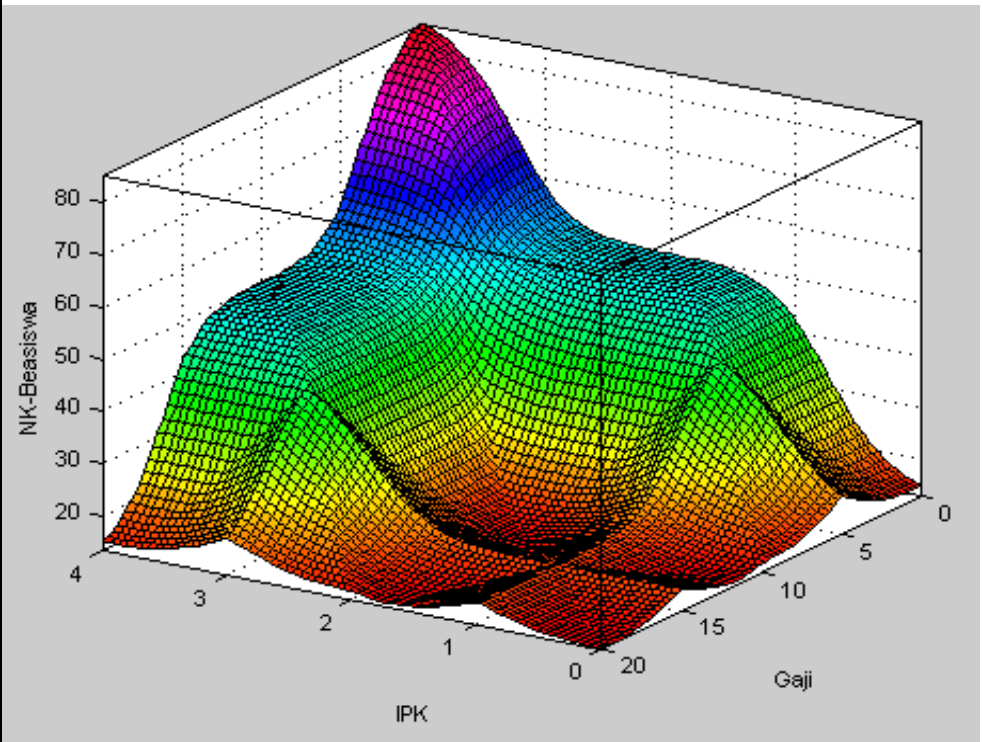



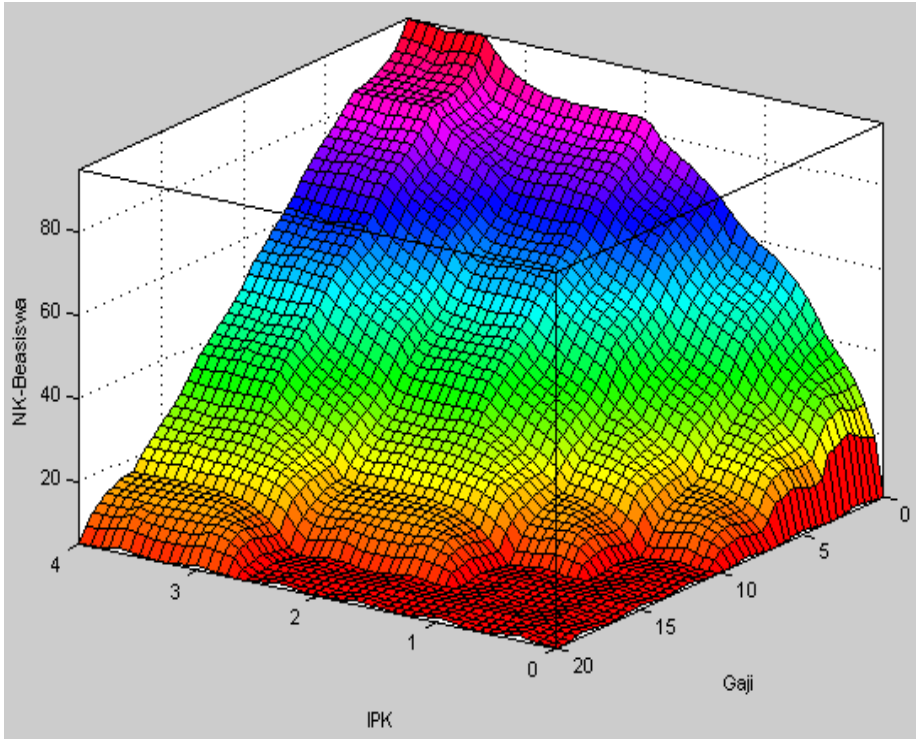




| IPK \ Gaji | Kecil | Sedang | Besar | Sangat Besar |
|---|---|---|---|---|
| Buruk | Rendah | Rendah | Rendah | Rendah |
| Cukup | Tinggi | Rendah | Rendah | Rendah |
| Bagus | Tinggi | Tinggi | Tinggi | Rendah |


Penghitungan Nilai Kelayakan menggunakan Pembobotan: IPK 80 dan Gaji 20
Nilai Kelayakan Menerima Beasiswa
IPK
Gaji Orang tua (Juta Rupiah per bulan)


Penghitungan Nilai Kelayakan menggunakan Fuzzy Systems
Nilai Kelayakan Menerima Beasiswa
IPK
Gaji Orang tua (Juta Rupiah per bulan)


NK-Beasiswa
IPK
Gaji


NK-Beasiswa
IPK
Gaji

# Kasus 2: *Sprinkler CS*

- Sistem kontrol untuk penyiraman air.
- *Input*: Suhu Udara ($^oC$) & Kelembaban Tanah (%)
- *Output*: Durasi Penyiraman (menit)

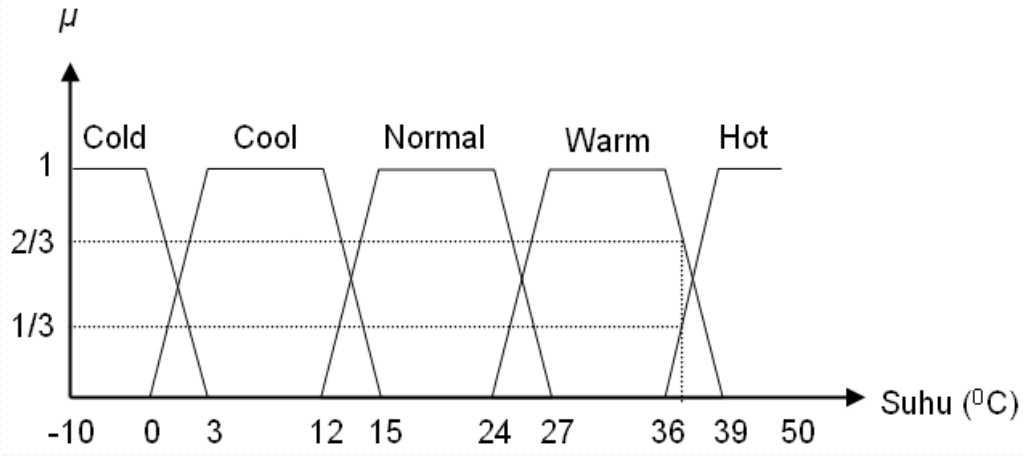
- Nilai *crisp* yang diterima oleh sensor suhu adalah $37^oC$ dan sensor kelembaban adalah 12%.
- Berapa lama durasi penyiraman yang dilakukan?


WMV
sprinkler.wmv

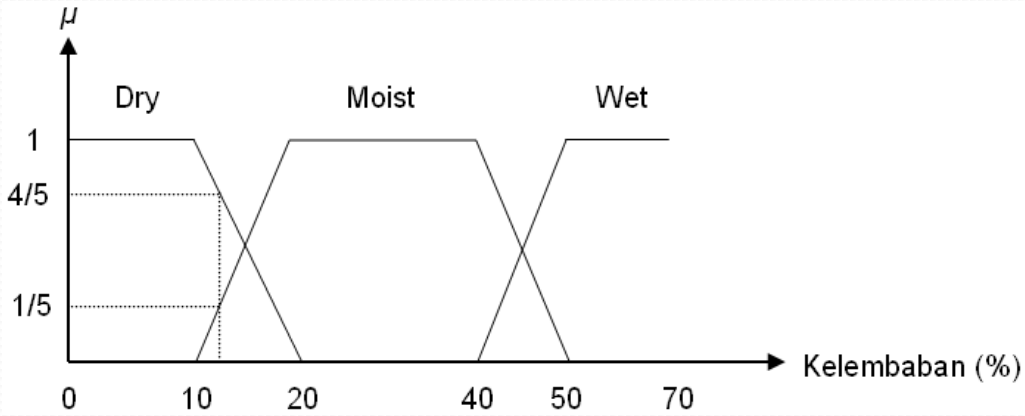
# Kasus 2: *Sprinkler CS*

- Model Mamdani atau Sugeno?
- Jumlah Nilai Linguistik untuk setiap variabel?
- Fungsi Keanggotaan: Segitiga, trapesium, phi, ...?
- Batas-batas Nilai Linguistik?
- *Fuzzy rule* yang tepat?

# Proses *fuzzification*




- Warm = -(37-39)/(39-36) = 2/3.
- Hot = (37-36)/(39-36) = 1/3.




- Dry = -(12-20)/(20-10) = 4/5
- Moist = (12-10)/(20-10) = 1/5

# Proses inferensi

**Antecedent 1 (Temperature)**

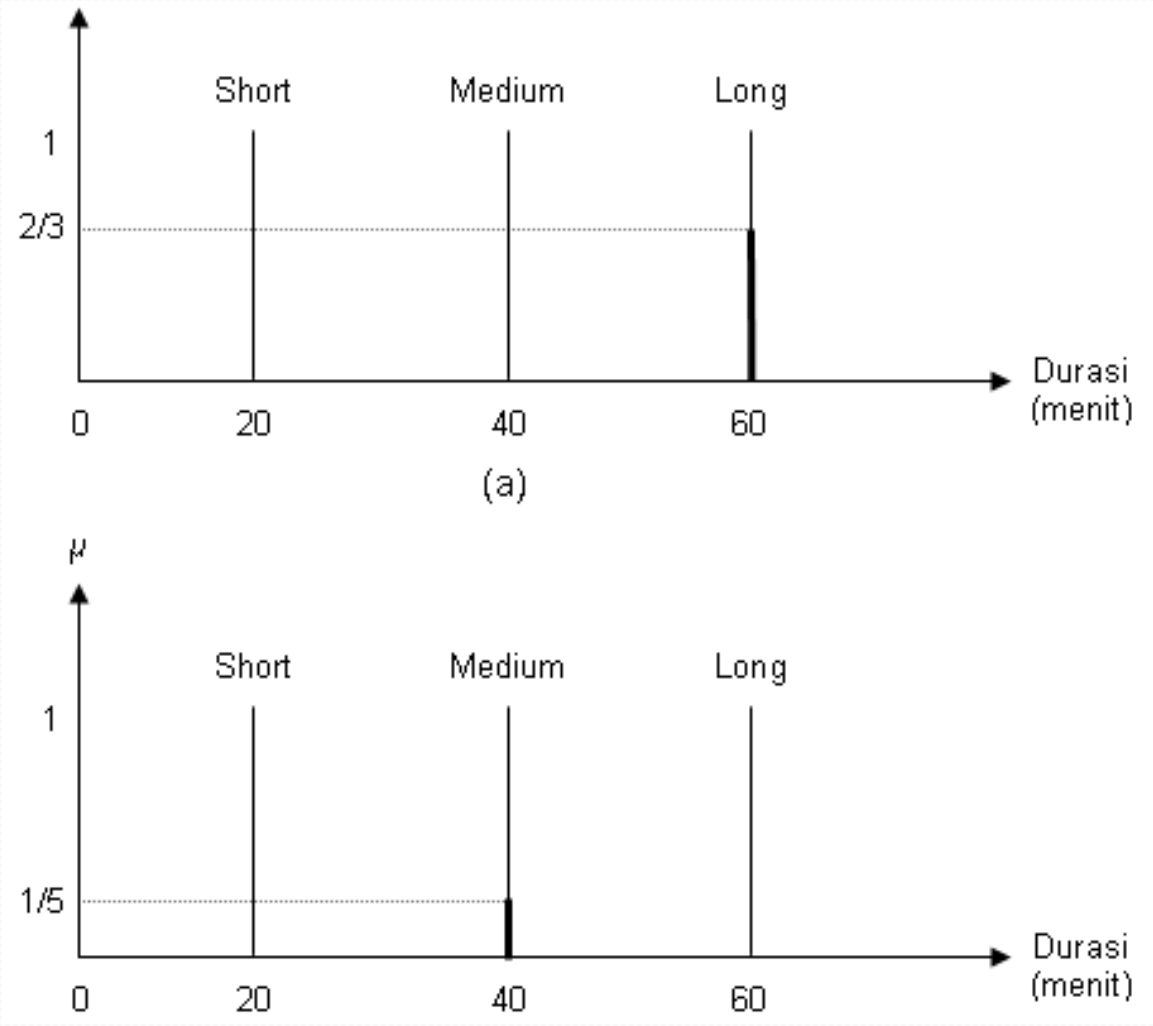
| Antecedent 2 (Moisture) | Cold | Cool | Normal | Warm | Hot |
|---|---|---|---|---|---|
| Dry | L | L | L | L | L |
| Moist | L | M | M | M | M |
| Wet | S | S | S | S | S |

**Note:** L = Long, M = Medium, S = Short

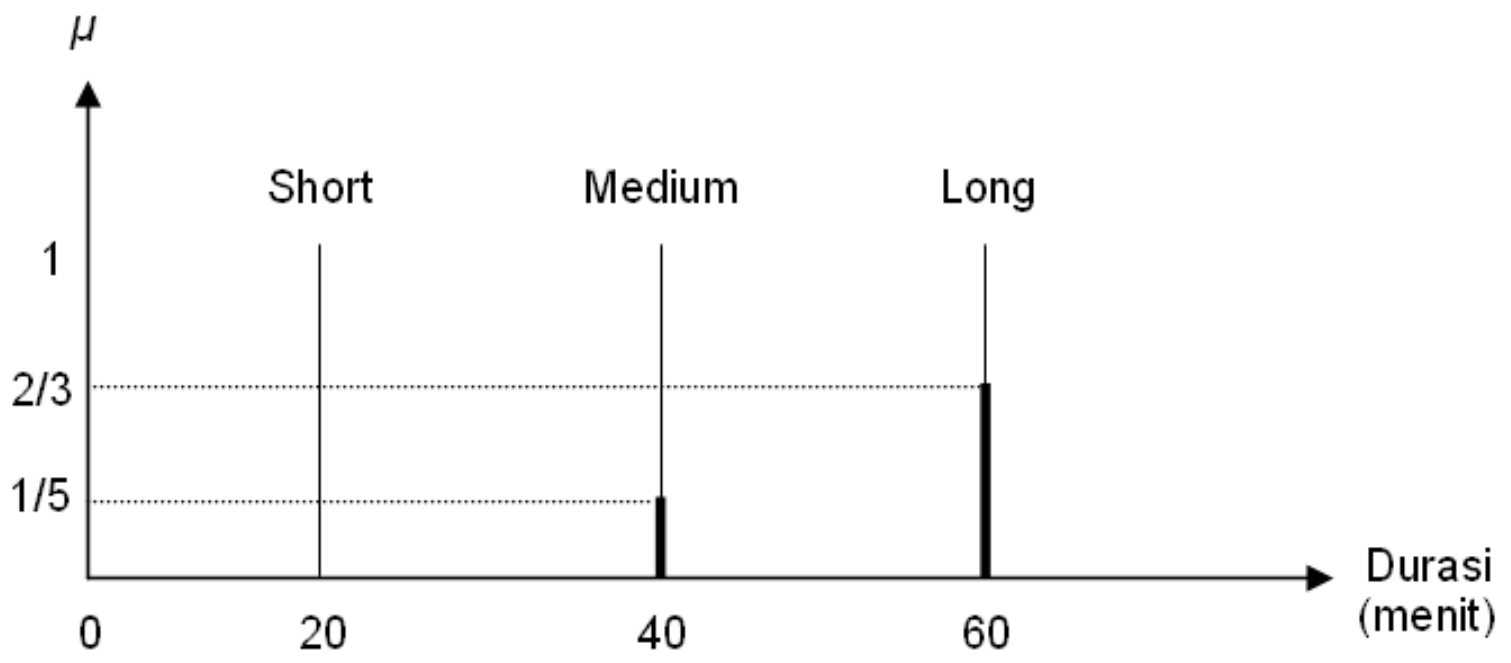
# Proses *inference*

- Dari empat data *fuzzy input* di atas, Warm (2/3), Hot (1/3), Dry (4/5) dan Moist (1/5), maka kita mendapatkan 4 aturan (dari 15 aturan) yang dapat diaplikasikan:
  - **IF** Suhu is Warm (2/3) **AND** Kelembaban is Dry (**4/5**) **THEN** Durasi is Long (**2/3**)
  - **IF** Suhu is Warm (2/3) **AND** Kelembaban is Moist (**1/5**) **THEN** Durasi is Medium (**1/5**)
  - **IF** Suhu is Hot (**1/3**) **AND** Kelembaban is Dry (4/5) **THEN** Durasi is Long (**1/3**)
  - **IF** Suhu is Hot (1/3) **AND** Kelembaban is Moist (**1/5**) **THEN** Durasi is Medium (**1/5**)

