

7.4.2 Building-window-nonfloat

Table 7.17 shows the results for classifying the Glass data set with patterns of the building-window-nonfloat class as the self set. The ALCs were trained with the negative selection method. The best classification result is obtained when $IS=160$ and $W1=25$. An average number of 39.700 ALCs formed part of the active set of ALCs. An average number of 18.683 of the ALCs in the active set had memory status. The ALCs misclassified an average of 33.200 patterns as building-window-nonfloat and 1.433 as not. Thus, $\#Misclassified = 33.200 + 1.433 = 34.633$ which gives a correct classification rate of 83.816%. The average number of ALCs and the average fitness of the ALC set were constant over the iterations.

Table 7.18 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=160$ and $W1=25$. An average number of 39.800 ALCs formed part of the active set of ALCs. An average number of 18.700 of the ALCs in the active set had memory status. The ALCs misclassified an average of 31.900 patterns as building-window-nonfloat and 1.367 as not. Thus, $\#Misclassified = 31.900 + 1.367 = 33.267$ which gives a correct classification rate of 84.454%. The average number of ALCs and the average fitness of the ALC set were constant over the iterations.

7.4.3 Containers

Table 7.19 shows the results for classifying the Glass data set with patterns of the containers class as the self set. The ALCs were trained with the negative selection method. The best classification result is obtained when $IS=214$ and $W1=75$ with an $fNeg$ value of 0.000. Table 7.19 shows that for other values of IS and $W1$ the value of $fNeg$ is also 0.000, but $IS=214$ and $W1=75$ is considered the best since the average number of ALCs is the lowest for all IS and $W1$ with an $fNeg$ value of 0.000. An average number of 35.067 ALCs formed part of the active set of ALCs and was constant over the iterations. An average number of 0.000 of the ALCs in the active set had memory status. The ALCs misclassified an average of 0.000 patterns as containers and 0.433 as not. Thus, $\#Misclassified = 0.000 + 0.433 = 0.433$ which gives a correct classification rate of 99.797%.

Table 7.20 shows the results when the ALCs were trained with the positive selection method. The best classification result is obtained when $IS=53$ and $W1=25$ since the average number of ALCs is the lowest for all IS and $W1$ with an $fNeg$ value of 0.000. An average number of 38.013 ALCs

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Table 7.17: *Building-window-nonfloat* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	36.540 (±3.030)	23.720 (±2.456)	1.400 (±1.976)	33.300 (±6.115)	21.246 (±0.192)	21.737 (±0.109)
	50	22.947 (±7.384)	15.593 (±5.863)	1.167 (±2.069)	53.300 (±13.916)	23.661 (±0.219)	19.449 (±0.264)
	75	33.927 (±9.090)	23.587 (±6.656)	1.367 (±1.991)	49.733 (±11.104)	25.373 (±0.211)	16.817 (±0.352)
	100	40.500 (±13.097)	27.660 (±9.356)	1.433 (±2.885)	53.467 (±12.610)	25.872 (±0.236)	15.515 (±0.331)
106	25	38.322 (±3.355)	22.178 (±2.494)	1.433 (±2.176)	34.900 (±5.851)	21.159 (±0.119)	21.813 (±0.047)
	50	25.211 (±6.388)	15.000 (±4.245)	1.200 (±2.340)	49.233 (±10.757)	23.680 (±0.260)	19.481 (±0.228)
	75	34.389 (±8.543)	21.211 (±5.974)	1.433 (±2.501)	51.933 (±12.051)	25.317 (±0.197)	16.910 (±0.280)
	100	46.400 (±17.230)	29.433 (±11.321)	1.433 (±2.515)	50.900 (±15.615)	25.858 (±0.202)	15.535 (±0.423)
160	25	39.700 (±3.064)	18.683 (±1.774)	1.433 (±1.794)	33.200 (±7.889)	21.125 (±0.134)	21.836 (±0.048)
	50	23.333 (±6.723)	11.317 (±3.480)	1.000 (±1.682)	52.367 (±12.417)	23.593 (±0.232)	19.566 (±0.209)
	75	32.800 (±9.722)	16.083 (±4.657)	1.267 (±1.837)	53.333 (±9.349)	25.280 (±0.202)	16.939 (±0.273)
	100	51.200 (±13.793)	25.183 (±6.801)	1.400 (±2.343)	47.800 (±9.729)	25.905 (±0.174)	15.534 (±0.268)
214	25	40.833 (±3.573)	0.000 (±0.000)	1.667 (±2.073)	33.733 (±7.027)	21.124 (±0.148)	21.844 (±0.051)
	50	24.933 (±6.214)	0.000 (±0.000)	1.233 (±1.995)	49.933 (±12.261)	23.640 (±0.244)	19.580 (±0.187)
	75	36.900 (±10.387)	0.000 (±0.000)	1.233 (±2.161)	50.133 (±10.837)	25.378 (±0.181)	16.827 (±0.252)
	100	50.533 (±17.156)	0.000 (±0.000)	1.167 (±2.198)	47.300 (±10.844)	25.861 (±0.206)	15.571 (±0.269)