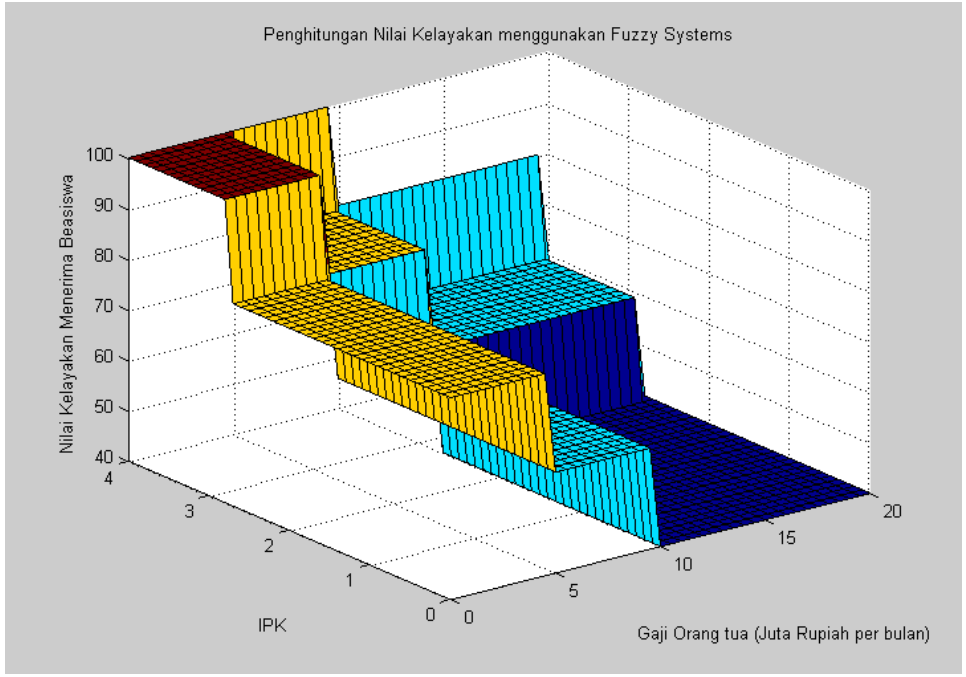
# *Inference*: Model Sugeno

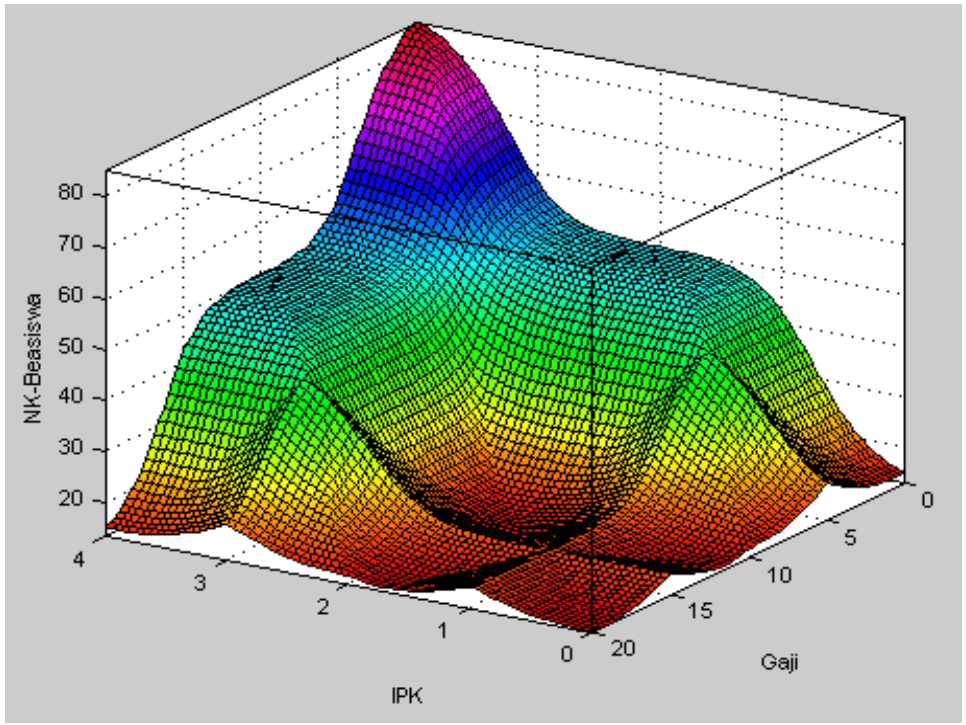


# *Defuzzyfication*: *Weighted Average*

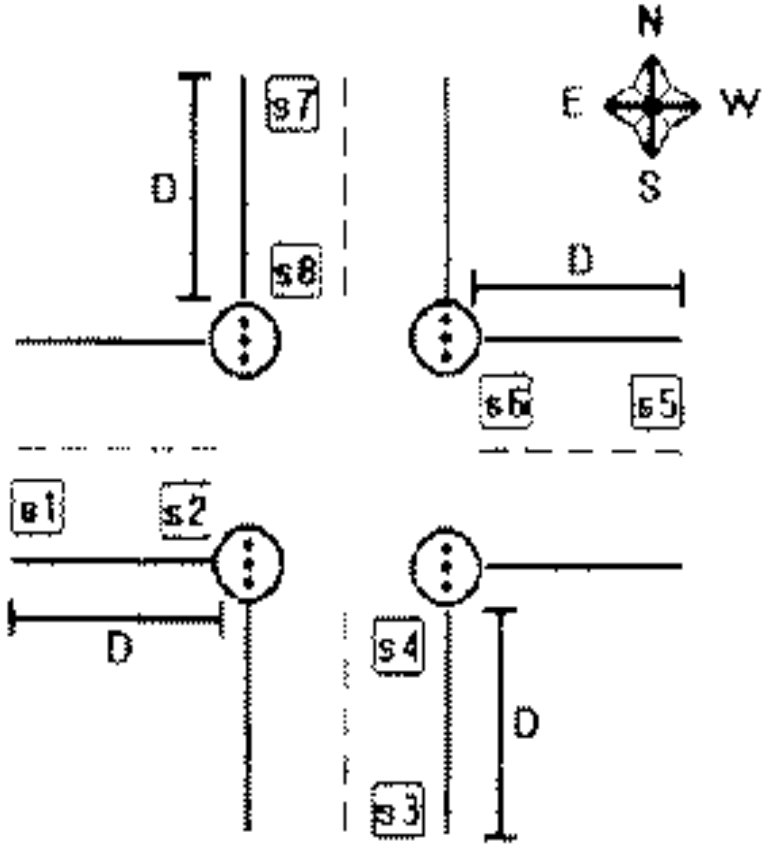



$$y^* = \frac{1/5(40) + 2/3(60)}{1/5 + 2/3} = 55{,}38$$

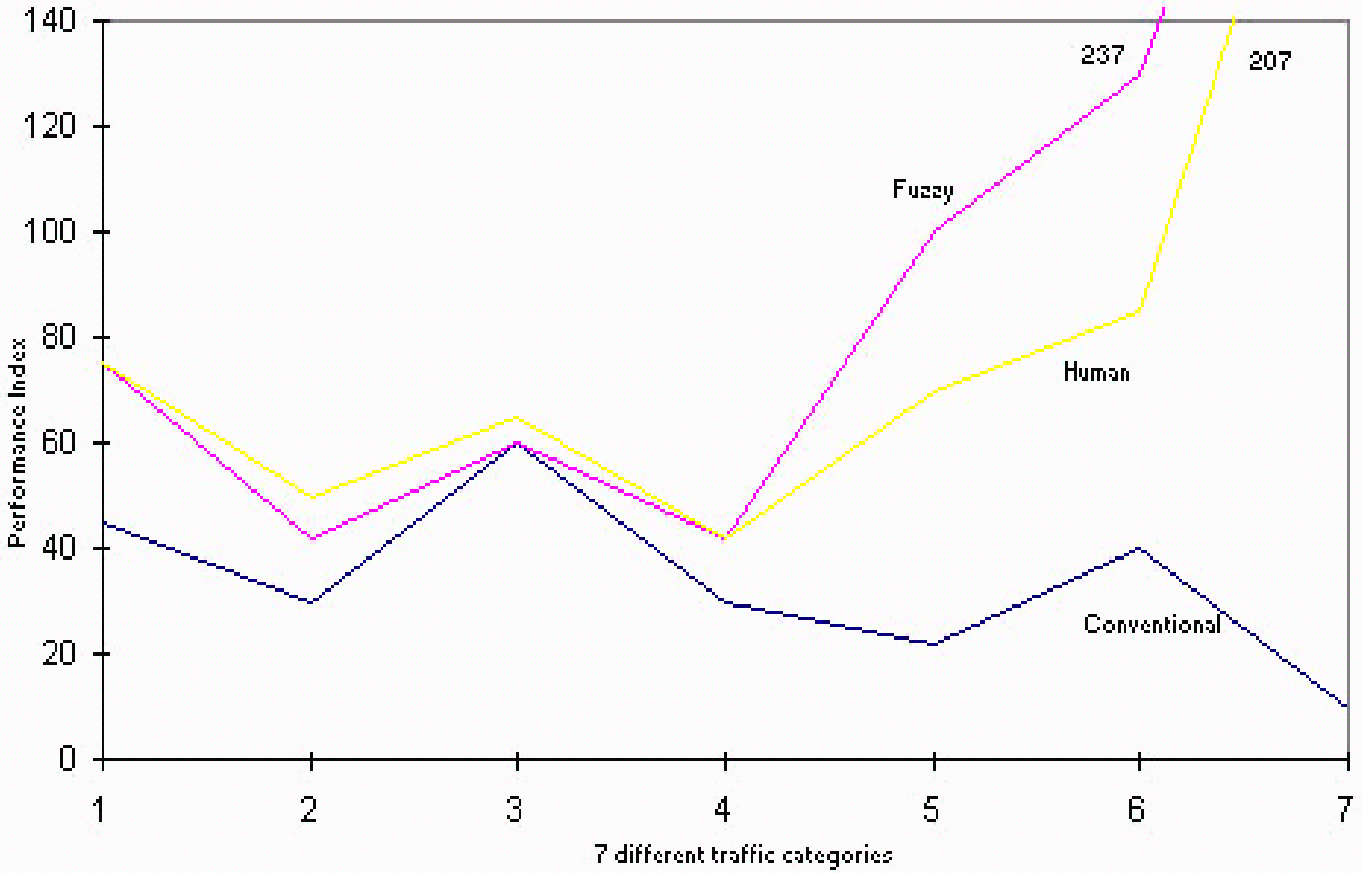

Penghitungan Nilai Kelayakan menggunakan Fuzzy Systems
Nilai Kelayakan Menerima Beasiswa
100
90
80
70
60
50
40
4
3
2
1
0
IPK
0
5
10
15
20
Gaji Orang tua (Juta Rupiah per bulan)


NK-Beasiswa
80
70
60
50
40
30
20
4
3
2
1
0
IPK
0
5
10
15
20
Gaji

# Kasus 3: *Traffic Light Controller*



# Kasus 3: *Traffic Light Controller*




[Shahariz Abdul Aziz & Jeyakody Parthiban]

# Kasus 4: Akreditasi Prodi

- Pendidikan dan Pengajaran
  - Pendidikan Dosen: S1, S2, S3?
  - Jabatan Akademik: AA, L, LK, GB?
  - Rasio Dosen : Mhs?
- Penelitian
  - Dana proyek?
  - Paper Ilmiah?
- Pengabdian Masyarakat
  - Jumlah kegiatan per tahun?
  - Manfaat bagi masyarakat?

# Kasus 5: *University Rankings*

- Bagaimana mengelompokkan universitas ke dalam ***cluster*** yang secara statistik mirip untuk semua kriteria yg ada?
- ***Clustering harus*** dilakukan tanpa asumsi apapun tentang tingkat kepentingan relatif dari semua kriteria.
- Kriteria:
  - Jumlah profesor?
  - Jumlah mhs asing?
  - Rasio Dosen:Mhs?
  - Besarnya Dana proyek?
  - Jumlah Paper Ilmiah?

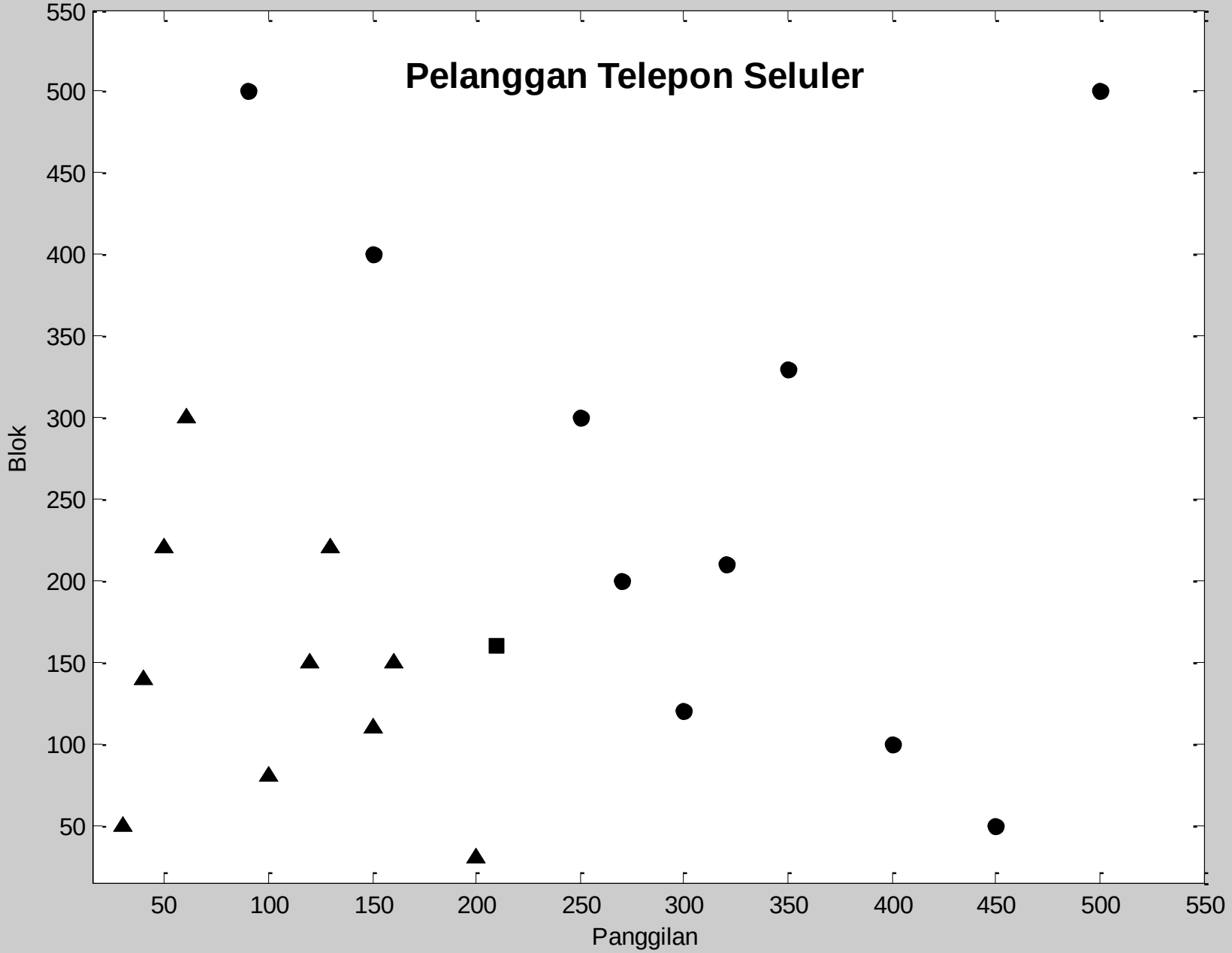
# Kasus 5: *University Rankings*

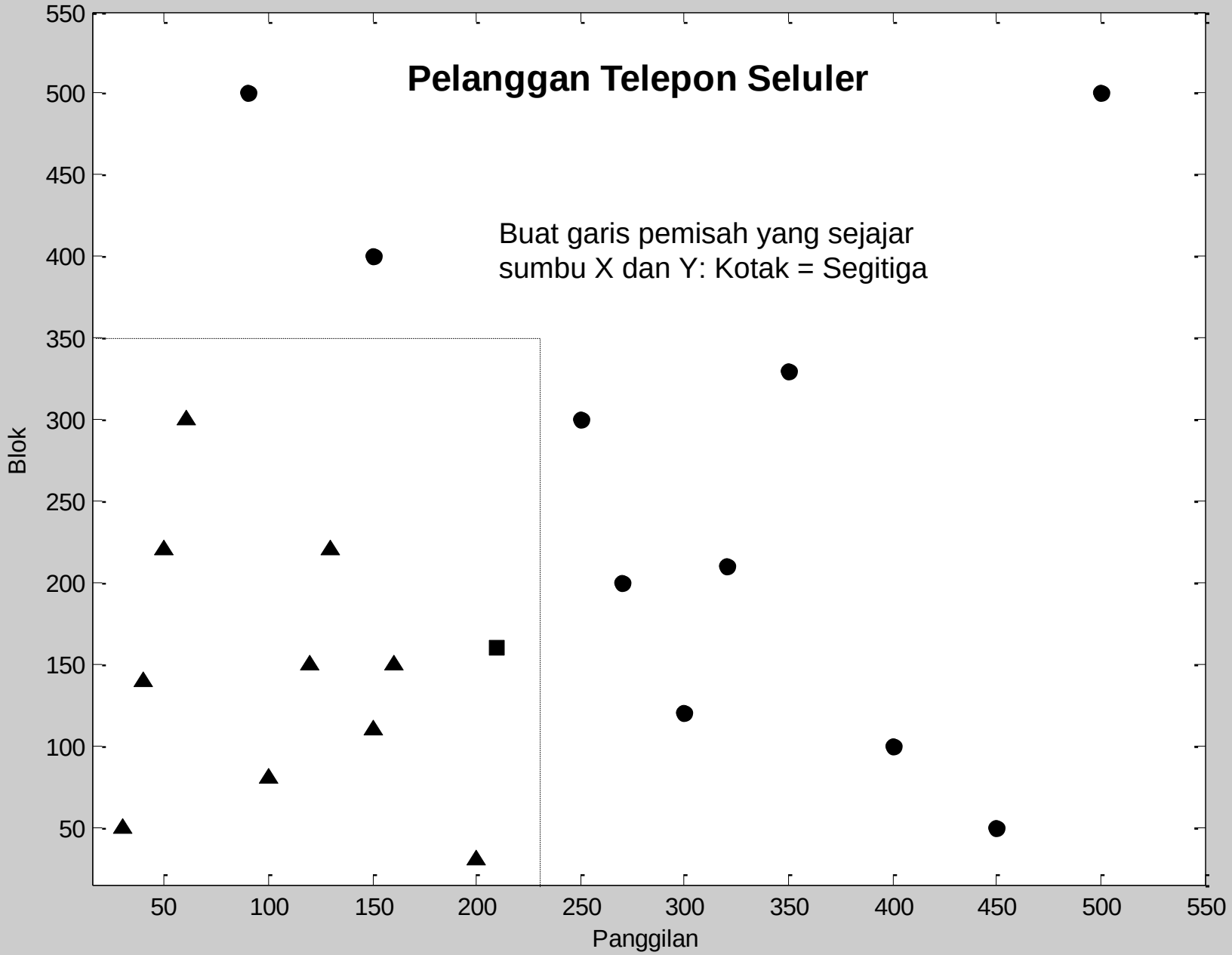
- Shanghai Jao Tong University (SJTU)
- The Time Higher League Table (THES)
- Metode: ***Fuzzy Clustering***
- Top 500 Univerisities in the world
  1. Harvard
  2. Stanford
  3. Cambridge

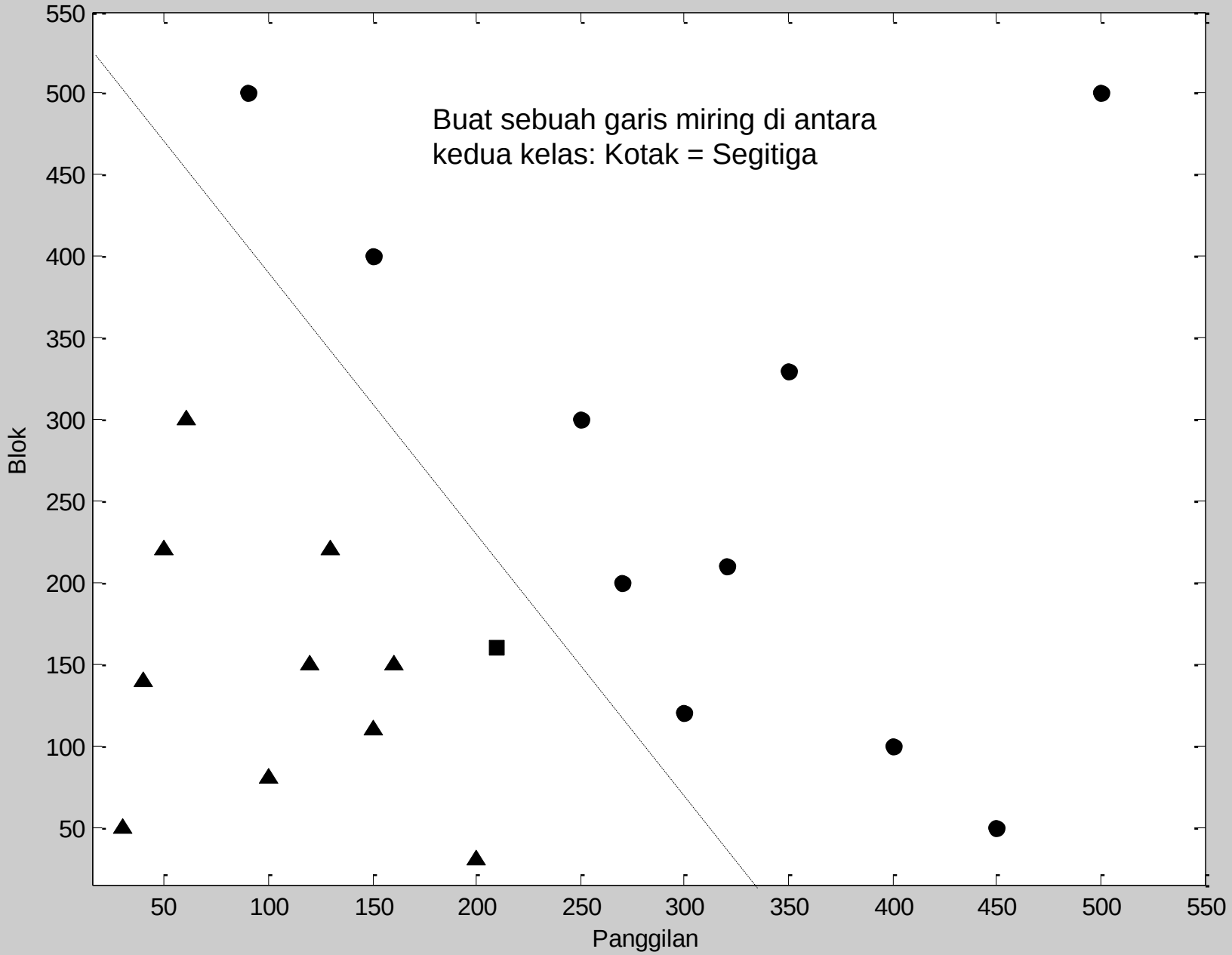
# Data Pelanggan Telepon Seluler

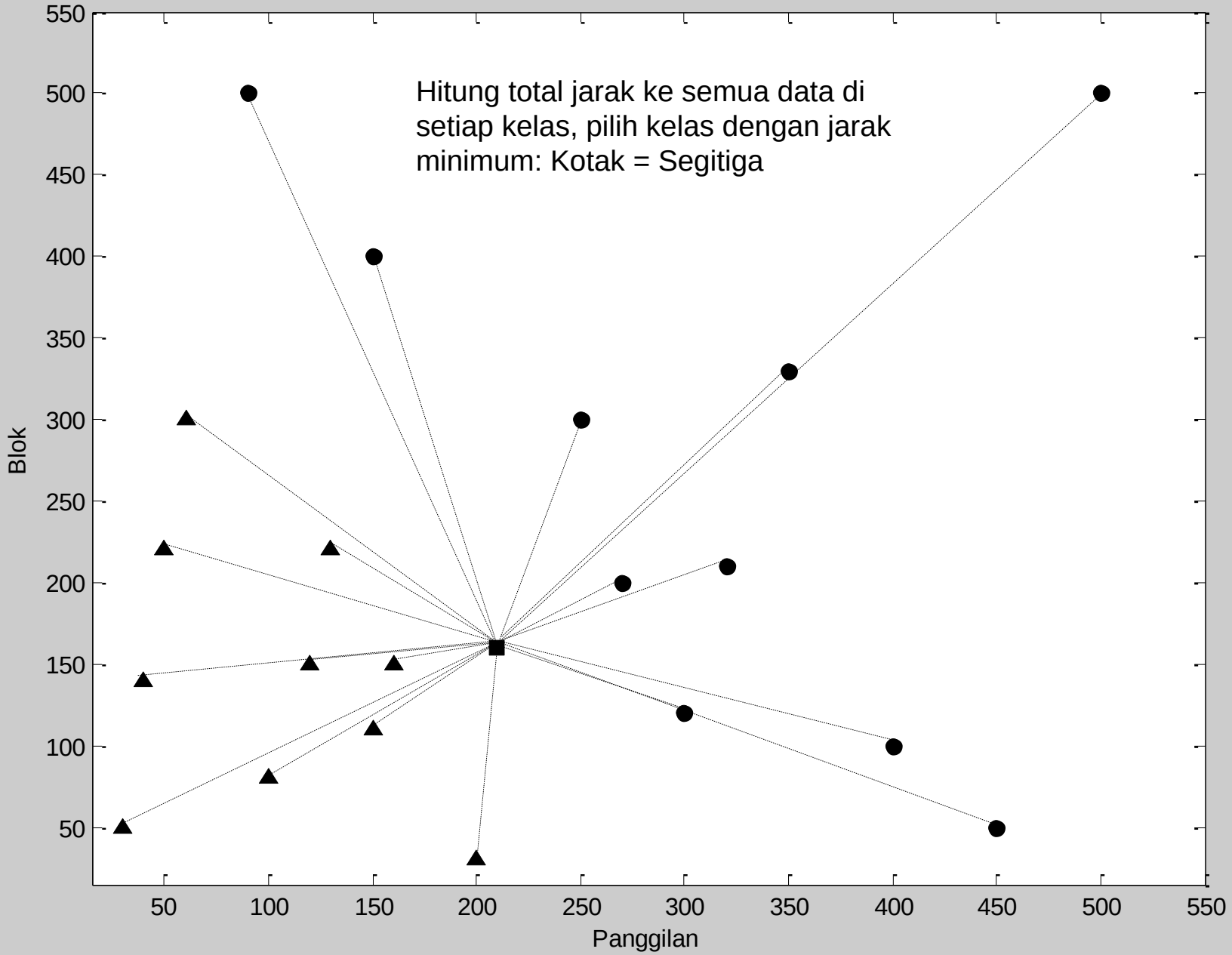
| Panggilan | Blok | Bonus |
|---|---|---|
| 30 | 50 | Tidak |
| 40 | 140 | Tidak |
| 50 | 220 | Tidak |
| 60 | 300 | Tidak |
| 100 | 80 | Tidak |
| 120 | 150 | Tidak |
| 130 | 220 | Tidak |
| 150 | 110 | Tidak |
| 160 | 150 | Tidak |
| 200 | 30 | Tidak |