Table 7.18: *Building-window-nonfloat* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	34.527 (±6.853)	22.193 (±5.086)	1.567 (±2.473)	35.800 (±12.510)	23.756 (±0.161)	21.691 (±0.196)
	50	24.107 (±6.210)	16.087 (±4.954)	1.200 (±1.669)	50.900 (±8.747)	21.293 (±0.172)	19.443 (±0.203)
	75	32.627 (±9.969)	22.553 (±6.964)	1.200 (±1.669)	51.333 (±10.896)	19.685 (±0.236)	16.858 (±0.284)
	100	44.360 (±16.150)	30.287 (±11.375)	1.233 (±2.528)	51.167 (±13.052)	19.056 (±0.199)	15.376 (±0.524)
106	25	38.889 (±4.168)	22.344 (±2.909)	1.567 (±2.674)	32.267 (±8.103)	23.827 (±0.166)	21.807 (±0.056)
	50	25.378 (±8.316)	15.311 (±5.013)	1.300 (±2.003)	50.300 (±12.103)	21.366 (±0.221)	19.552 (±0.188)
	75	36.056 (±10.013)	22.333 (±6.701)	1.200 (±1.690)	48.600 (±10.595)	19.634 (±0.198)	16.856 (±0.326)
	100	51.867 (±15.567)	33.044 (±10.076)	1.367 (±2.327)	48.533 (±11.355)	19.097 (±0.206)	15.520 (±0.354)
160	25	39.800 (±3.671)	18.700 (±1.720)	1.367 (±2.157)	31.900 (±7.303)	23.879 (±0.119)	21.846 (±0.052)
	50	25.567 (±7.035)	12.517 (±3.475)	1.167 (±2.379)	50.400 (±9.357)	21.338 (±0.270)	19.556 (±0.264)
	75	33.733 (±8.267)	16.567 (±3.939)	1.233 (±2.192)	49.367 (±10.294)	19.630 (±0.211)	16.844 (±0.312)
	100	49.067 (±13.115)	24.050 (±6.383)	1.233 (±2.029)	48.500 (±7.305)	19.158 (±0.227)	15.593 (±0.320)
214	25	39.100 (±3.854)	0.000 (±0.000)	1.467 (±2.515)	32.733 (±8.550)	23.905 (±0.163)	21.853 (±0.044)
	50	24.333 (±7.712)	0.000 (±0.000)	1.267 (±2.333)	53.500 (±12.500)	21.399 (±0.263)	19.561 (±0.176)
	75	34.000 (±10.567)	0.000 (±0.000)	1.167 (±2.534)	51.233 (±12.182)	19.626 (±0.210)	16.807 (±0.323)
	100	54.700 (±15.132)	0.000 (±0.000)	1.600 (±2.634)	46.500 (±7.615)	19.105 (±0.164)	15.595 (±0.267)

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Table 7.19: Containers - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	39.513 (±4.375)	29.387 (±6.604)	0.433 (±2.373)	0.000 (±0.000)	23.838 (±3.999)	21.753 (±0.152)
	50	29.800 (±8.195)	22.640 (±7.813)	0.433 (±2.373)	0.100 (±0.403)	26.582 (±3.483)	19.220 (±0.661)
	75	35.153 (±11.439)	27.773 (±9.901)	0.433 (±2.373)	0.367 (±0.928)	28.298 (±3.160)	16.435 (±1.143)
	100	55.520 (±19.997)	44.227 (±16.371)	0.433 (±2.373)	0.100 (±0.403)	28.874 (±3.051)	14.952 (±0.817)
106	25	39.567 (±4.034)	24.644 (±5.420)	0.433 (±2.373)	0.000 (±0.000)	23.780 (±4.010)	21.792 (±0.145)
	50	25.189 (±7.312)	15.922 (±5.727)	0.433 (±2.373)	0.067 (±0.254)	26.503 (±3.502)	19.260 (±0.685)
	75	34.400 (±9.565)	22.600 (±7.257)	0.433 (±2.373)	0.133 (±0.571)	28.339 (±3.151)	16.360 (±1.197)
	100	56.767 (±18.335)	37.722 (±12.550)	0.433 (±2.373)	0.000 (±0.000)	28.876 (±3.049)	14.917 (±0.517)
160	25	40.333 (±2.869)	19.167 (±3.905)	0.433 (±2.373)	0.000 (±0.000)	23.758 (±4.014)	21.822 (±0.136)
	50	24.167 (±6.711)	11.517 (±3.890)	0.433 (±2.373)	0.200 (±0.761)	26.518 (±3.500)	19.235 (±0.666)
	75	37.433 (±10.020)	18.533 (±5.578)	0.433 (±2.373)	0.167 (±0.461)	28.307 (±3.158)	16.456 (±1.140)
	100	63.433 (±22.201)	31.633 (±11.334)	0.433 (±2.373)	0.200 (±0.805)	28.917 (±3.042)	14.916 (±0.628)
214	25	40.900 (±3.537)	0.000 (±0.000)	0.433 (±2.373)	0.000 (±0.000)	23.796 (±4.007)	21.799 (±0.143)
	50	27.200 (±5.945)	0.000 (±0.000)	0.433 (±2.373)	0.167 (±0.592)	26.536 (±3.491)	19.280 (±0.627)
	75	35.067 (±10.392)	0.000 (±0.000)	0.433 (±2.373)	0.000 (±0.000)	28.335 (±3.152)	16.437 (±1.157)
	100	53.933 (±18.040)	0.000 (±0.000)	0.433 (±2.373)	0.000 (±0.000)	28.909 (±3.042)	14.943 (±0.808)

Table 7.20: Containers - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	38.013 (±6.682)	29.113 (±6.343)	0.433 (±2.373)	0.000 (±0.000)	21.125 (±3.992)	21.152 (±3.146)
	50	26.620 (±9.261)	20.813 (±7.905)	0.433 (±2.373)	0.067 (±0.254)	18.496 (±3.502)	18.707 (±2.693)
	75	36.447 (±10.207)	29.013 (±8.476)	0.433 (±2.373)	0.033 (±0.183)	16.731 (±3.165)	15.915 (±2.193)
	100	55.320 (±22.065)	44.133 (±17.802)	0.433 (±2.373)	0.333 (±1.493)	16.132 (±3.053)	14.435 (±2.070)
106	25	38.622 (±5.288)	24.644 (±5.041)	0.433 (±2.373)	0.000 (±0.000)	21.187 (±4.003)	21.292 (±2.606)
	50	24.678 (±8.022)	15.989 (±5.940)	0.433 (±2.373)	0.167 (±0.531)	18.503 (±3.500)	18.801 (±2.152)
	75	36.311 (±13.129)	24.044 (±9.009)	0.433 (±2.373)	0.433 (±1.695)	16.689 (±3.159)	15.922 (±1.637)
	100	57.678 (±15.944)	38.400 (±10.817)	0.433 (±2.373)	0.000 (±0.000)	16.064 (±3.036)	14.492 (±1.615)
160	25	37.583 (±8.404)	18.267 (±5.273)	0.433 (±2.373)	0.200 (±0.925)	21.281 (±4.025)	21.418 (±1.923)
	50	24.633 (±6.294)	12.033 (±3.815)	0.433 (±2.373)	0.200 (±0.610)	18.492 (±3.499)	18.897 (±1.469)
	75	34.767 (±12.555)	17.283 (±6.533)	0.433 (±2.373)	0.300 (±0.952)	16.709 (±3.163)	16.042 (±0.981)
	100	50.133 (±17.459)	25.017 (±8.872)	0.433 (±2.373)	0.033 (±0.183)	16.029 (±3.030)	14.439 (±1.114)
214	25	39.767 (±3.692)	0.000 (±0.000)	0.433 (±2.373)	0.000 (±0.000)	21.233 (±4.014)	21.801 (±0.142)
	50	26.233 (±6.806)	0.000 (±0.000)	0.433 (±2.373)	0.333 (±1.155)	18.527 (±3.504)	19.334 (±0.630)
	75	33.100 (±9.517)	0.000 (±0.000)	0.433 (±2.373)	0.233 (±0.568)	16.721 (±3.164)	16.452 (±1.157)
	100	52.867 (±19.158)	0.000 (±0.000)	0.433 (±2.373)	0.167 (±0.747)	16.106 (±3.046)	14.900 (±0.841)