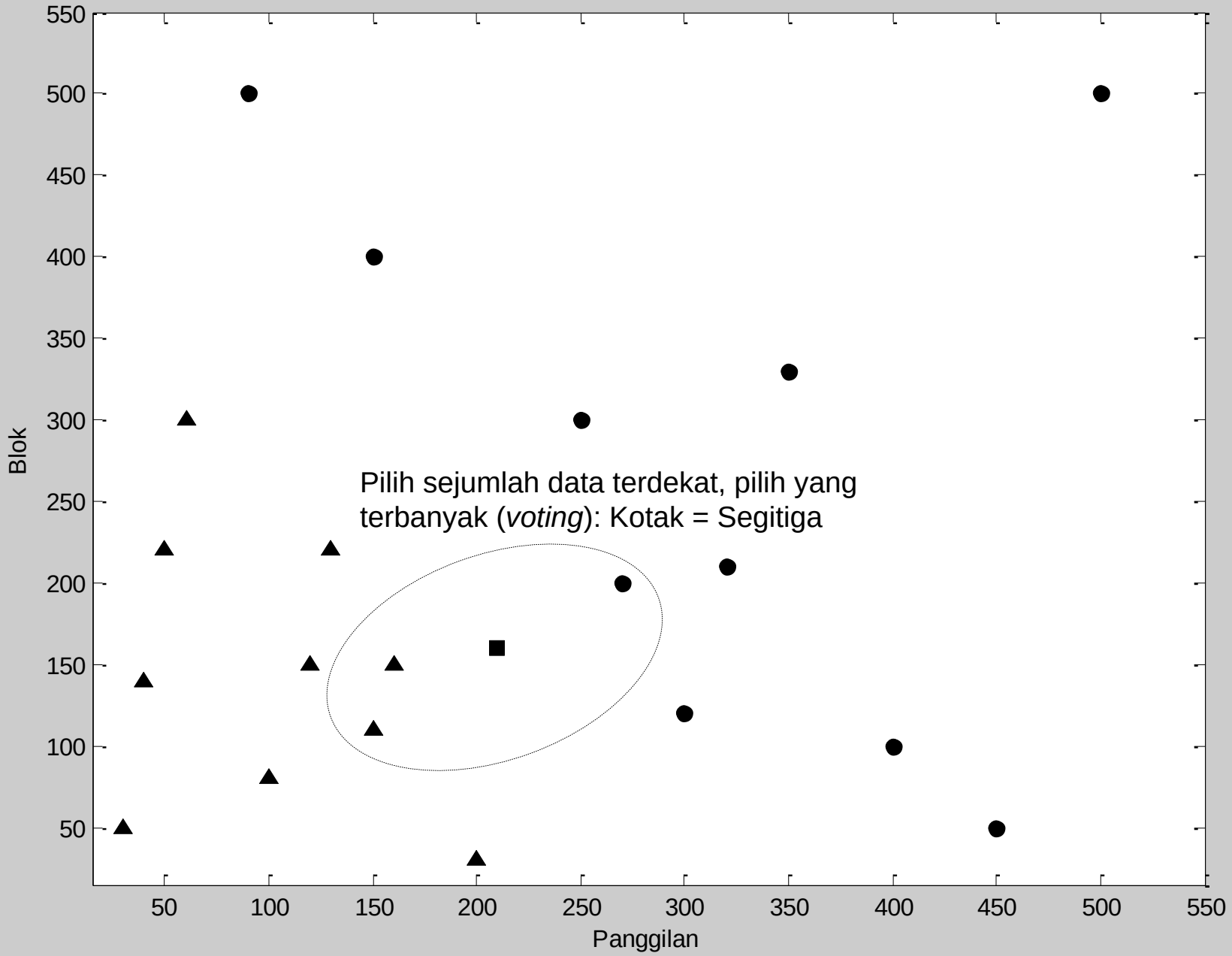
| Panggilan | Blok | Bonus |
|---|---|---|
| 90 | 500 | Ya |
| 150 | 400 | Ya |
| 250 | 300 | Ya |
| 270 | 200 | Ya |
| 300 | 120 | Ya |
| 320 | 210 | Ya |
| 350 | 330 | Ya |
| 400 | 100 | Ya |
| 450 | 50 | Ya |
| 500 | 500 | Ya |

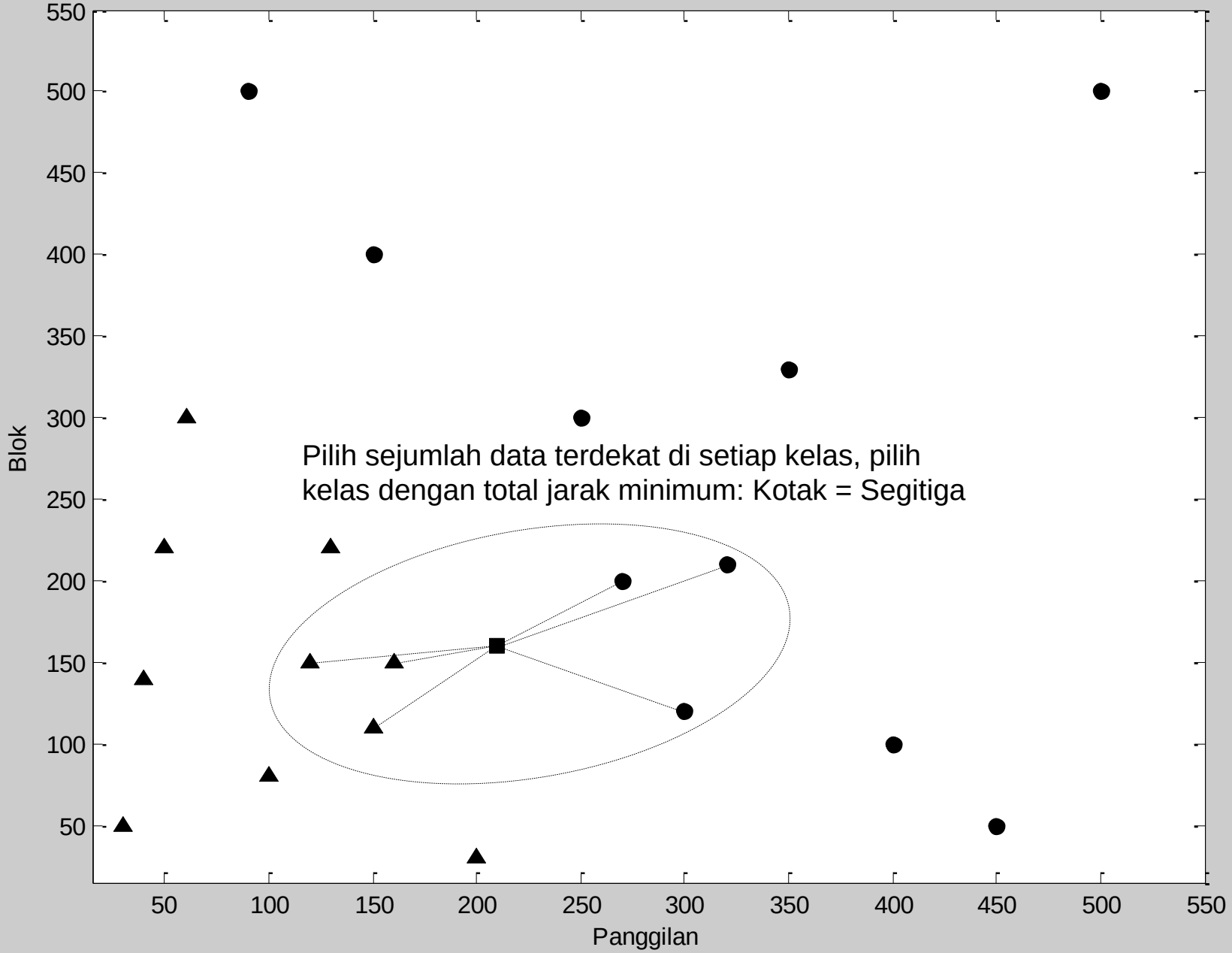

Pelanggan Telepon Seluler
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550

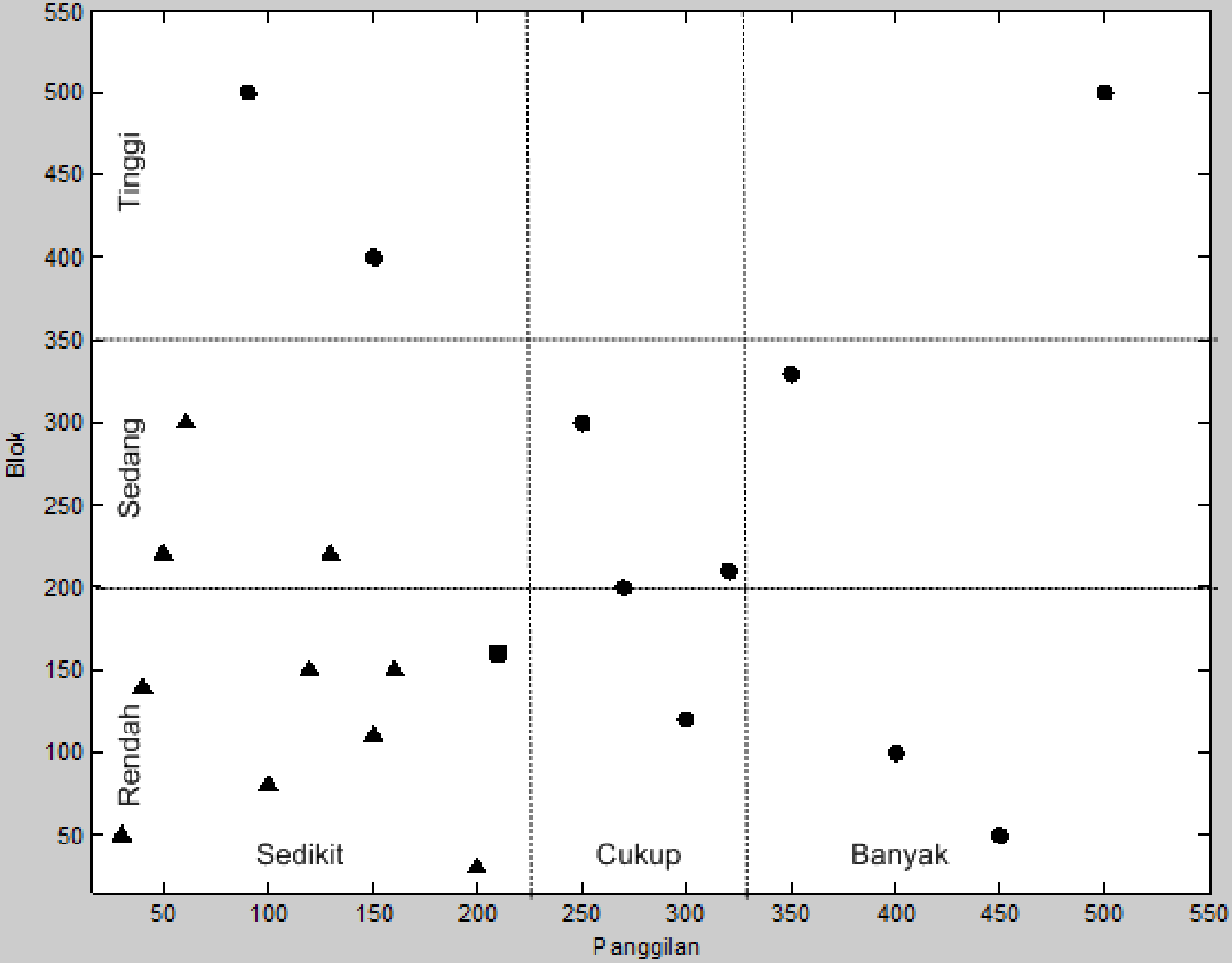

Pelanggan Telepon Seluler
Buat garis pemisah yang sejajar sumbu X dan Y: Kotak = Segitiga
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550


Buat sebuah garis miring di antara
kedua kelas: Kotak = Segitiga
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550

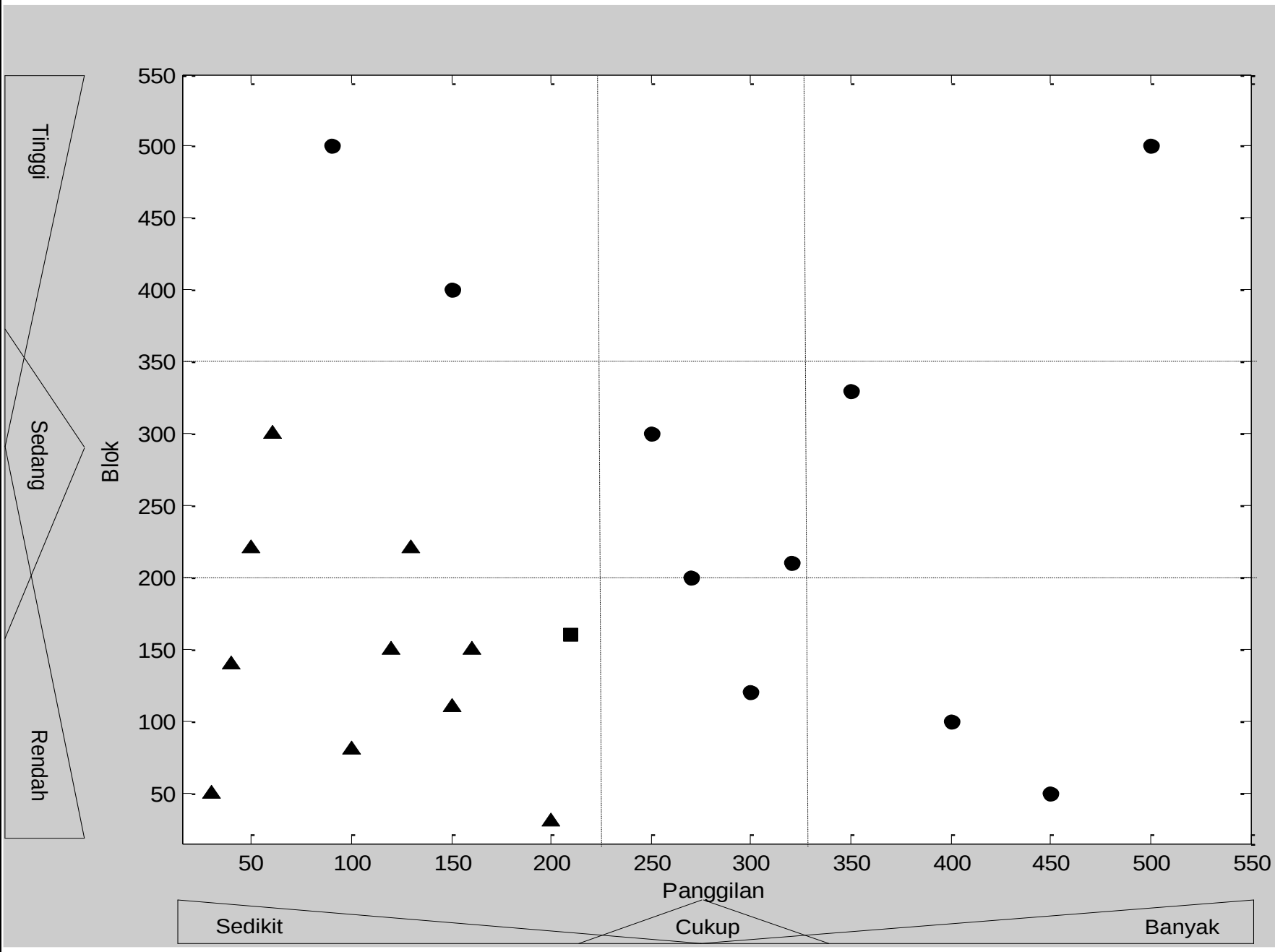

Hitung total jarak ke semua data di setiap kelas, pilih kelas dengan jarak minimum: Kotak = Segitiga
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550


Pilih sejumlah data terdekat, pilih yang terbanyak (*voting*): Kotak = Segitiga
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550

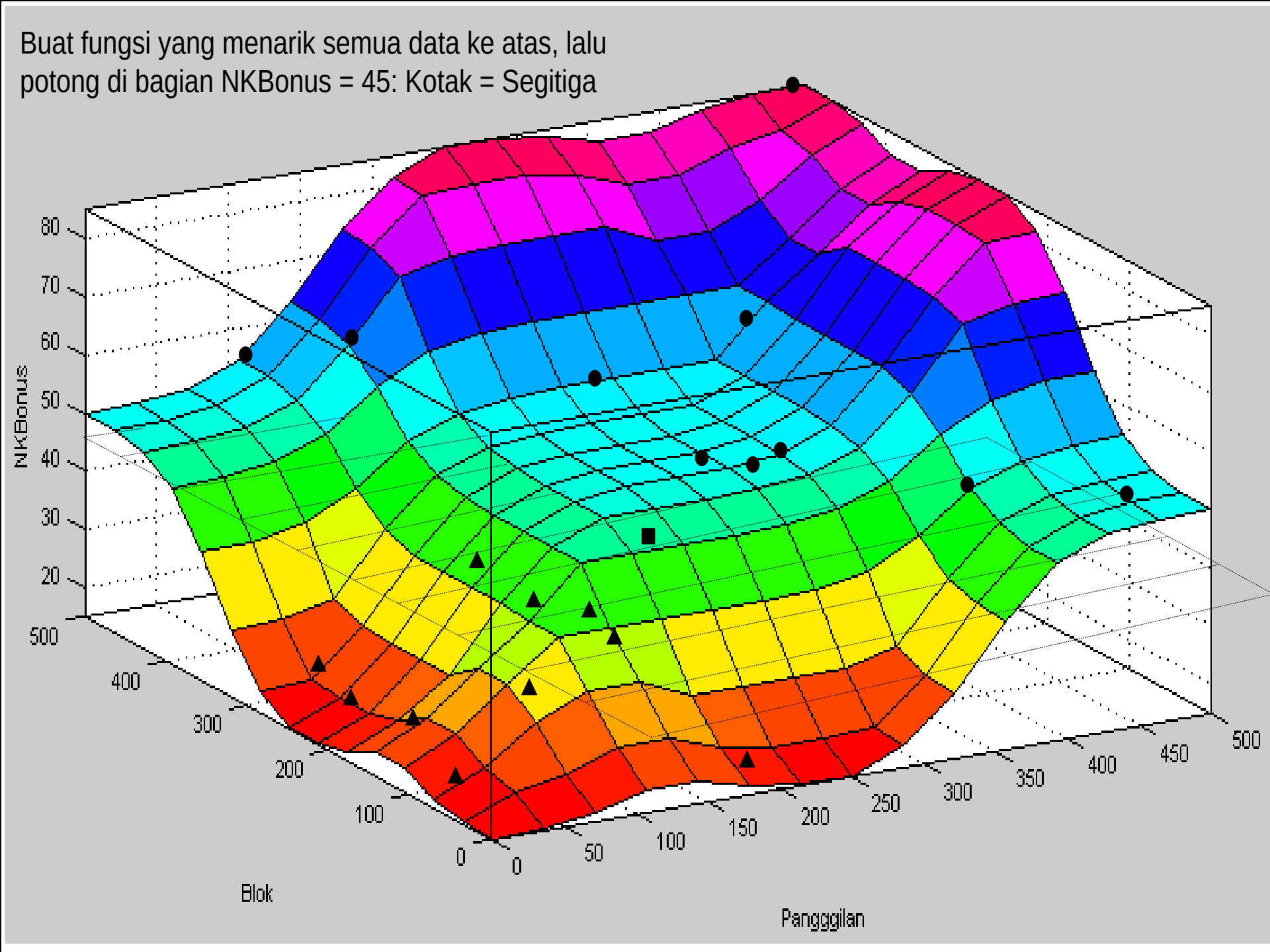

Pilih sejumlah data terdekat di setiap kelas, pilih
kelas dengan total jarak minimum: Kotak = Segitiga
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550

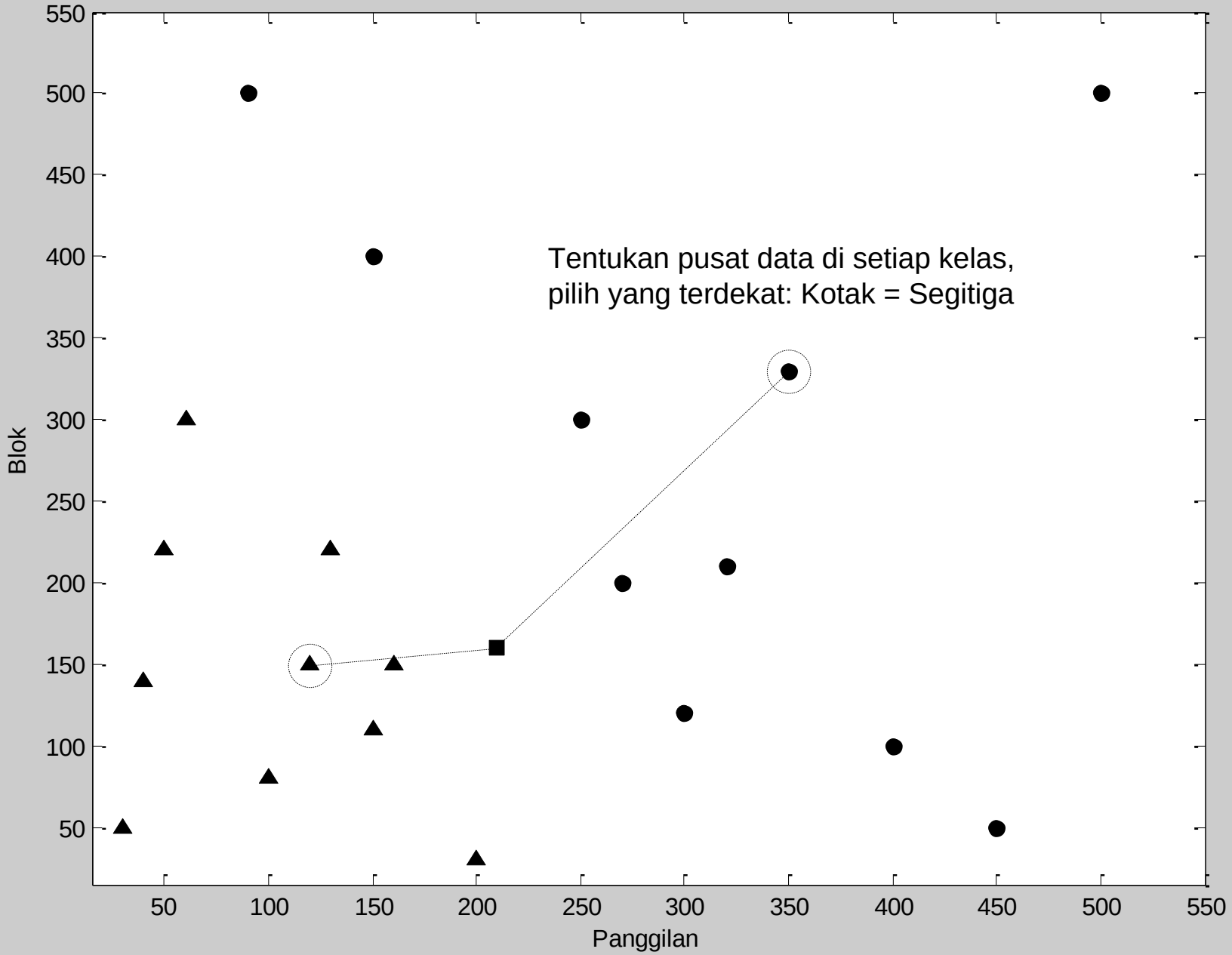

Tinggi
Sedang
Rendah
Sedikit
Cukup
Banyak
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550

Bagi Panggilan dan Blok ke dalam tiga nilai linguistik, lalu lakukan *fuzzification* dan inferensi *berbasis fuzzy rules* untuk menentukan kelas. Kotak = Segitiga



Buat fungsi yang menarik semua data ke atas, lalu potong di bagian NKBonus = 45: Kotak = Segitiga




Tentukan pusat data di setiap kelas,
pilih yang terdekat: Kotak = Segitiga
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550

# Construction of fuzzy classification systems with rectangular fuzzy rules using genetic algorithms

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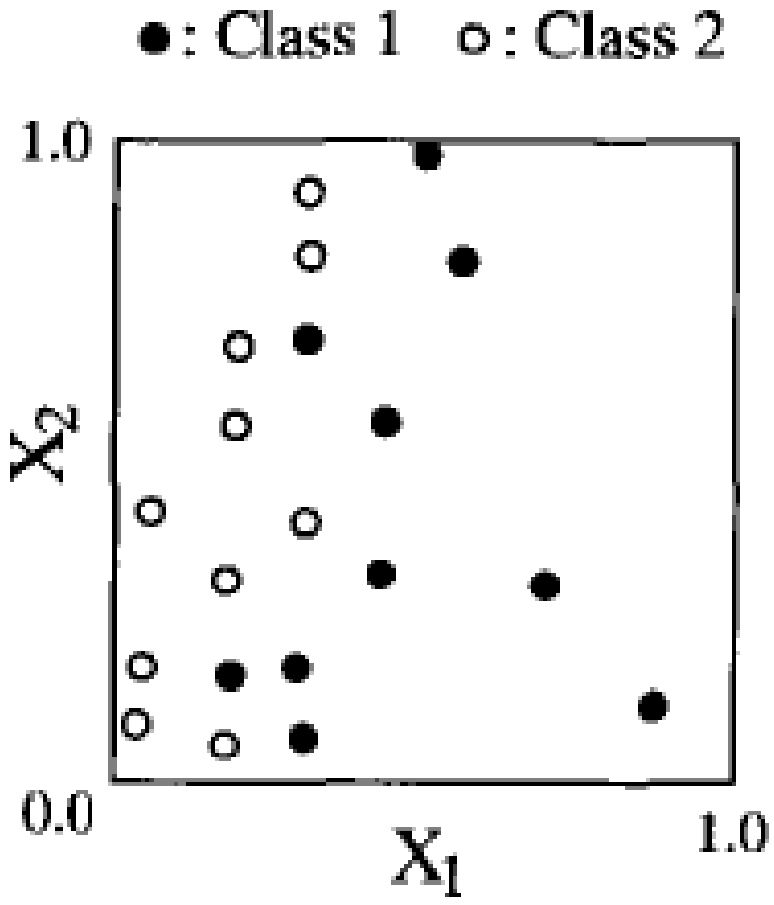
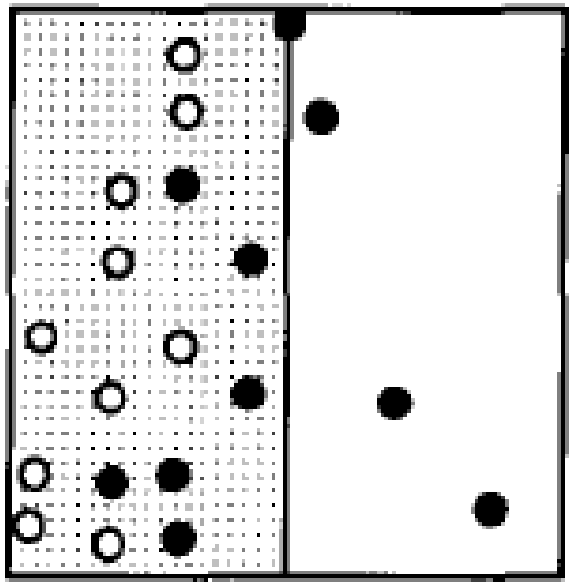
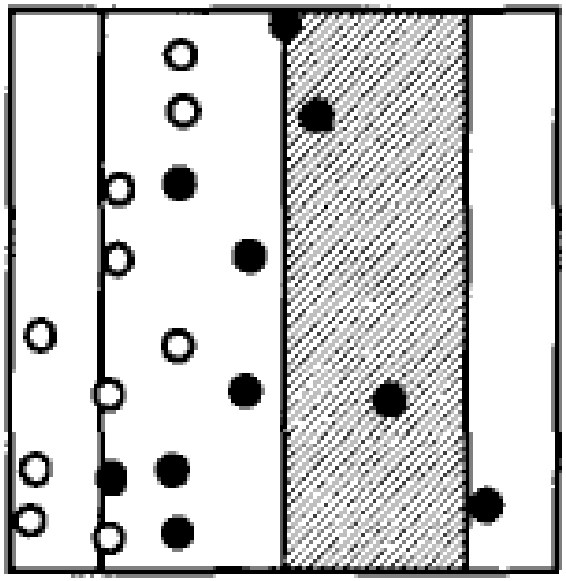
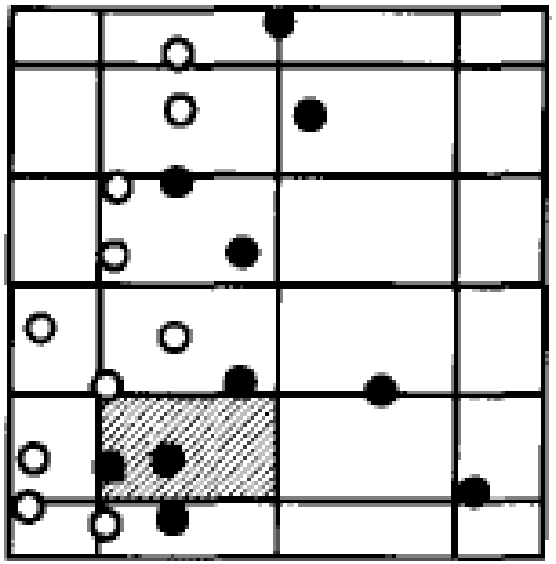
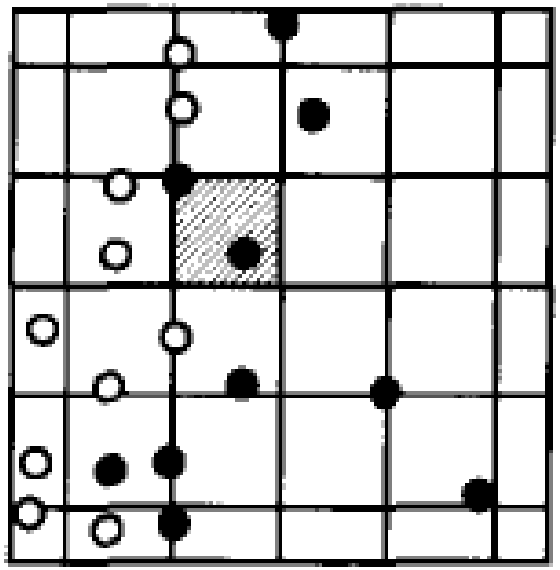
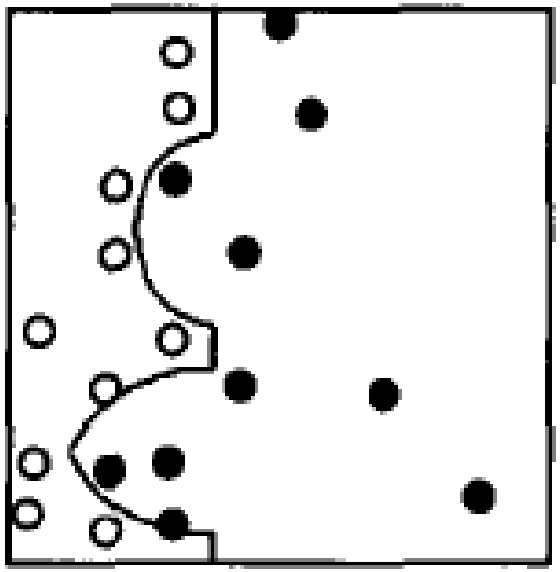
Received January 1994; revised February 1994

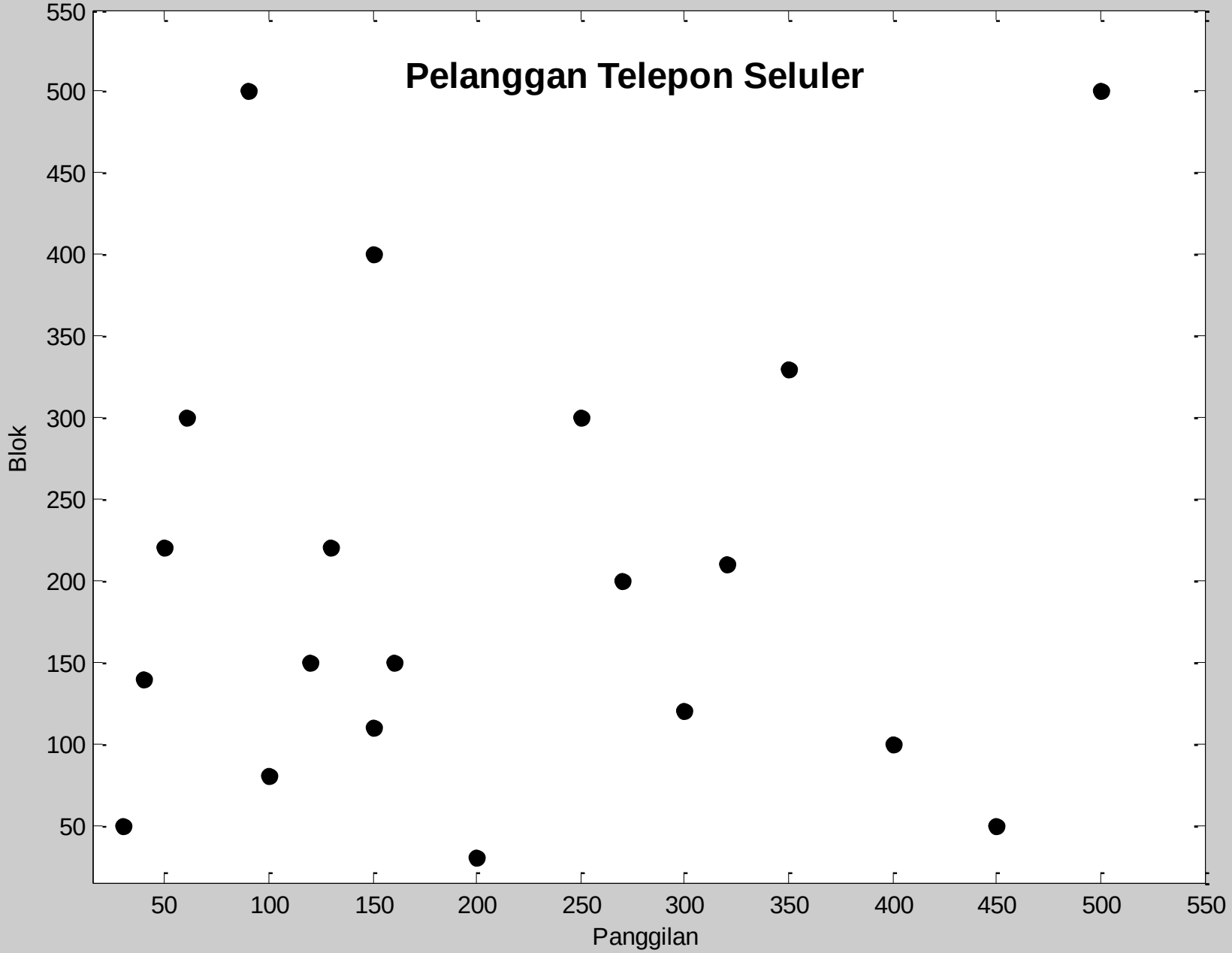


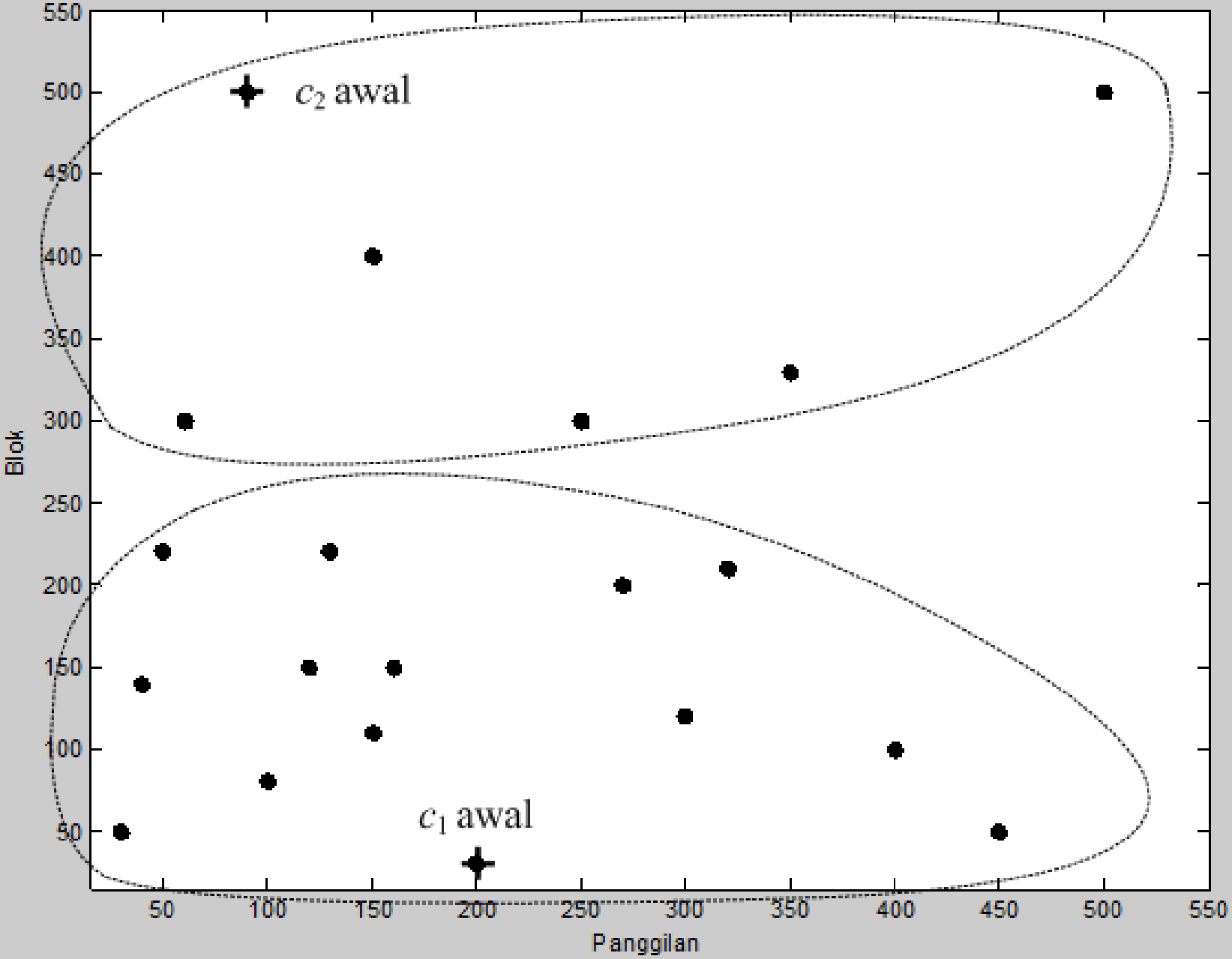






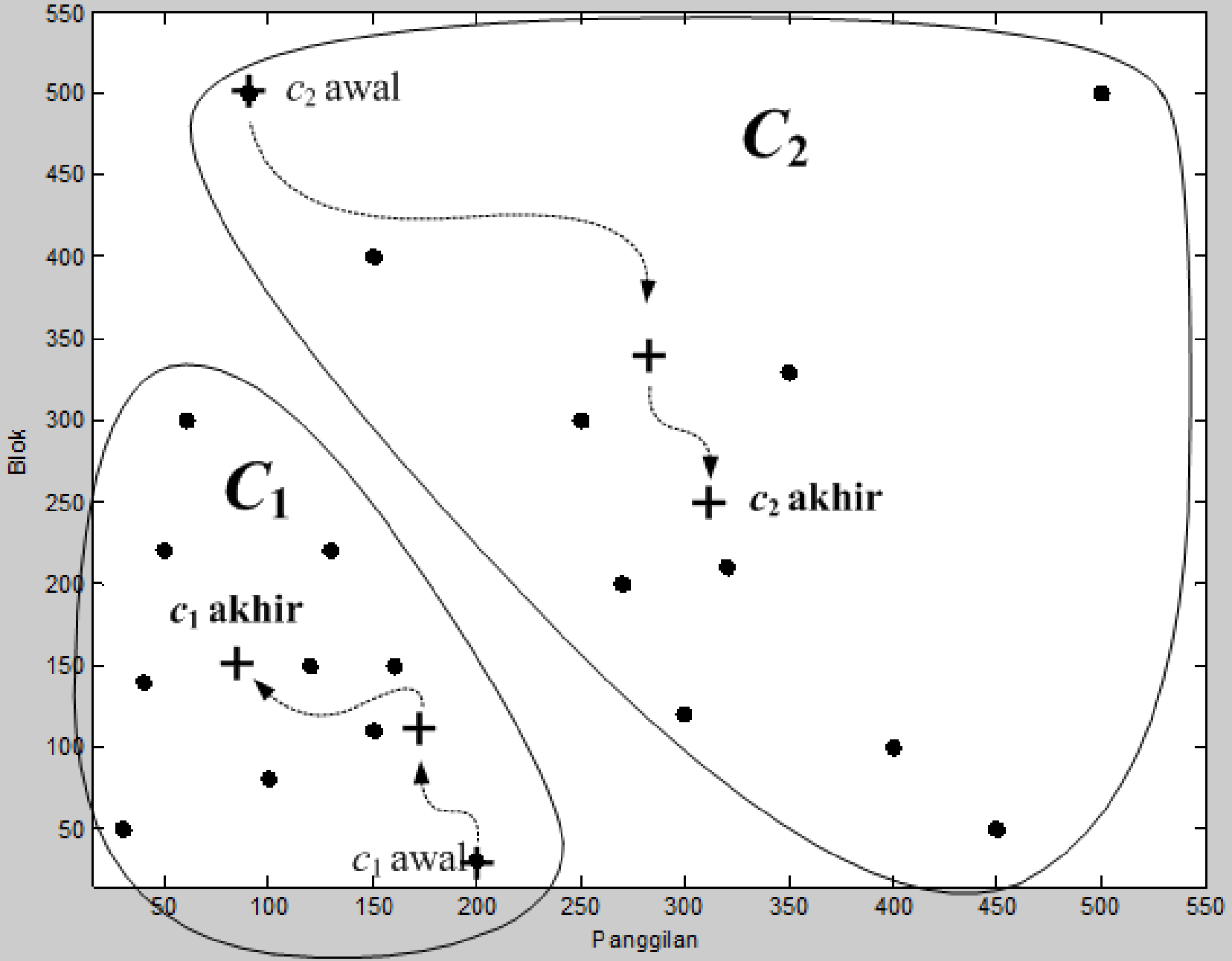
# Data Pelanggan Telepon Seluler

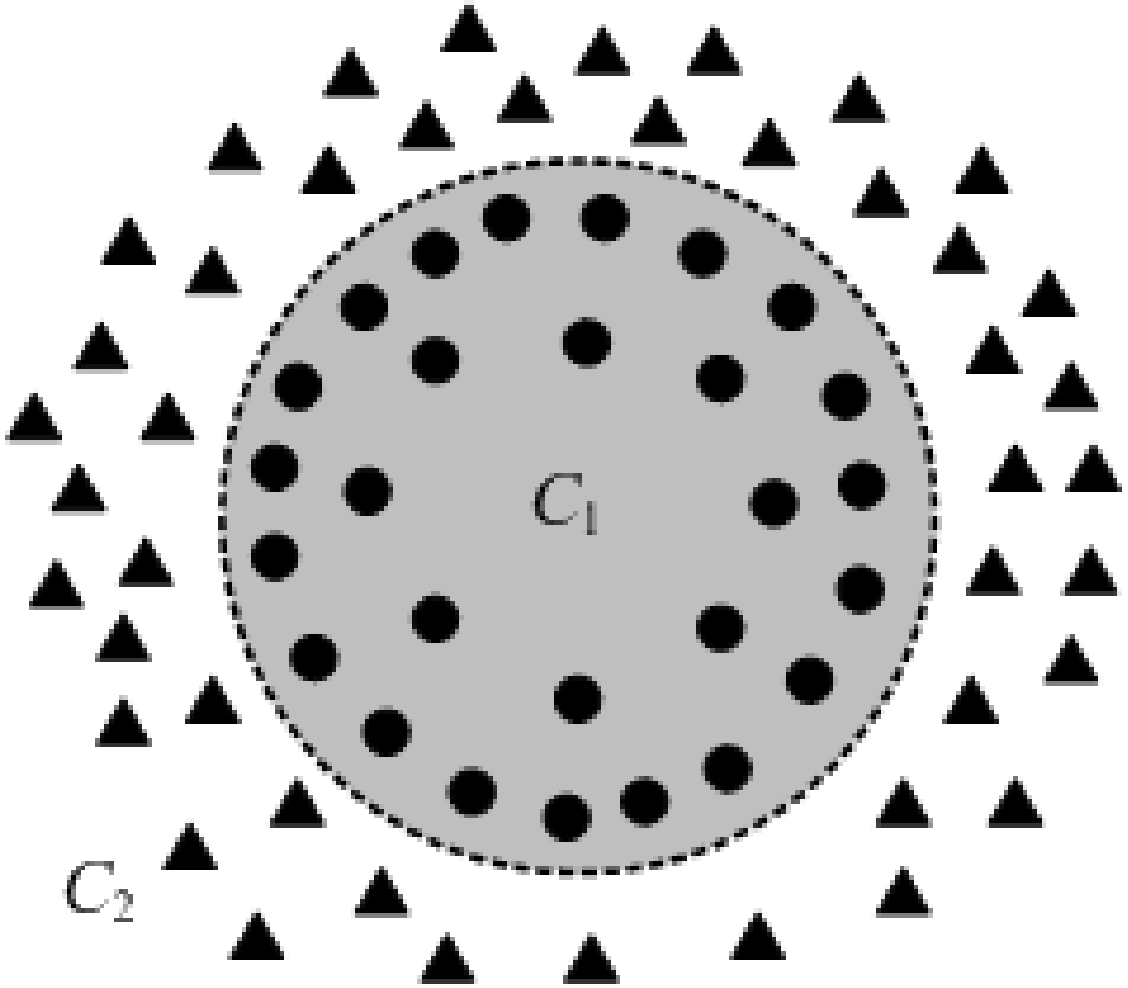
| Panggilan | Blok |
|---|---|
| 30 | 50 |
| 40 | 140 |
| 50 | 220 |
| 60 | 300 |
| 100 | 80 |
| 120 | 150 |
| 130 | 220 |
| 150 | 110 |
| 160 | 150 |
| 200 | 30 |