formed part of the active set of ALCs. An average number of 29.113 of the ALCs in the active set had memory status. The ALCs misclassified an average of 0.000 patterns as containers and 0.433 as not. Thus, $\#Misclassified = 0.000 + 0.433 = 0.433$ which gives a correct classification rate of 99.797%. Figure 7.10 shows that the average number of ALCs decreased from 39.866 to 36.733 over five iterations with a decreasing average fitness of the ALC set. The average number of misclassification decreased from iteration one to two, then increased again after iteration two and decreased at iteration five.

7.4.4 Headlamps

Table 7.21 shows the results for classifying the Glass data set with patterns of the headlamps class as the self set. The ALCs were trained with the negative selection method. The best classification result was obtained when $IS=53$ and $W1=25$ since the average number of ALCs was the lowest for all IS and $W1$ with an $fNeg$ value of 0.367. An average number of 37.693 ALCs formed part of the active set of ALCs. An average number of 27.133 of the ALCs in the active set had memory status. The ALCs misclassified an average of 0.367 patterns as headlamps and 0.967 as not. Thus, $\#Misclassified = 0.367 + 0.967 = 1.334$ which gives a correct classification rate of 99.376%. Figure 7.11 shows a decreasing average number of ALCs, from 39.166 to 35.833 and a decreasing average fitness of the ALC set from 22.121 to 22.054 over five iterations. The average number of misclassification increased from iteration one to four and drops to 0.0 in iteration five.

Table 7.22 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=214$ and $W1=25$. An average number of 39.000 ALCs formed part of the active set of ALCs and was constant over the iterations. An average number of 0.000 of the ALCs in the active set had memory status. The ALCs misclassified an average of 0.467 patterns as headlamps and 0.967 as not. Thus, $\#Misclassified = 0.467 + 0.967 = 1.434$ which gives a correct classification rate of 99.329%.

7.4.5 Tableware

Table 7.23 shows the results for classifying the Glass data set with patterns of the tableware class as the self set. The ALCs were trained with the negative selection method. The best classification result was obtained when $IS=53$ and $W1=50$ since the average number of ALCs was the lowest for all IS and $W1$ with an $fNeg$ value of 0.000. An average number of 30.220 ALCs formed part of the active set of ALCs. An average number of 23.280 of the ALCs in the active set had