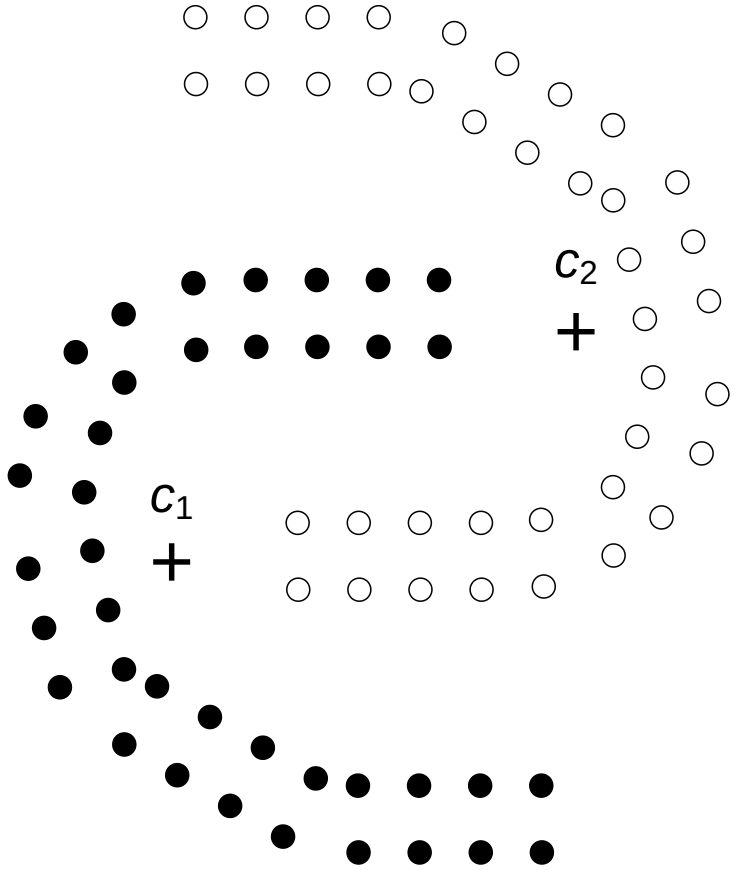
| Panggilan | Blok |
|---|---|
| 90 | 500 |
| 150 | 400 |
| 250 | 300 |
| 270 | 200 |
| 300 | 120 |
| 320 | 210 |
| 350 | 330 |
| 400 | 100 |
| 450 | 50 |
| 500 | 500 |

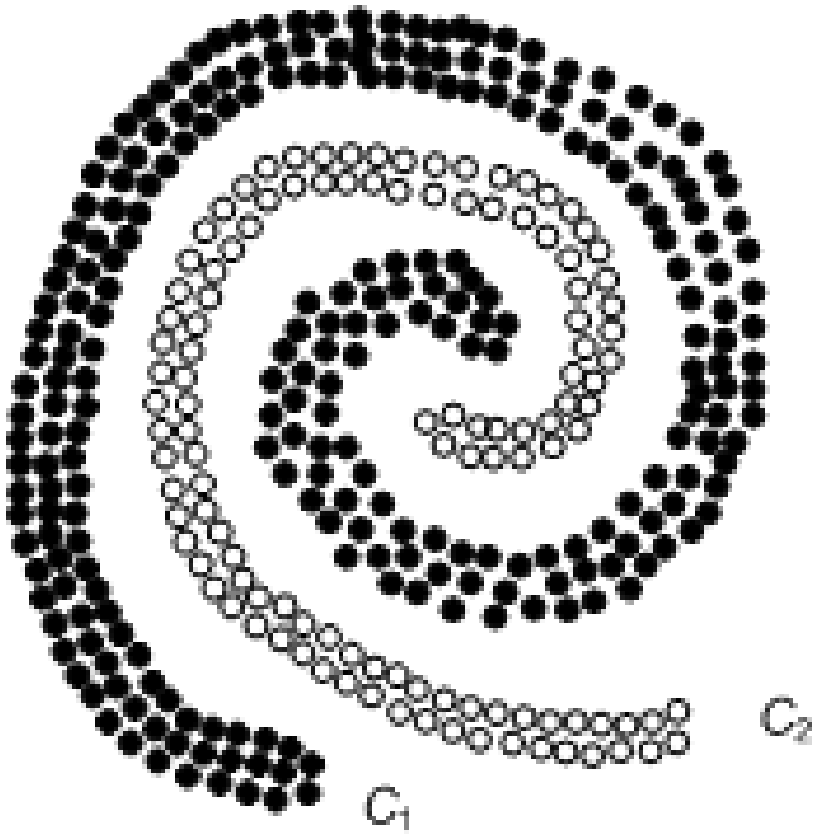

Pelanggan Telepon Seluler
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550


$c_2$ awal
$c_1$ awal
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550


$c_2$ awal
$C_2$
$C_1$
$c_2$ akhir
$c_1$ akhir
$c_1$ awal
Blok
Panggilan
550
500
450
400
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400
450
500
550


$C_1$
$C_2$


$c_1$
$c_2$


$C_2$
$C_1$

# *Fuzzy Clustering*

- To extract rules from data
- Fuzzy c-means
- Aplikasi:
  - Cracked Tile Detection
  - Finding Cancer Cells
  - Image Segmentation
  - Document clustering

# *Cluster*

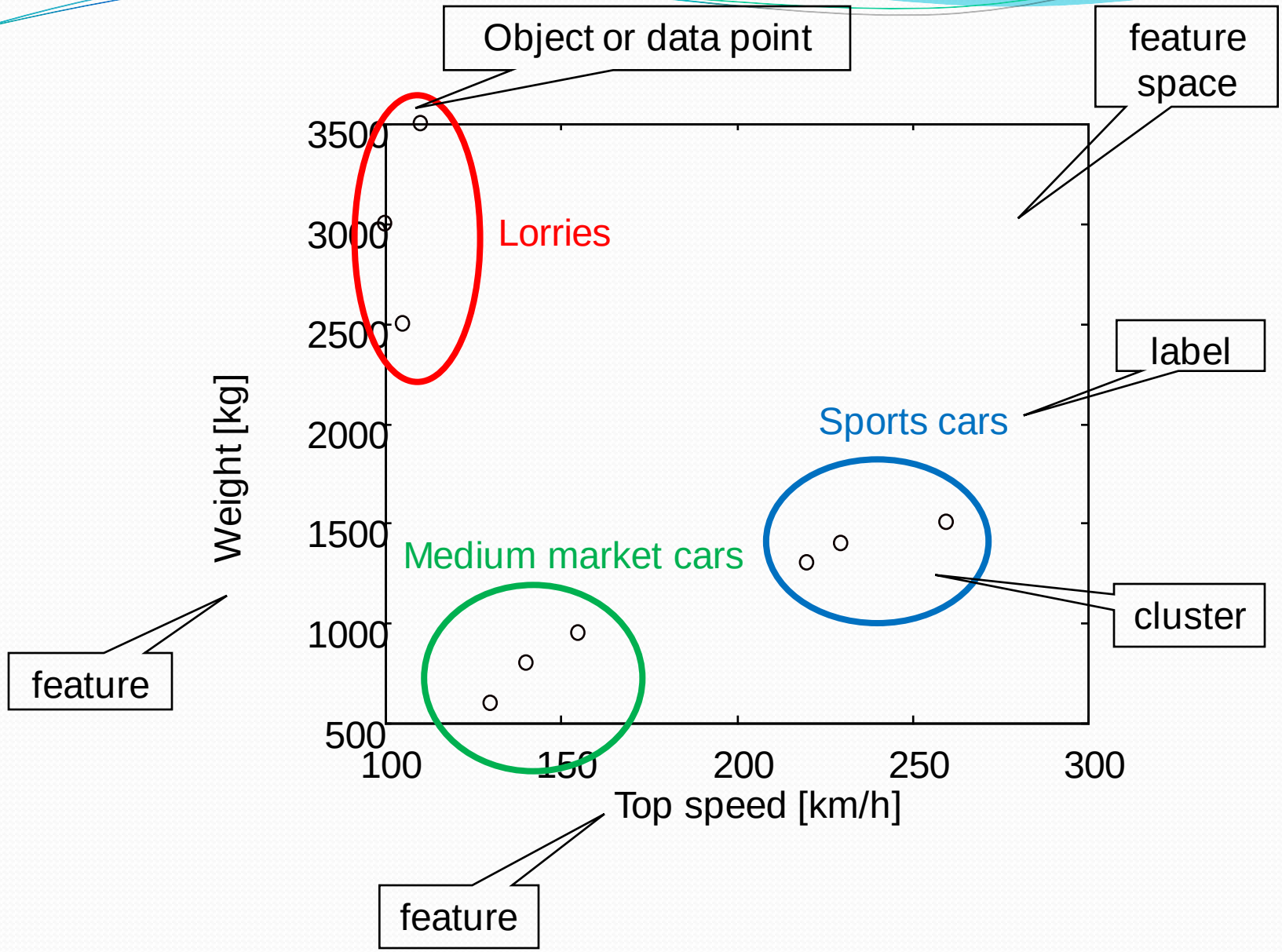
- Sejumlah individu yang memiliki sifat hampir sama atau terjadi bersama-sama
- Kelompok universitas kelas dunia
- Kelompok mobil kategori tertentu
- Kumpulan spam email
- Kumpulan tipe penyakit kanker

# *Cluster Analysis*

- A statistical classification technique
- for discovering whether the individuals of a population fall into different groups
- by making **quantitative comparisons** of multiple characteristics.

# Vehicle

| Vehicle | Top speed km/h | Colour | Air resistance | Weight Kg |
|---|---|---|---|---|
| V1 | 220 | red | 0.30 | 1300 |
| V2 | 230 | black | 0.32 | 1400 |
| V3 | 260 | red | 0.29 | 1500 |
| V4 | 140 | gray | 0.35 | 800 |
| V5 | 155 | blue | 0.33 | 950 |
| V6 | 130 | white | 0.40 | 600 |
| V7 | 100 | black | 0.50 | 3000 |
| V8 | 105 | red | 0.60 | 2500 |
| V9 | 110 | gray | 0.55 | 3500 |


Object or data point
feature space
Lorries
label
Sports cars
Medium market cars
cluster
feature
feature
Weight [kg]
Top speed [km/h]
3500
3000
2500
2000
1500
1000
500
100
150
200
250
300

# Kasus 6: *Tile Clustering*

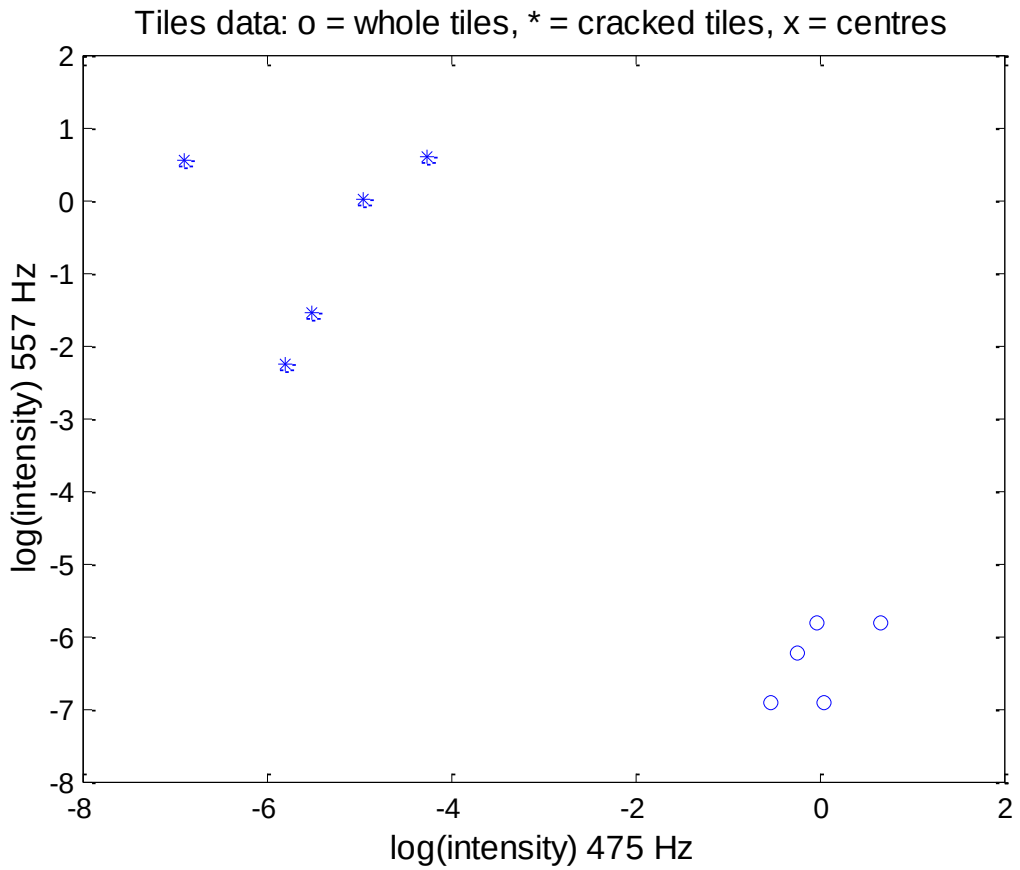
- Tiles are made from clay moulded into the right shape, brushed, glazed, and baked.
- Unfortunately, the baking may produce invisible cracks.
- Operators can detect the cracks by hitting the tiles with a hammer, and in an automated system the response is recorded with a microphone, filtered, Fourier transformed, and normalised.
- A small set of data is given in the TABLE below.

# Kasus 6: *Tile Clustering*

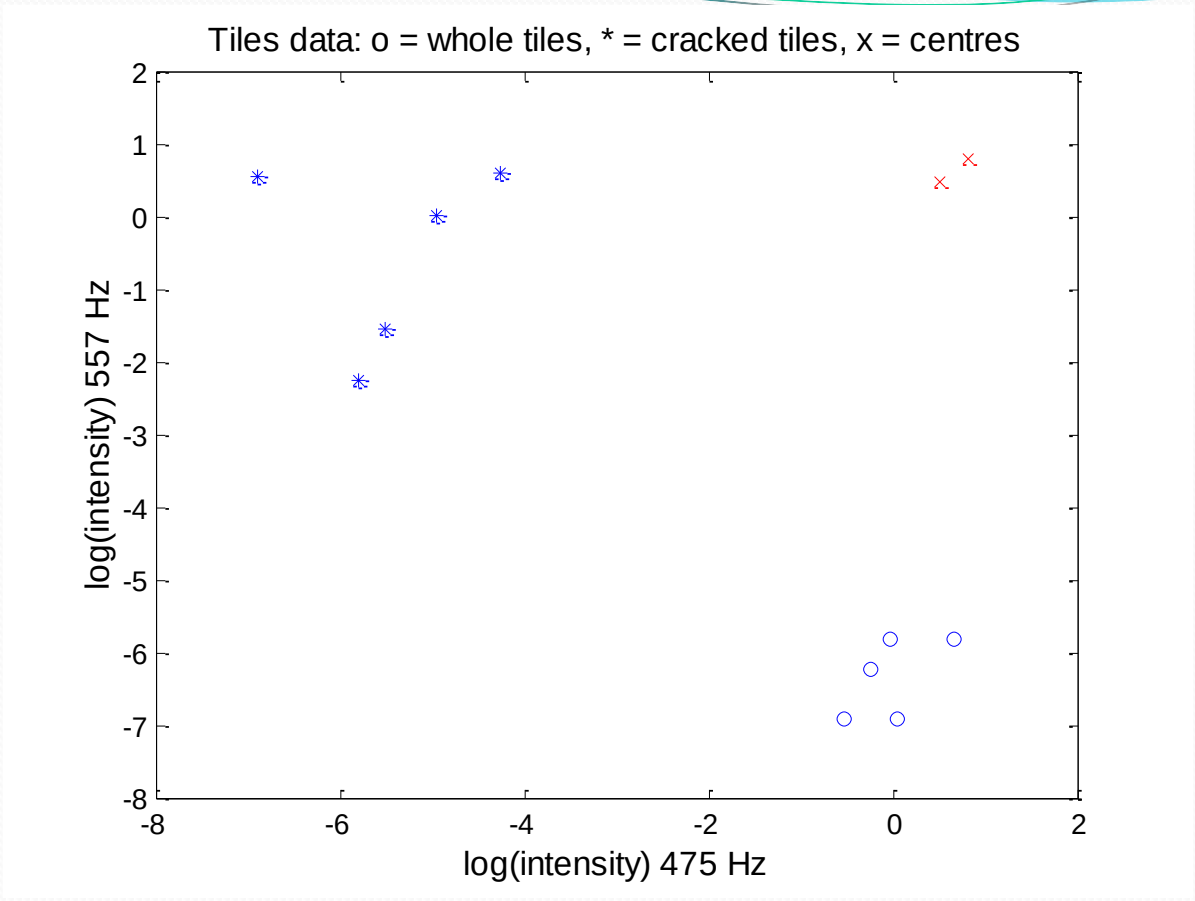
| 475Hz | 557Hz | Ok? |
|---|---|---|
| 0.958 | 0.003 | Yes |
| 1.043 | 0.001 | Yes |
| 1.907 | 0.003 | Yes |
| 0.780 | 0.002 | Yes |
| 0.579 | 0.001 | Yes |
| 0.003 | 0.105 | No |
| 0.001 | 1.748 | No |
| 0.014 | 1.839 | No |
| 0.007 | 1.021 | No |
| 0.004 | 0.214 | No |

[MIT, 1997]

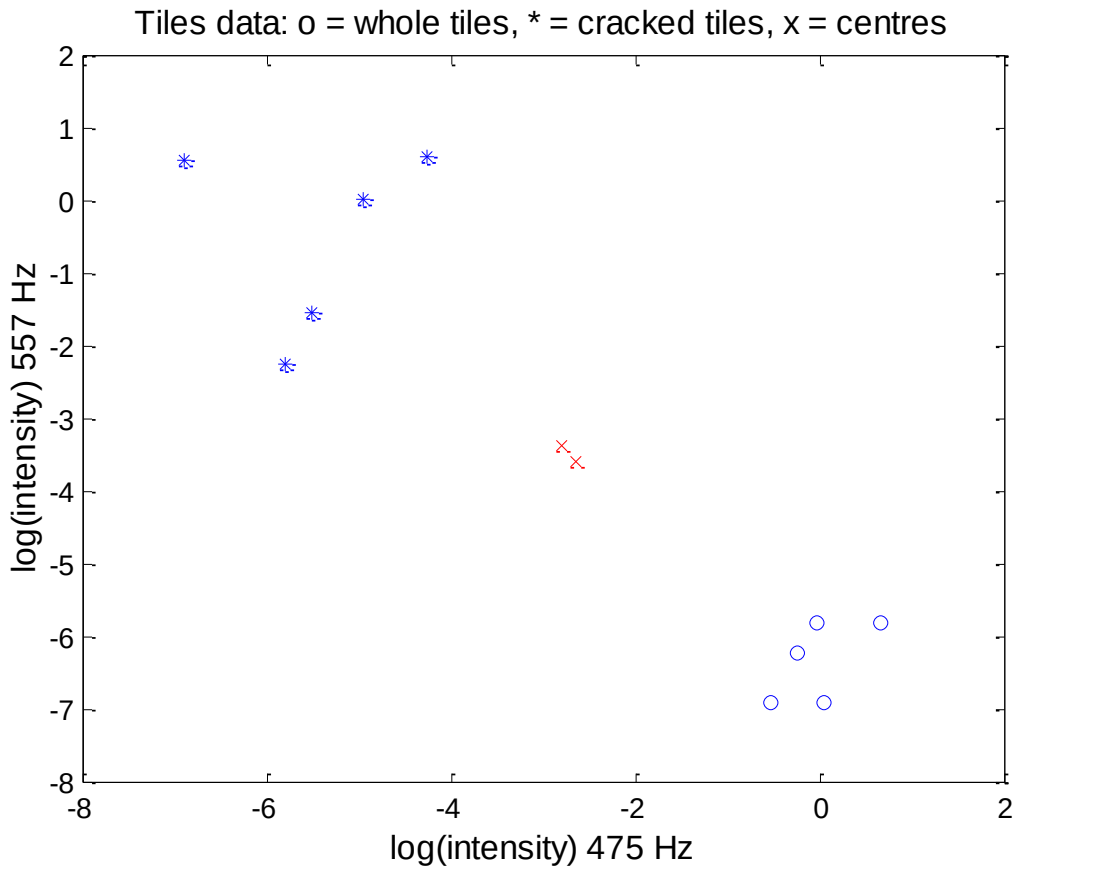
# Hard c-means (HCM)
# (biasa disebut *k-means*)