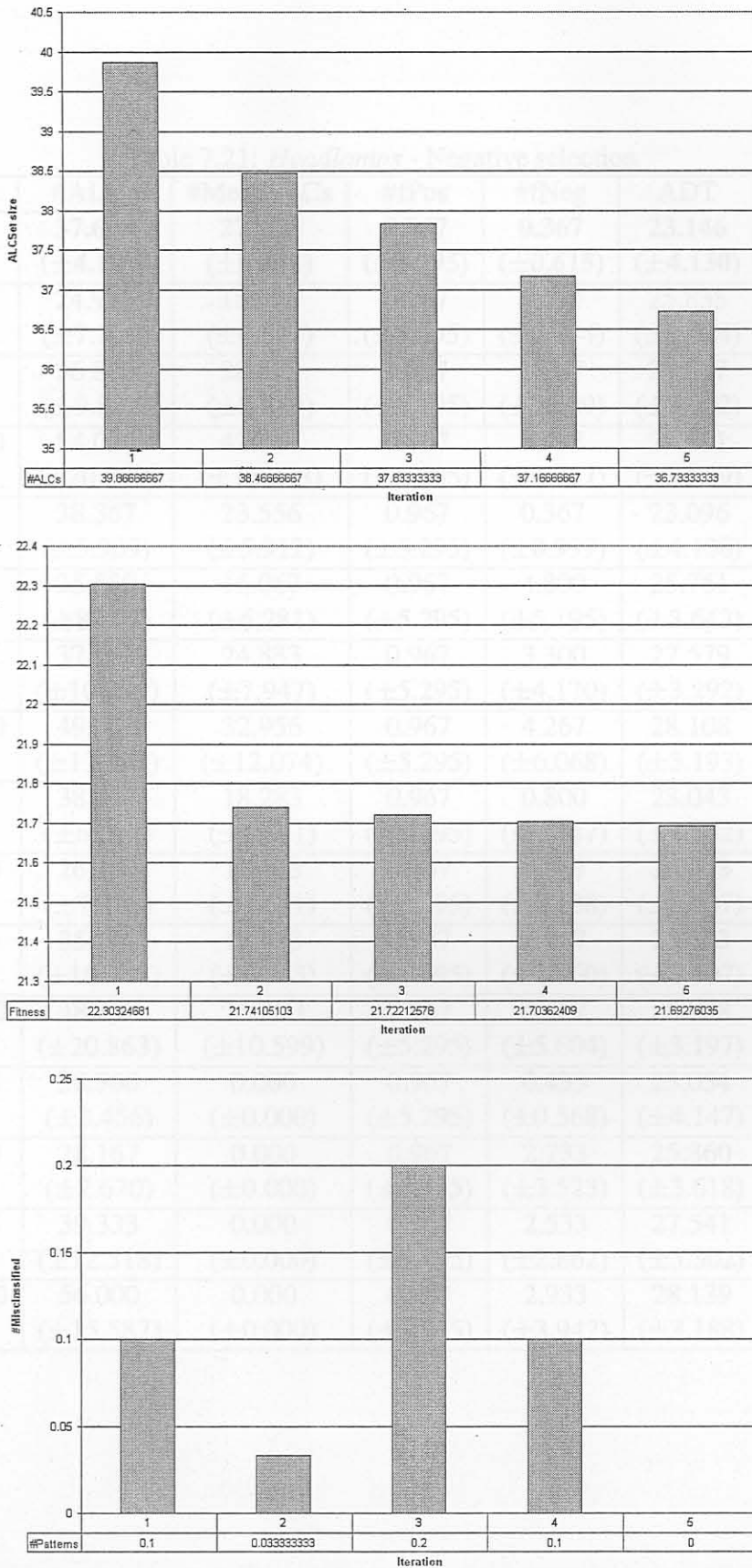


Figure 7.10: Containers - Positive selection with IS=53 and W1=25

Table 7.21: *Headlamps - Negative selection*

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	37.693 (±4.189)	27.133 (±6.224)	0.967 (±5.295)	0.367 (±0.615)	23.146 (±4.130)	21.739 (±0.160)
	50	24.973 (±7.100)	18.300 (±6.504)	0.967 (±5.295)	5.633 (±7.374)	25.835 (±3.624)	19.205 (±0.663)
	75	36.840 (±9.887)	28.833 (±8.849)	0.967 (±5.295)	3.767 (±3.329)	27.537 (±3.302)	16.659 (±1.093)
	100	54.027 (±20.529)	42.747 (±16.873)	0.967 (±5.295)	4.533 (±6.917)	28.031 (±3.209)	15.318 (±0.736)
106	25	38.367 (±5.909)	23.556 (±5.912)	0.967 (±5.295)	0.367 (±0.999)	23.096 (±4.138)	21.762 (±0.151)
	50	25.589 (±8.129)	16.067 (±6.281)	0.967 (±5.295)	4.800 (±5.195)	25.761 (±3.643)	19.361 (±0.628)
	75	37.667 (±10.819)	24.833 (±7.947)	0.967 (±5.295)	3.300 (±4.170)	27.579 (±3.292)	16.575 (±1.099)
	100	49.633 (±17.670)	32.956 (±12.074)	0.967 (±5.295)	4.267 (±6.068)	28.108 (±3.193)	15.209 (±0.889)
160	25	38.667 (±6.692)	18.283 (±4.861)	0.967 (±5.295)	0.800 (±2.747)	23.043 (±4.152)	21.791 (±0.143)
	50	26.100 (±7.928)	12.483 (±4.551)	0.967 (±5.295)	3.867 (±5.138)	25.773 (±3.637)	19.333 (±0.635)
	75	35.267 (±10.948)	17.433 (±5.943)	0.967 (±5.295)	2.467 (±2.360)	27.513 (±3.307)	16.691 (±1.102)
	100	48.800 (±20.863)	24.300 (±10.599)	0.967 (±5.295)	5.667 (±5.604)	28.088 (±3.197)	15.107 (±0.642)
214	25	38.700 (±3.456)	0.000 (±0.000)	0.967 (±5.295)	0.433 (±0.568)	23.054 (±4.147)	21.812 (±0.136)
	50	28.167 (±7.670)	0.000 (±0.000)	0.967 (±5.295)	2.733 (±3.523)	25.860 (±3.618)	19.309 (±0.615)
	75	39.333 (±12.518)	0.000 (±0.000)	0.967 (±5.295)	2.533 (±2.862)	27.541 (±3.302)	16.659 (±1.126)
	100	56.000 (±15.587)	0.000 (±0.000)	0.967 (±5.295)	2.933 (±3.947)	28.139 (±3.188)	15.107 (±0.750)

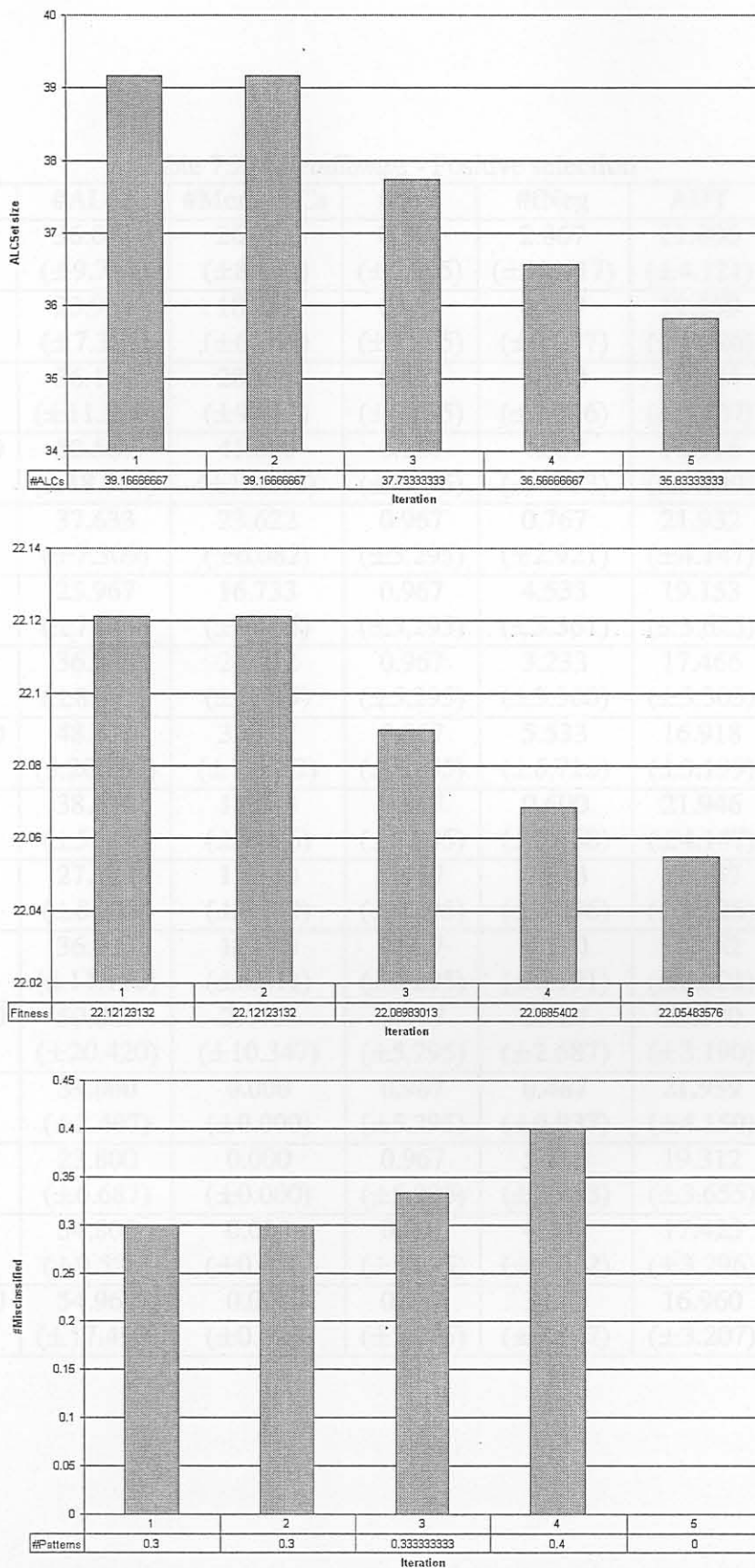


Figure 7.11: Headlamps - Negative selection with IS=53 and W1=25

Table 7.22: *Headlamps - Positive selection*

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	36.033 (±9.754)	26.713 (±8.493)	0.967 (±5.295)	2.867 (±12.417)	21.806 (±4.121)	21.069 (±3.138)
	50	23.960 (±7.319)	18.253 (±6.349)	0.967 (±5.295)	4.267 (±5.037)	19.159 (±3.626)	18.637 (±2.683)
	75	36.140 (±11.528)	28.593 (±9.517)	0.967 (±5.295)	3.700 (±2.996)	17.484 (±3.307)	16.066 (±2.212)
	100	52.567 (±18.917)	41.680 (±15.268)	0.967 (±5.295)	4.033 (±4.803)	16.916 (±3.199)	14.688 (±2.115)
106	25	37.633 (±7.309)	23.622 (±6.082)	0.967 (±5.295)	0.767 (±2.921)	21.932 (±4.147)	21.278 (±2.604)
	50	25.967 (±7.917)	16.733 (±5.955)	0.967 (±5.295)	4.533 (±5.361)	19.153 (±3.625)	18.756 (±2.142)
	75	36.333 (±8.373)	24.022 (±5.919)	0.967 (±5.295)	3.233 (±3.360)	17.466 (±3.303)	16.198 (±1.685)
	100	48.378 (±20.339)	32.167 (±13.682)	0.967 (±5.295)	5.533 (±6.715)	16.918 (±3.199)	14.748 (±1.737)
160	25	38.450 (±5.207)	18.583 (±4.096)	0.967 (±5.295)	0.600 (±0.968)	21.946 (±4.147)	21.421 (±1.923)
	50	27.183 (±8.278)	13.300 (±4.739)	0.967 (±5.295)	2.633 (±3.296)	19.167 (±3.625)	18.966 (±1.475)
	75	36.433 (±11.116)	18.000 (±6.011)	0.967 (±5.295)	4.500 (±6.191)	17.452 (±3.301)	16.244 (±1.026)