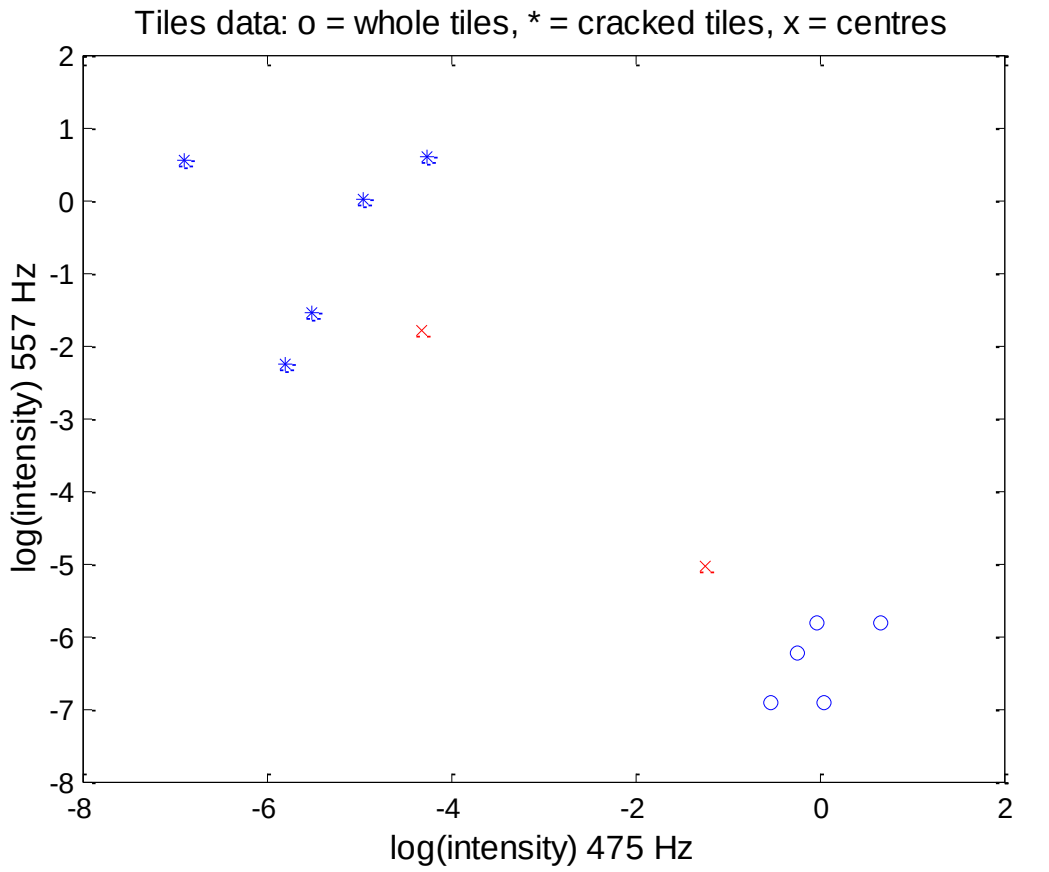

Plot of tiles by frequencies (logarithms). The whole tiles (o) seem well separated from the cracked tiles (*). The **objective** is to find the two clusters.



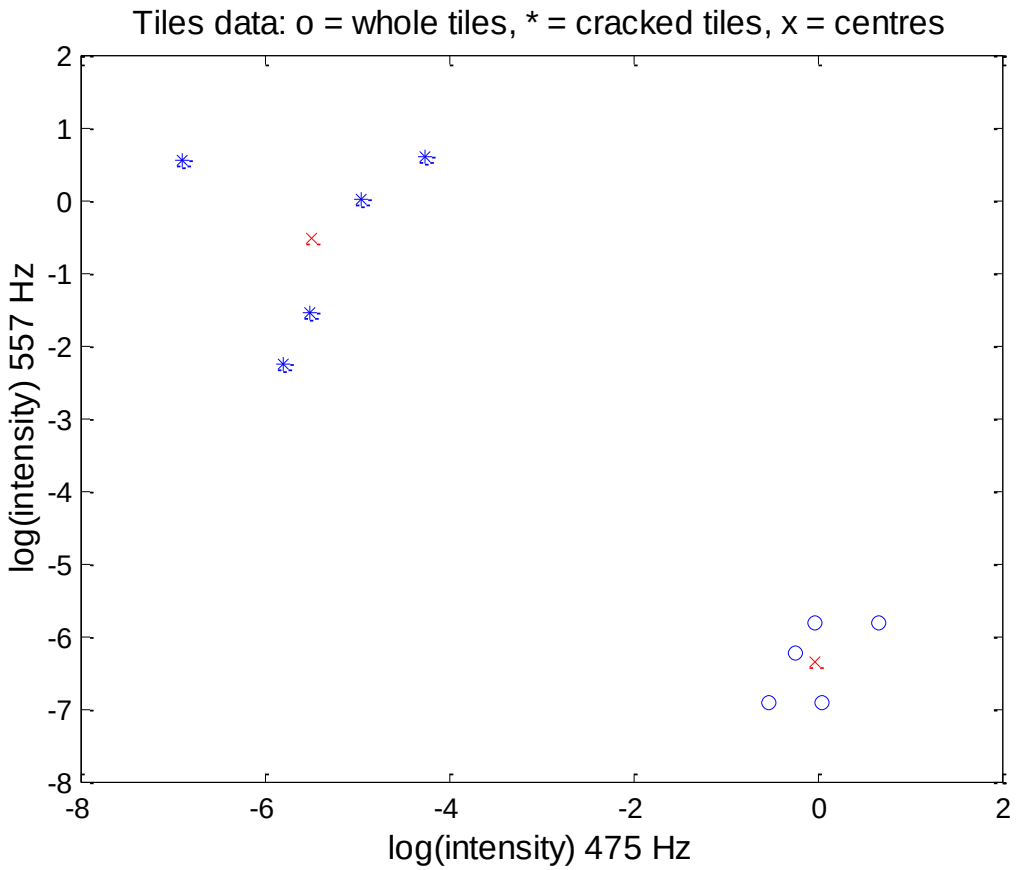

1. Place two cluster centres (x) at random.
2. Assign each data point (* and o) to the nearest cluster centre (x)



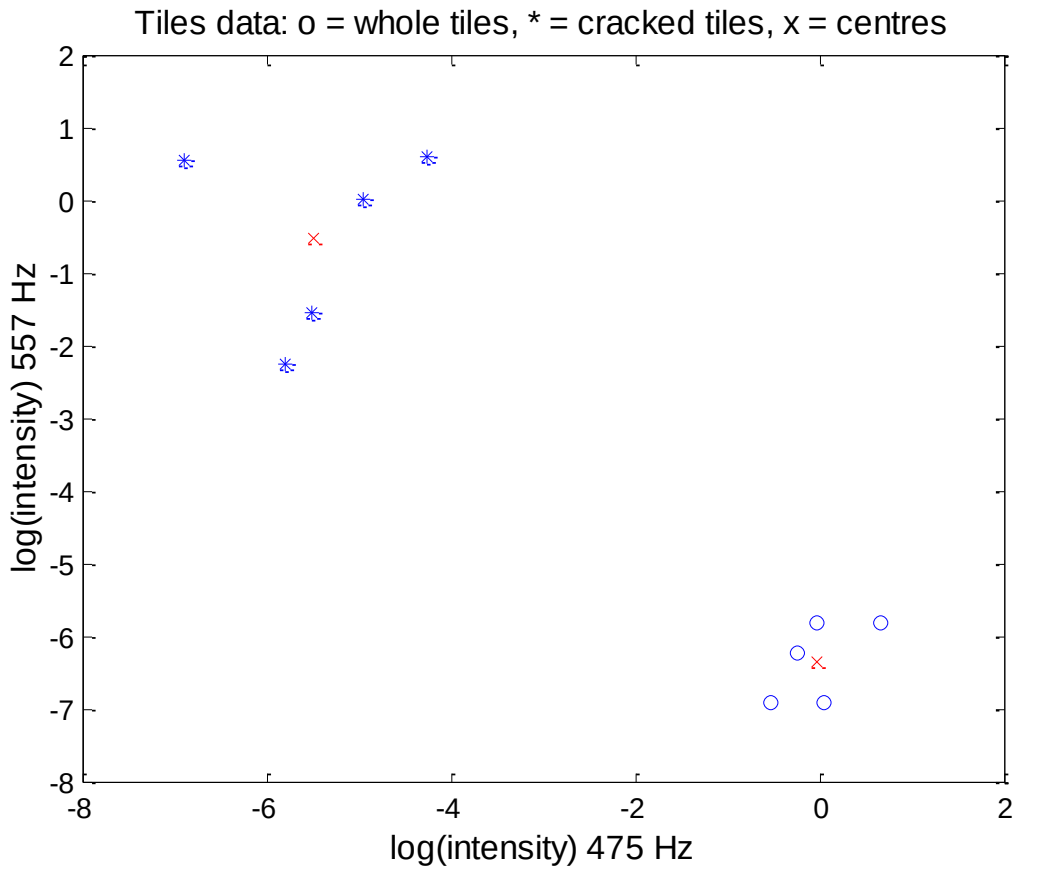

1. Compute the new centre of each class
2. Move the crosses (x)


Tiles data: o = whole tiles, * = cracked tiles, x = centres
log(intensity) 557 Hz
log(intensity) 475 Hz
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-8
-6
-4
-2
0
2

**Iteration 2**


Tiles data: o = whole tiles, * = cracked tiles, x = centres
log(intensity) 557 Hz
log(intensity) 475 Hz
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-8
-6
-4
-2
0
2

**Iteration 3**




**Iteration 4** (then stop, because no visible change)
Each data point belongs to the cluster defined by the nearest centre

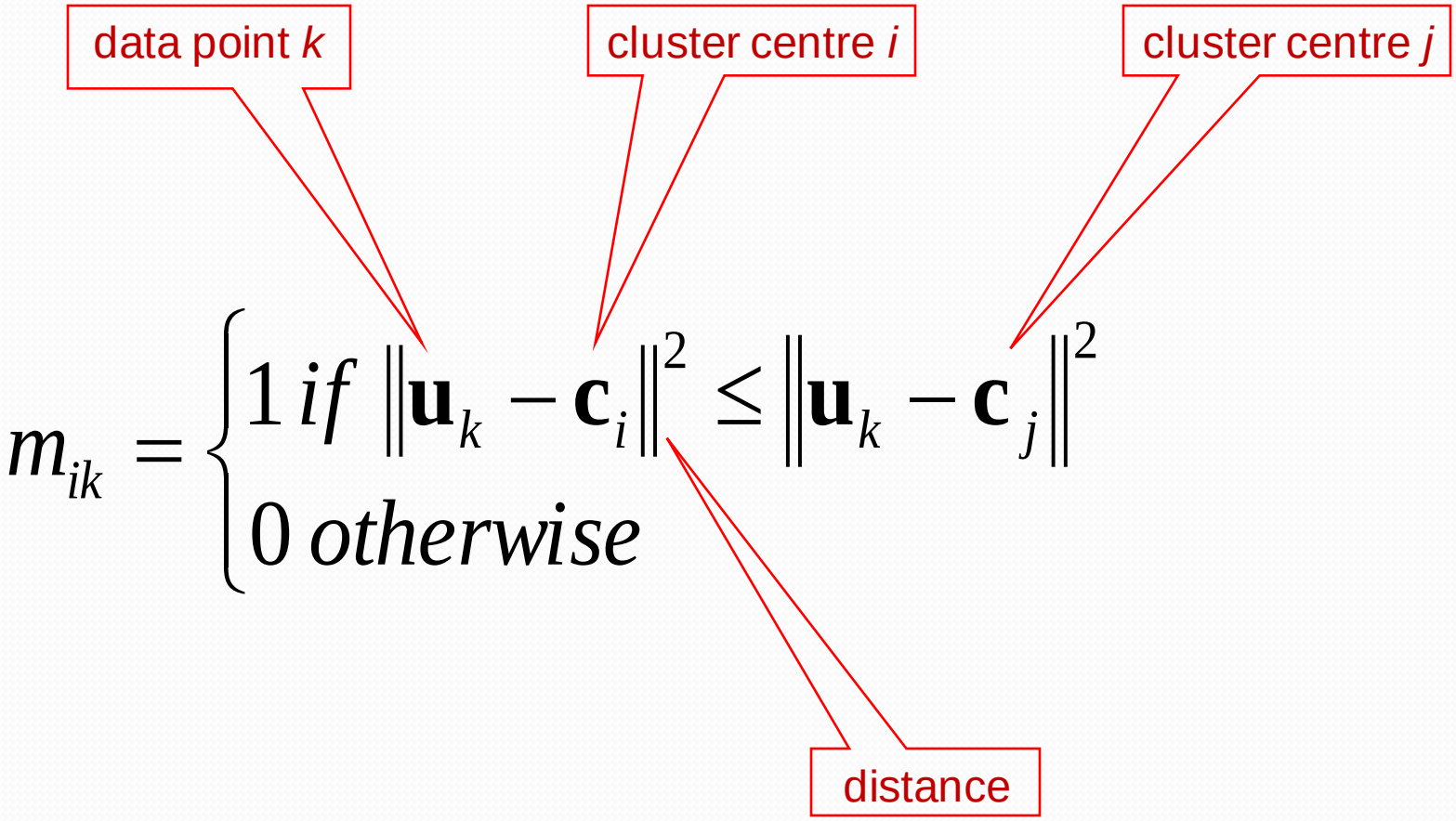
M =

| | |
|---|---|
| 0.0000 | 1.0000 |
| 0.0000 | 1.0000 |
| 0.0000 | 1.0000 |
| 0.0000 | 1.0000 |
| 0.0000 | 1.0000 |
| 1.0000 | 0.0000 |
| 1.0000 | 0.0000 |
| 1.0000 | 0.0000 |
| 1.0000 | 0.0000 |
| 1.0000 | 0.0000 |

The membership matrix M:

1. The last five data points (rows) belong to the first cluster (column)
2. The first five data points (rows) belong to the second cluster (column)

# Membership matrix **M**



# c-partition

All clusters C together fills the whole universe *U*

$$\bigcup_{i=1}^{c} C_i = U$$

Clusters do not overlap

$$C_i \cap C_j = \emptyset \quad for\ all\ i \neq j$$

$$\emptyset \subset C_i \subset U \quad for\ all\ i$$

A cluster *C* is never empty and it is smaller than the whole universe *U*

$$2 \leq c \leq K$$

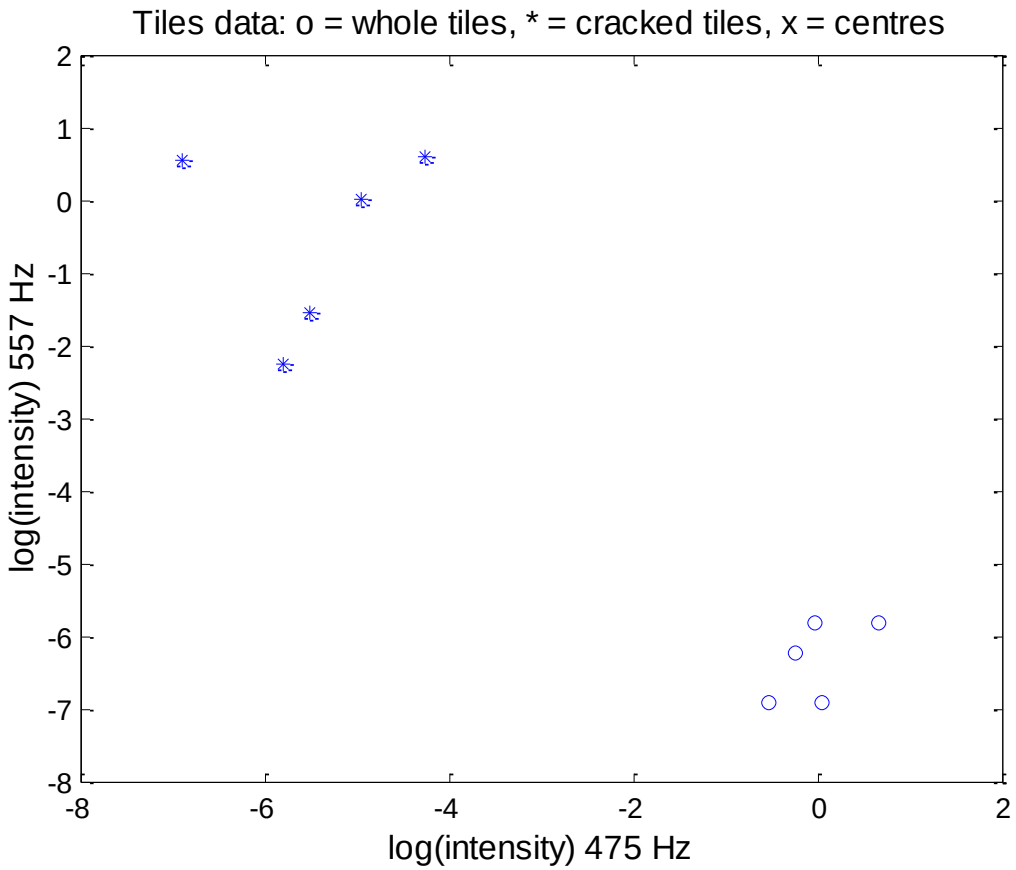
There must be at least 2 clusters in a c-partition and at most as many as the number of data points *K*

# Objective function

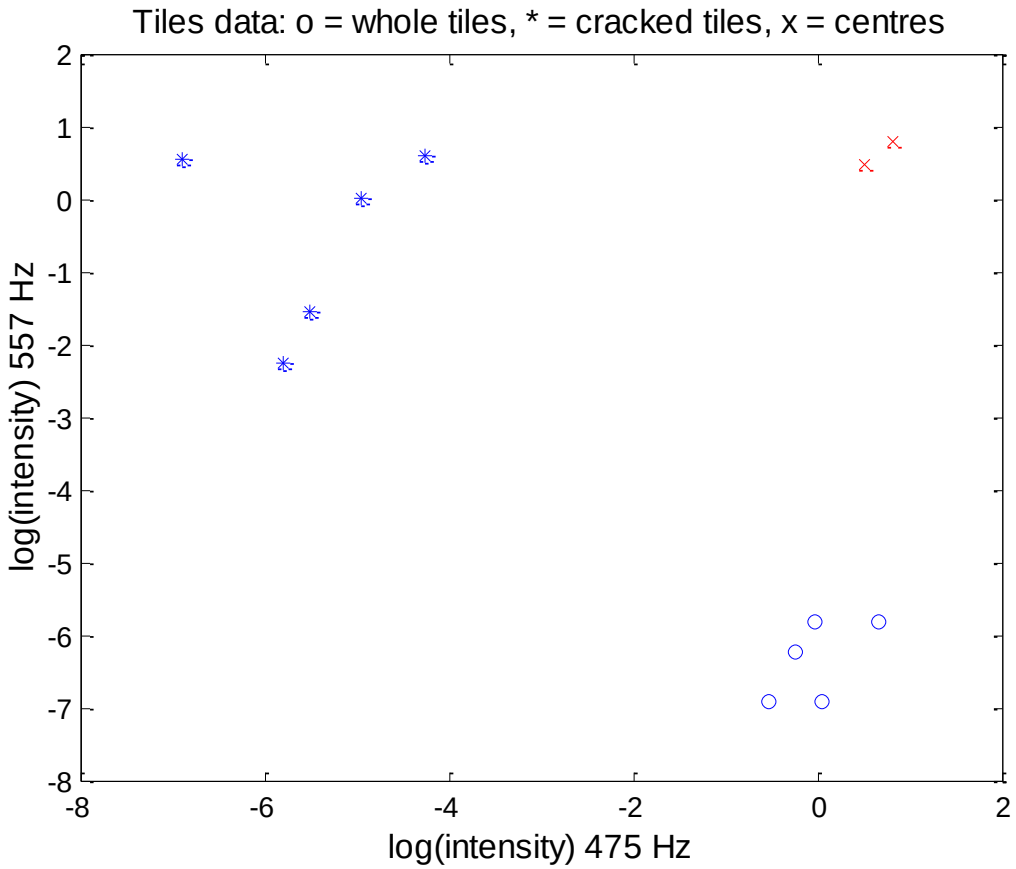
Minimise the total sum of all distances

$$J = \sum_{i=1}^{c} J_i = \sum_{i=1}^{c} \left( \sum_{k, \mathbf{u}_k \in C_i} \left\| \mathbf{u}_k - \mathbf{c}_i \right\|^2 \right)$$

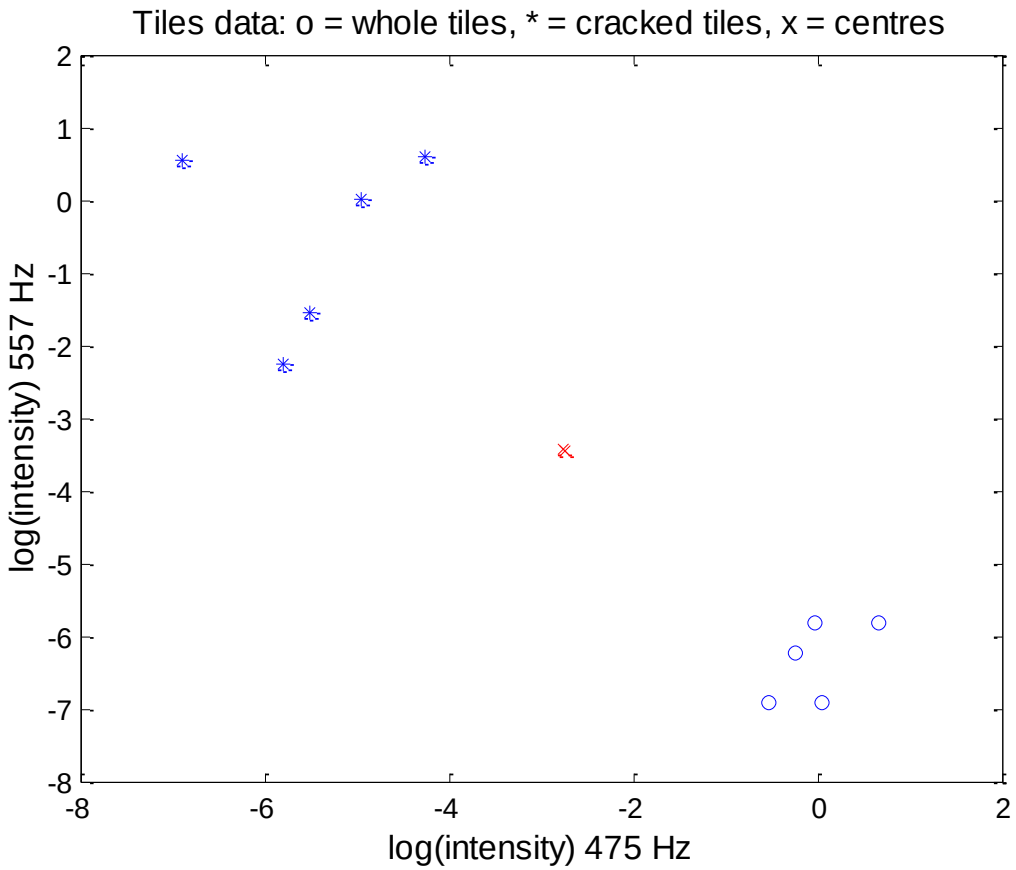
# Fuzzy c-means (FCM)



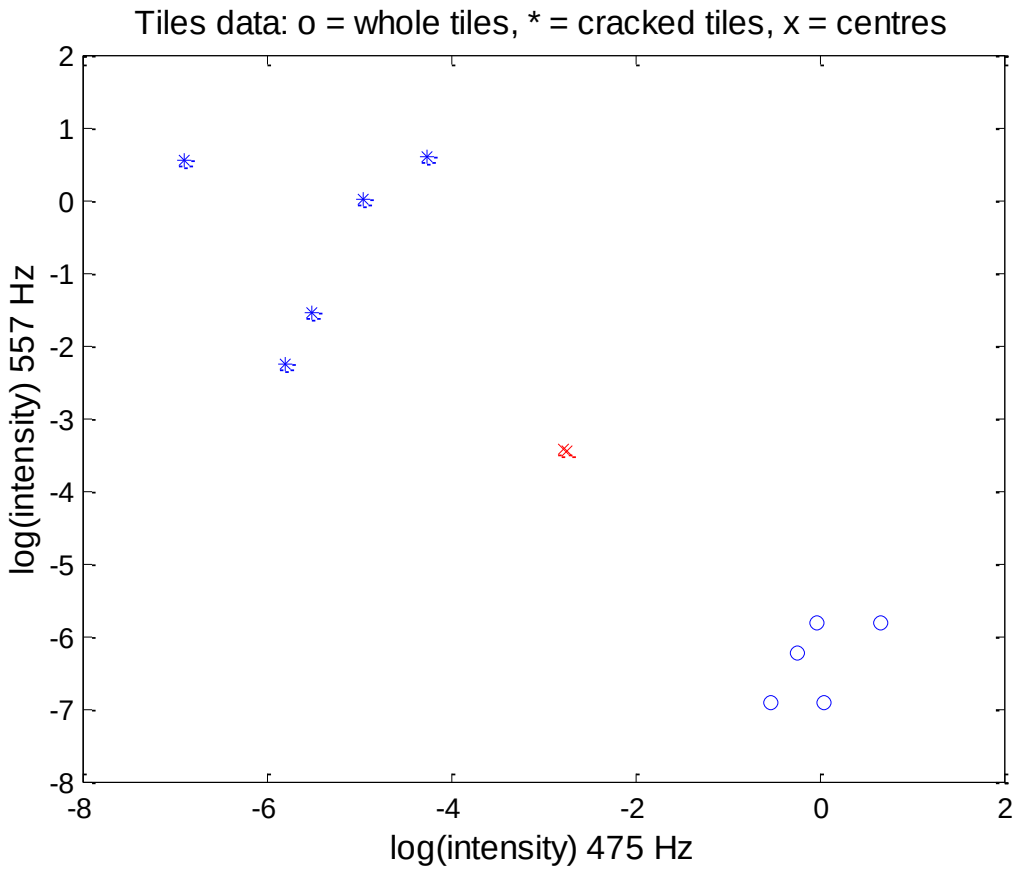

Each data point belongs to two clusters to different degrees



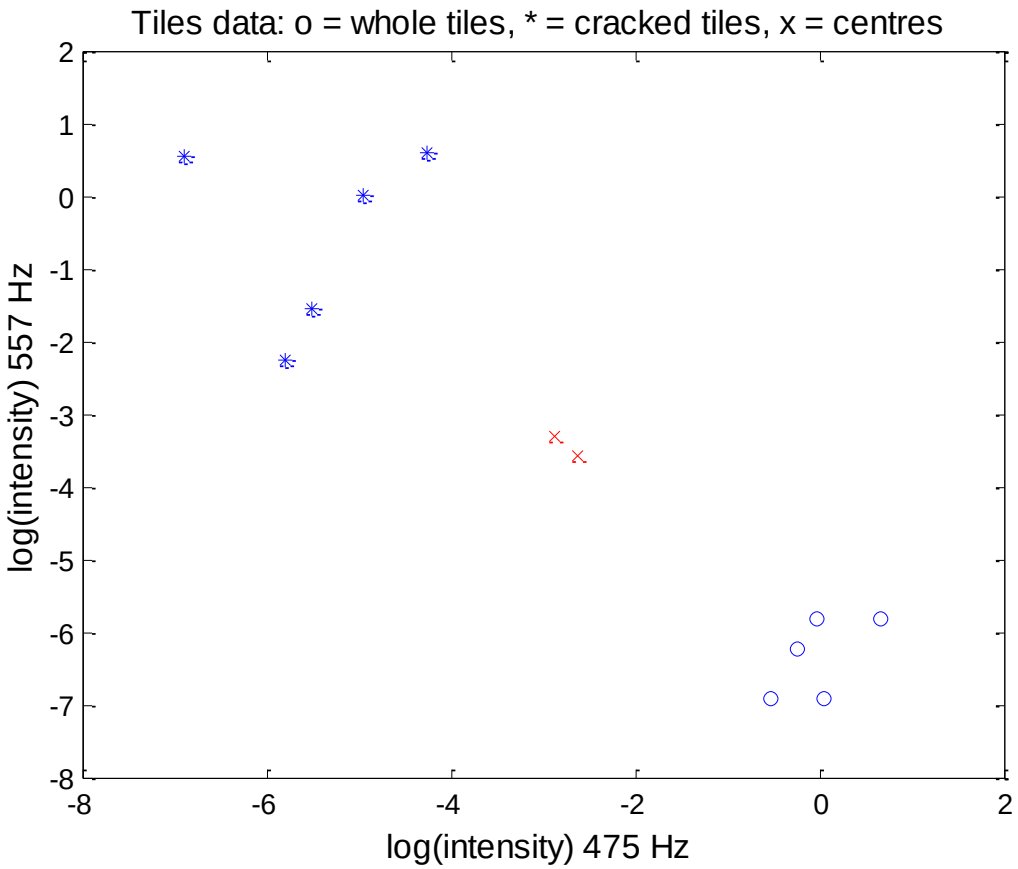

1. Place two cluster centres
2. Assign a fuzzy membership to each data point depending on distance



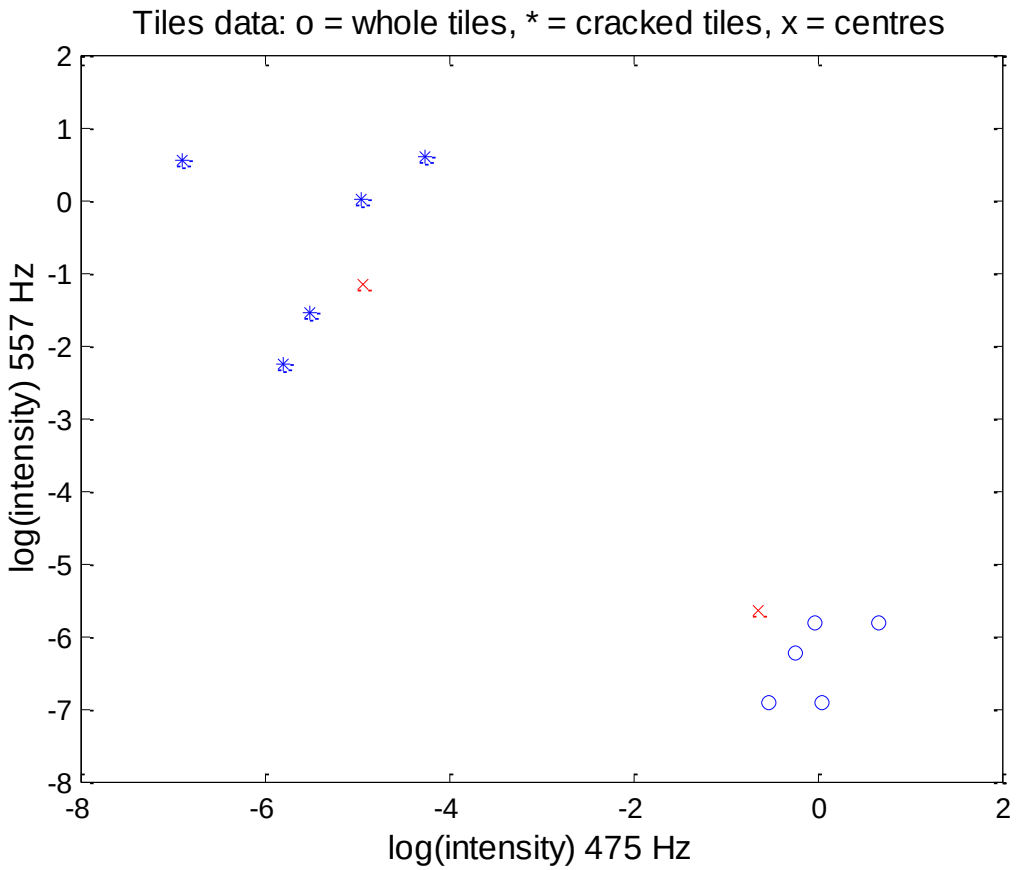

1. Compute the new centre of each class
2. Move the crosses (x)


Tiles data: o = whole tiles, * = cracked tiles, x = centres
log(intensity) 557 Hz
log(intensity) 475 Hz
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-8
-6
-4
-2
0
2

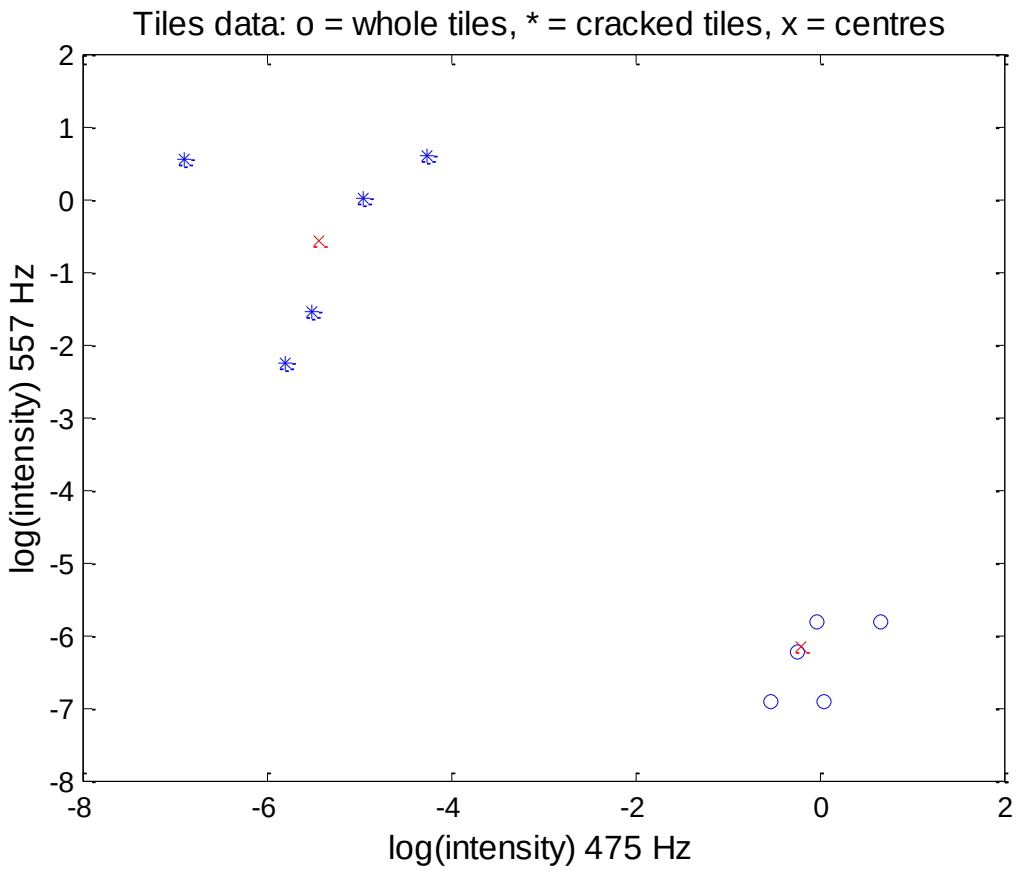
**Iteration 2**


Tiles data: o = whole tiles, * = cracked tiles, x = centres
log(intensity) 557 Hz
log(intensity) 475 Hz
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-8
-6
-4
-2
0
2

**Iteration 5**




**Iteration 10**




**Iteration 13** (then stop, because no visible change)
Each data point belongs to the two clusters to a degree

**M =**

| | |
|---|---|
| 0.0025 | 0.9975 |
| 0.0091 | 0.9909 |
| 0.0129 | 0.9871 |
| 0.0001 | 0.9999 |
| 0.0107 | 0.9893 |
| 0.9393 | 0.0607 |
| 0.9638 | 0.0362 |
| 0.9574 | 0.0426 |
| 0.9906 | 0.0094 |
| 0.9807 | 0.0193 |

The membership matrix M:

1. The last five data points (rows) belong mostly to the first cluster (column)
2. The first five data points (rows) belong mostly to the second cluster (column)

# Fuzzy membership matrix **M**

Point *k*'s membership of cluster *i*

Fuzziness exponent

$$m_{ik} = \frac{1}{\sum_{j=1}^{c} \left( \frac{d_{ik}}{d_{jk}} \right)^{2/(q-1)}}$$

Distance from point *k* to current cluster centre *i*

Distance from point *k* to other cluster centres *j*

$$d_{ik} = \left\| \mathbf{u}_k - \mathbf{c}_i \right\|$$

# Fuzzy membership matrix **M**

$$m_{ik} = \frac{1}{\sum_{j=1}^{c} \left( \frac{d_{ik}}{d_{jk}} \right)^{2/(q-1)}}$$

$$= \frac{1}{\left( \frac{d_{ik}}{d_{1k}} \right)^{2/(q-1)} + \left( \frac{d_{ik}}{d_{2k}} \right)^{2/(q-1)} + \cdots + \left( \frac{d_{ik}}{d_{ck}} \right)^{2/(q-1)}}$$

$$= \frac{\frac{1}{d_{ik}^{\,2/(q-1)}}}{\frac{1}{d_{1k}^{\,2/(q-1)}} + \frac{1}{d_{2k}^{\,2/(q-1)}} + \cdots + \frac{1}{d_{ck}^{\,2/(q-1)}}}$$

Gravitation to cluster *i* relative to total gravitation

# Fuzzy c-partition

All clusters *C* together fill the whole universe *U*. *Remark: The sum of memberships for a data point is 1, and the total for all points is K*

$$\bigcup_{i=1}^{c} C_i = U$$

*Not valid: Clusters do overlap*

$$C_i \cap C_j = \emptyset \quad for\ all\ i \neq j$$

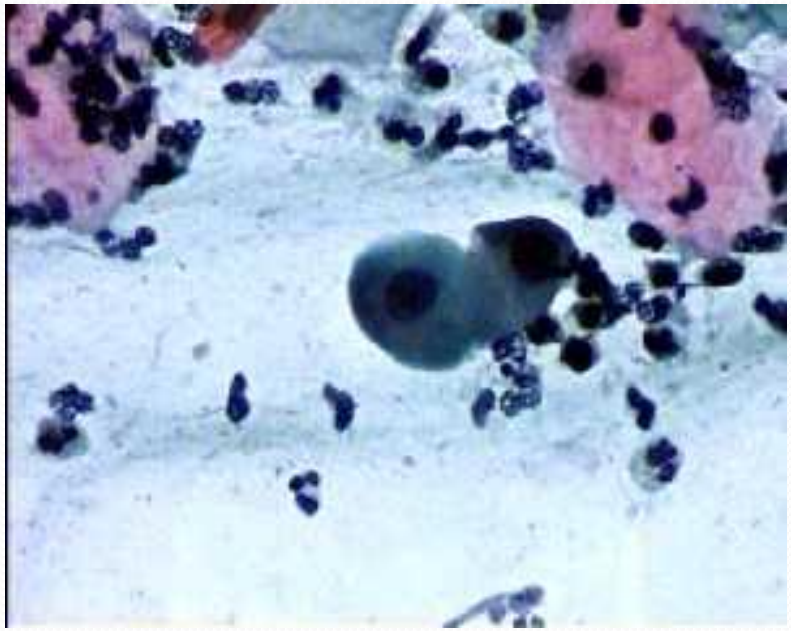
$$\emptyset \subset C_i \subset U \quad for\ all\ i$$

$$2 \leq c \leq K$$

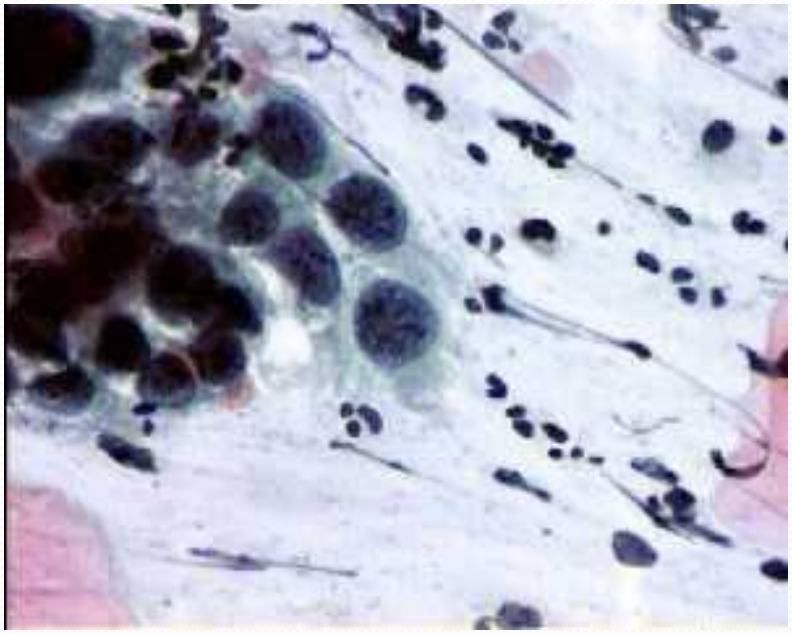
A cluster *C* is never empty and it is smaller than the whole universe *U*

There must be at least 2 clusters in a c-partition and at most as many as the number of data points *K*

# Kasus 7: Klasifikasi Sel Kanker



Normal smear

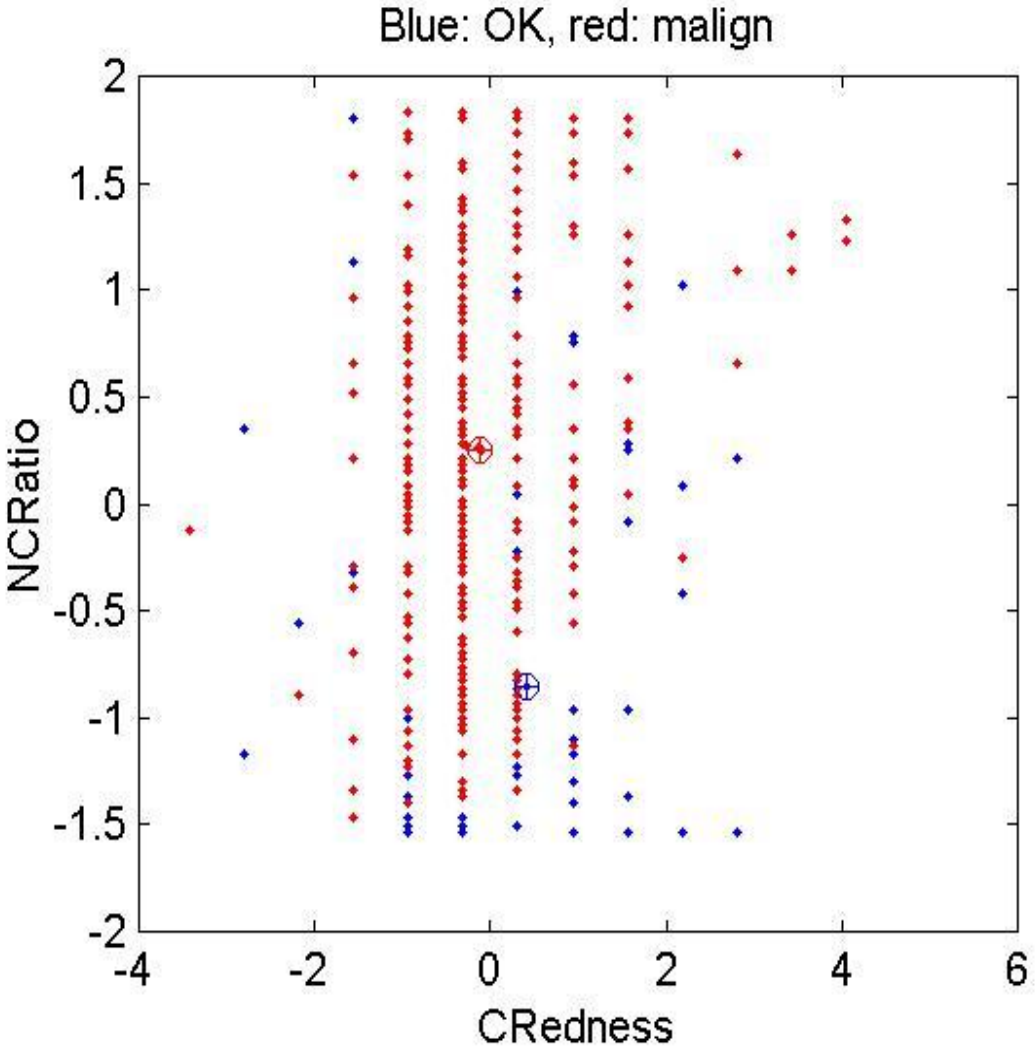


Severely dysplastic smear

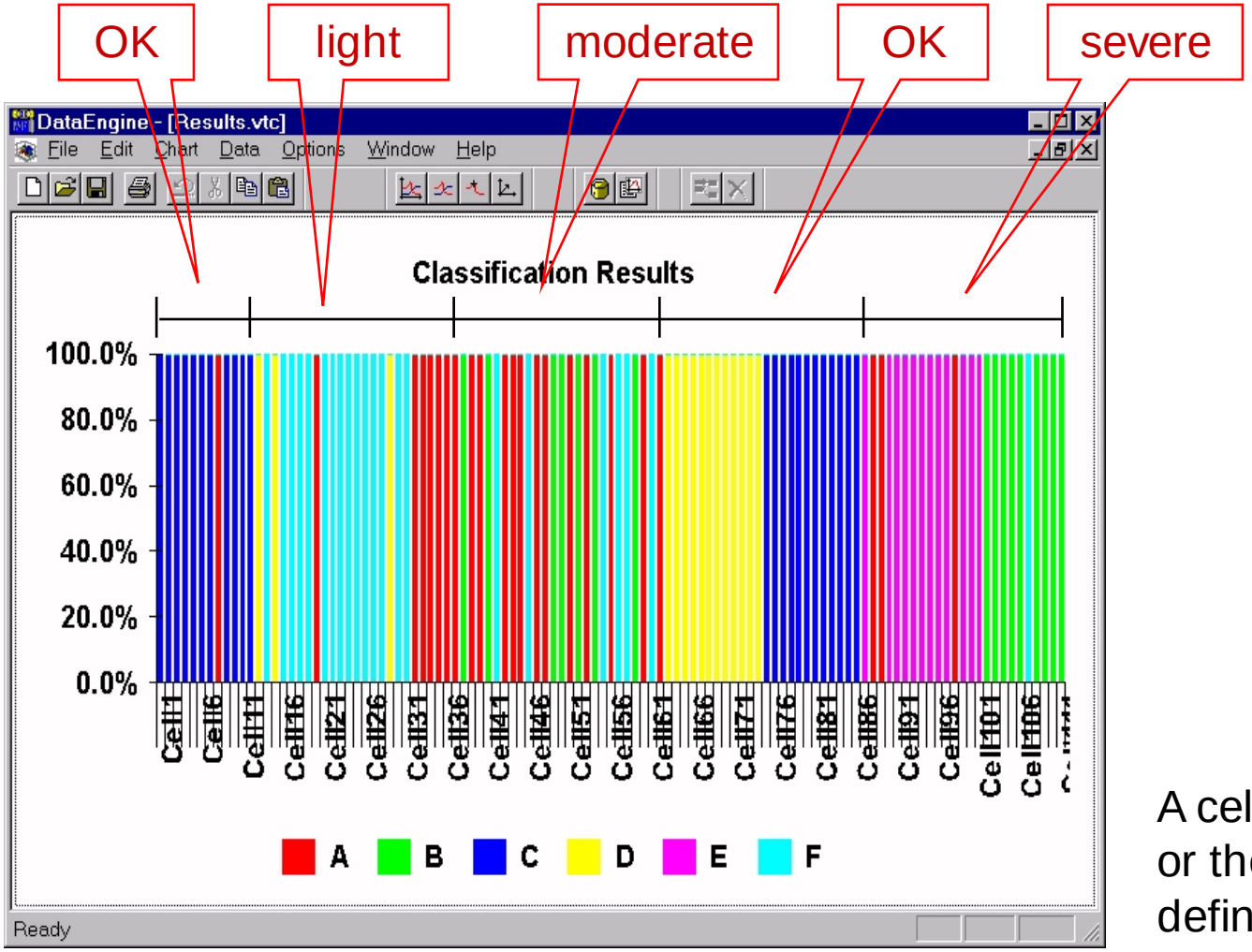
# Possible Features

- Nucleus and cytoplasm area
- Nucleus and cyto brightness
- Nucleus shortest and longest diameter
- Cyto shortest and longest diameter
- Nucleus and cyto perimeter
- Nucleus and cyto no of maxima
- …

# Classes are nonseparable

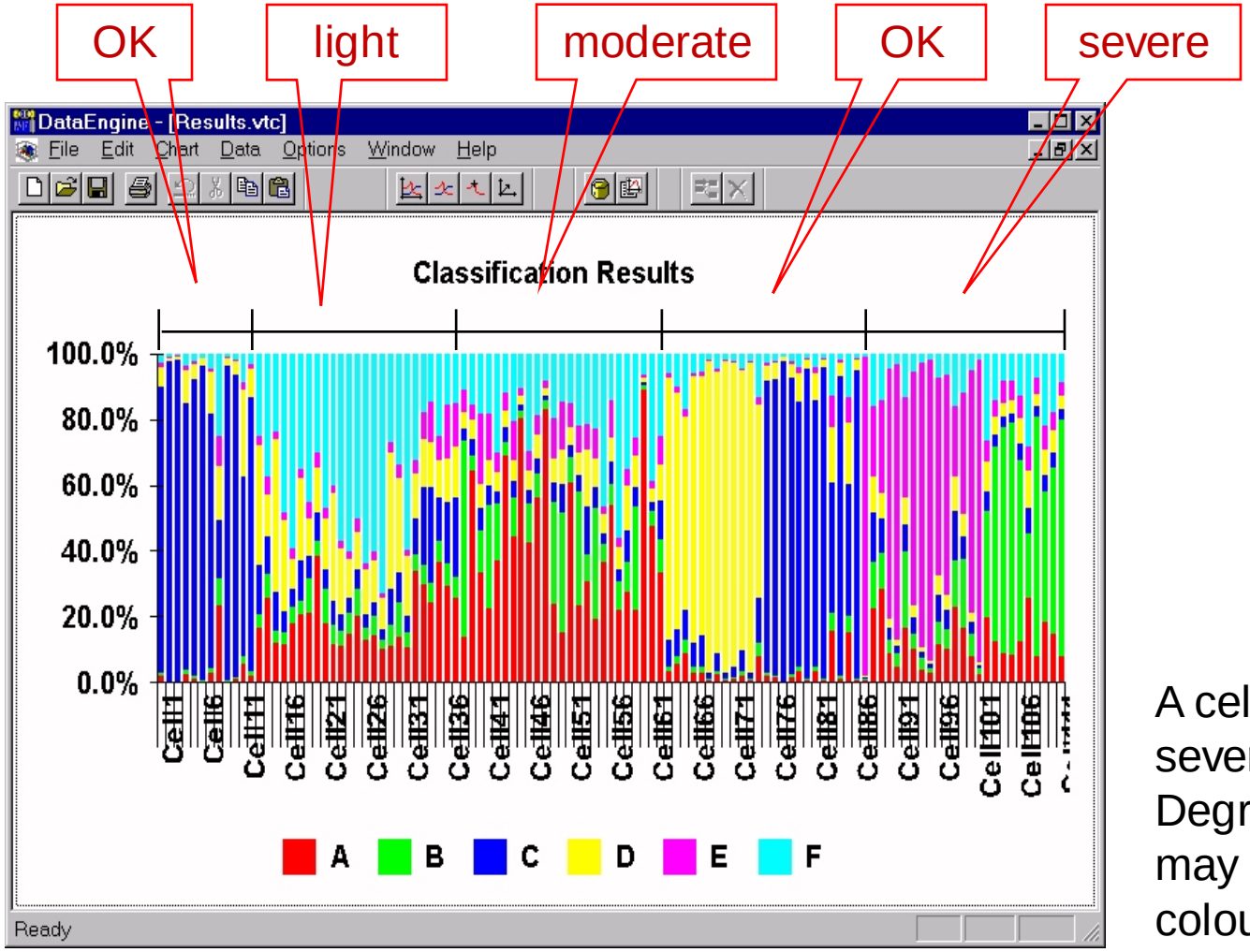


# Hard Classifier (HCM)




A cell is either one or the other class defined by a colour.

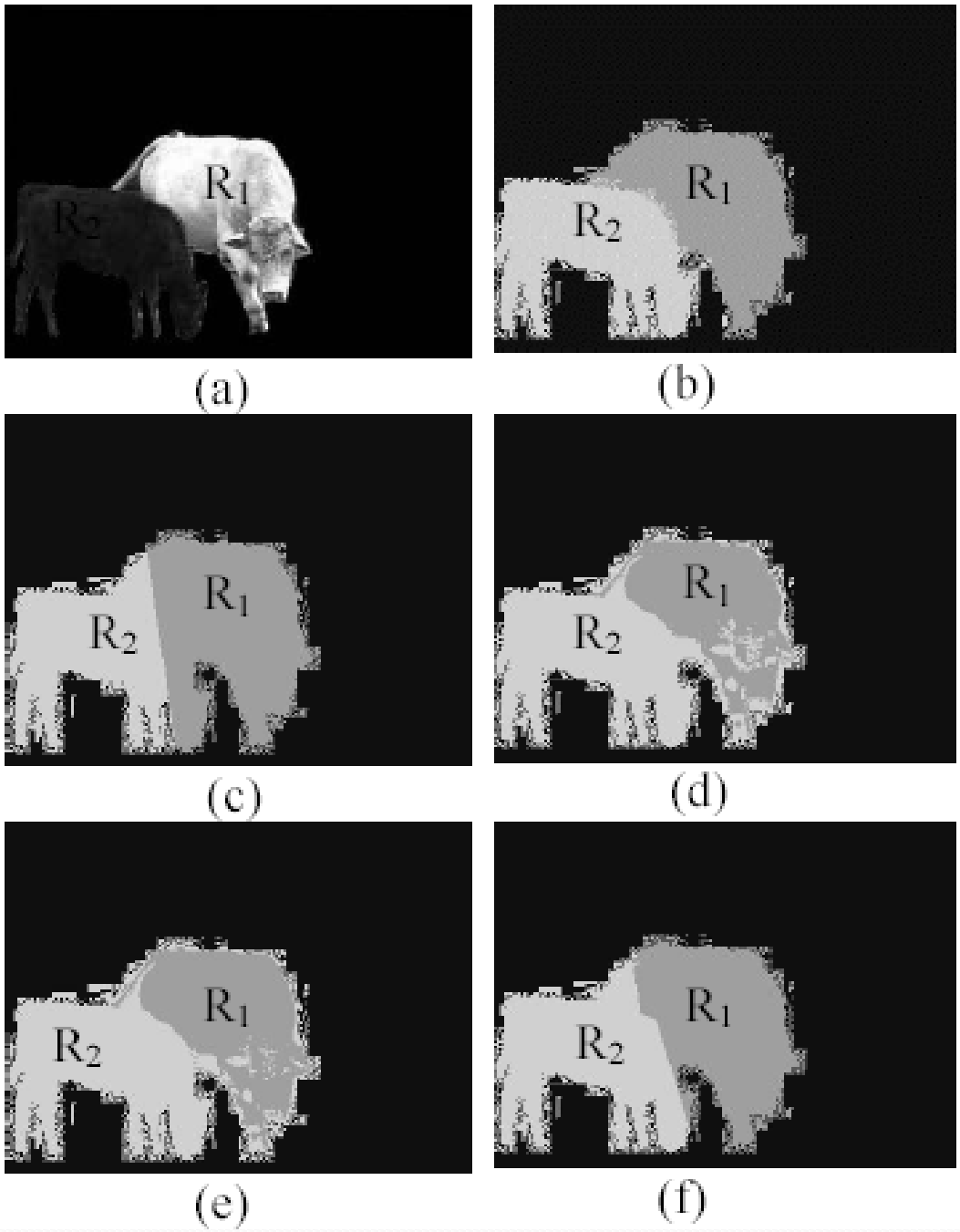
# Fuzzy Classifier (FCM)




A cell can belong to several classes to a Degree, i.e., one column may have several colours.

# Kasus 8: *Image Segmentation*

- Sangat penting untuk *image analysis*, *understanding*, dan *coding*
- Bagaimana memisahkan satu objek yang diingingkan dari objek2 lainnya?
- Pada image terdapat banyak ambiguitas




(a) Original cow image,
(b) Manually segmented reference image for (a).
(c) FCM with pixel locations
(d) FCM with pixel intensity
(e) FCM with both features
(f) Fuzzy Clustering Incorporating Spatial Information (FCSI).

[M. Ameer Ali, Gour C Karmakar and Laurence S Dooley, “Image Segmentation Using Fuzzy Clustering Incorporating Spatial Information, Monash University, Australia]

# Kasus 9: *Documents Clustering*

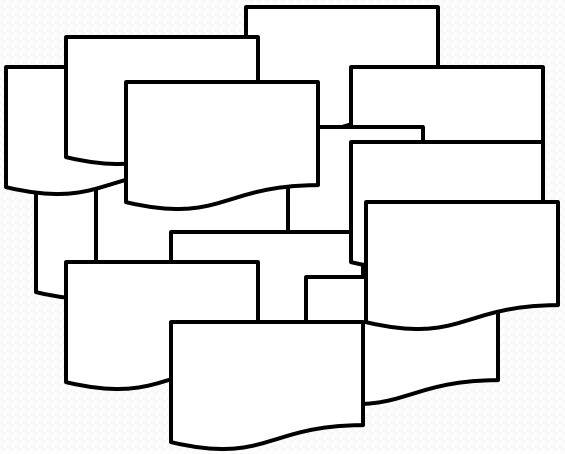
- Text represented as an unordered collection of words
- Using tf-idf (term frequency–inverse document frequency)
- Document = one vector in high dimensional space
- Similarity = cosine similarity between vectors

## PROBLEM

Grouping conference papers with regard to their contents into predefined sessions schedule.

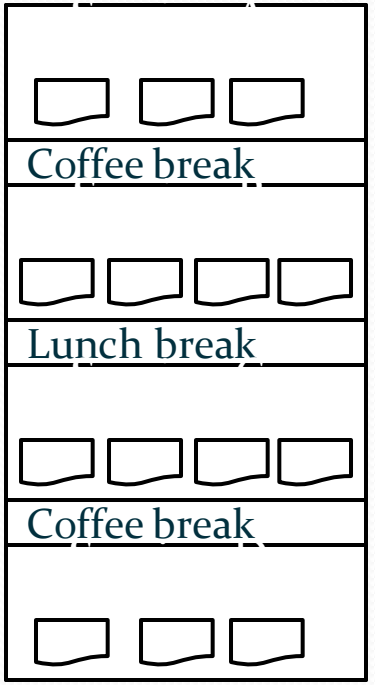
## EXAMPLE

Papers



**Constraint-based clustering**

Sessions schedule




[Matjaž Juršič, Vid Podpečan, Nada Lavrač]

# Combining CBC & Fuzzy Clustering

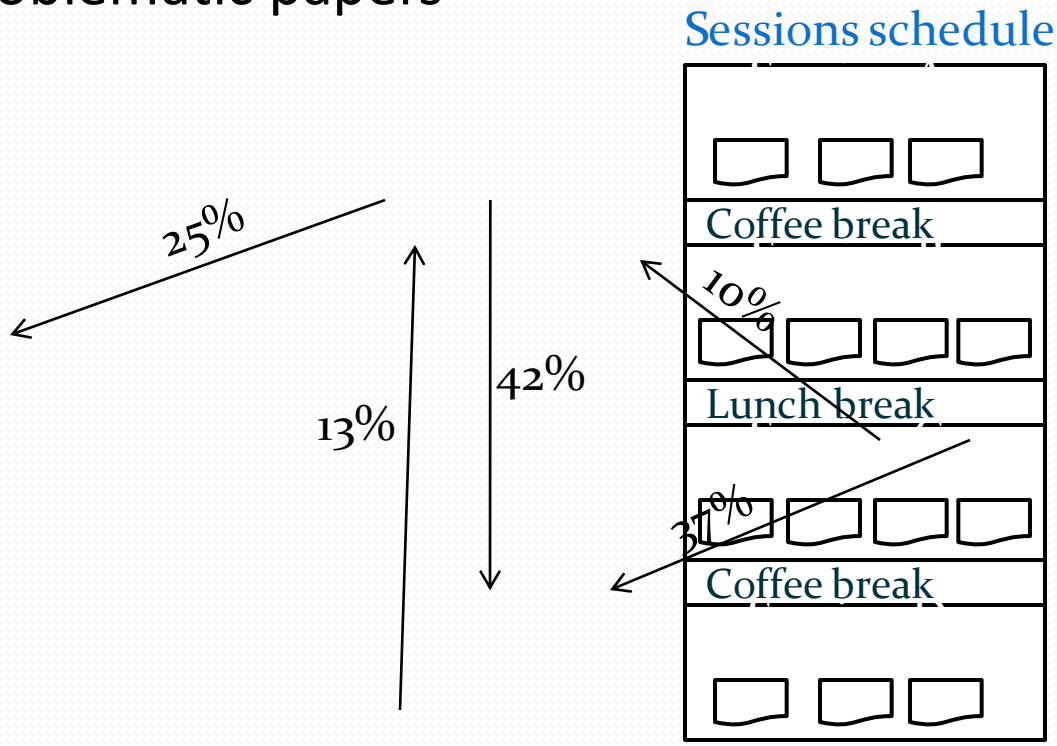
- **Phase 1 Solution**
  - constrained-based clustering (CBC)
- **Difficulties**
  - CBC can get stuck in local minimum
  - often low quality result (created schedule)
  - user interaction needed to repair schedule
- **Phase 2 Needed**
  - run fuzzy clustering (FC) with initial clusters from CBC
  - if output clusters of FC differ from CBC repeat everything
  - if the clusters of FC equal to CBC show new info to user

[Matjaž Juršič, Vid Podpečan, Nada Lavrač]

## Run Fuzzy Clustering on Phase 1 Results

- insight into result quality
- identify problematic papers

## Example




[Matjaž Juršič, Vid Podpečan, Nada Lavrač]

# Masalah Tugas Akhir IF

- Clustering dokumen TA berdasarkan KBK
- Clustering Dosen berdasarkan Keahliannya
- Penentuan Dosen Penguji Sidang TA

## Hard Classifier

**Ketidakpastian didekati dengan Kepastian**

**→ Ketidakpastian**

[Matjaž Juršič, Vid Podpečan, Nada Lavrač]

# Fuzzy Classifier

**Ketidakpastian didekati dengan Kesamaran**

**→ (mendekati) Kepastian**

[Matjaž Juršič, Vid Podpečan, Nada Lavrač]

# Kesulitan *Fuzzy Systems*

- Model Mamdani atau Sugeno atau model lain?
- Jumlah Nilai Linguistik untuk setiap variabel?
- Fungsi Keanggotaan: Segitiga, trapesium, phi, ...?
- Batas-batas Nilai Linguistik?
- *Fuzzy rule* yang tepat?

# Solusi

- Semua komponen *fuzzy* bisa didefinisikan secara otomatis menggunakan EAs atau ANN.
- *Evolving Fuzzy Systems*
- *Neuro-Fuzzy*

- *Fuzzy Systems* yang bisa *LEARNING*
- Perlu data latih yang MEMADAI

# Pemberian Beasiswa

| NIM | IPK | Gaji Ortu (juta rupiah) | Nilai Kelayakan |
|---|---|---|---|
| 070001 | 2,0 | 16 | 45 |
| 070002 | 2,5 | 12 | 50 |
| 070003 | 3,6 | 30 | 55 |
| 070004 | 1,5 | 140 | 10 |
| 070005 | 2,7 | 10 | 40 |
| 070006 | 3,9 | 0,5 | 95 |
| 070007 | 1,9 | 1 | 52 |
| 070008 | 2,8 | 8 | 68 |
| 070009 | 3,5 | 6 | 72 |
| 070010 | 2,0 | 7 | 53 |

# Sprinkler Control System

| Tanggal | Waktu | Suhu (°C) | Kelembaban Tanah (%) | Durasi Penyiraman (menit) |
|---|---|---|---|---|
| 01-02-2006 | 08:00 | 20 | 16 | 55,7 |
| 01-02-2006 | 13:00 | 25 | 12 | 59,3 |
| 01-02-2006 | 18:00 | 16 | 30 | 5,6 |
| 02-02-2006 | 07:00 | 15 | 14 | 30,1 |
| 02-02-2006 | 12:00 | 27 | 10 | 43,4 |
| 02-02-2006 | 19:00 | 12 | 19 | 18,6 |
| 03-02-2006 | 06:30 | 19 | 12 | 22,1 |
| 03-02-2006 | 10:00 | 28 | 8 | 47,3 |
| 03-02-2006 | 13:30 | 35 | 6 | 76,4 |
| 03-02-2006 | 16:00 | 20 | 17 | 20,9 |

# *Evolving Fuzzy Systems*

- Representasi Individu?
- Fungsi fitness-nya?
- Algoritma EAs?
- Operator-operator evolusi?

# Masa Depan *Fuzzy*

- Computers that understand and respond to normal human language.
- Machines that write interesting novels and screenplays in a selected style, such as Hemingway's.
- Huge expert decision makers, theoretically able to extract the wisdom of every document ever witten.
- Molecule-sized soldiers of health that will roam the blood-stream, killing cancer cells and slowing the aging process.

[Professor Bart Kosko, UC Southern California]

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