	100	59.067 (±20.420)	29.467 (±10.347)	0.967 (±5.295)	2.767 (±2.687)	16.870 (±3.190)	14.834 (±1.061)
214	25	39.000 (±2.407)	0.000 (±0.000)	0.967 (±5.295)	0.467 (±0.937)	21.959 (±4.150)	21.803 (±0.144)
	50	23.800 (±6.687)	0.000 (±0.000)	0.967 (±5.295)	5.133 (±5.463)	19.312 (±3.655)	19.401 (±0.631)
	75	34.800 (±9.528)	0.000 (±0.000)	0.967 (±5.295)	4.233 (±3.812)	17.425 (±3.296)	16.565 (±1.143)
	100	54.967 (±17.490)	0.000 (±0.000)	0.967 (±5.295)	3.600 (±3.597)	16.960 (±3.207)	15.261 (±0.643)

Table 7.23: *Tableware* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	41.153 (±6.913)	31.407 (±8.113)	0.300 (±1.643)	0.000 (±0.000)	25.355 (±3.714)	21.451 (±0.218)
	50	30.220 (±7.324)	23.280 (±7.316)	0.300 (±1.643)	0.000 (±0.000)	28.786 (±3.072)	18.268 (±0.824)
	75	43.333 (±10.996)	34.373 (±9.781)	0.300 (±1.643)	0.000 (±0.000)	30.718 (±2.706)	15.494 (±1.326)
	100	68.833 (±21.849)	54.933 (±17.893)	0.300 (±1.643)	0.000 (±0.000)	31.425 (±2.568)	14.005 (±1.135)
106	25	41.533 (±3.652)	26.556 (±5.616)	0.300 (±1.643)	0.000 (±0.000)	25.241 (±3.735)	21.519 (±0.196)
	50	26.656 (±8.050)	17.022 (±6.242)	0.300 (±1.643)	0.033 (±0.183)	28.732 (±3.079)	18.285 (±0.823)
	75	44.400 (±14.628)	29.356 (±10.400)	0.300 (±1.643)	0.033 (±0.183)	30.738 (±2.698)	15.449 (±1.326)
	100	61.800 (±22.884)	41.089 (±15.551)	0.300 (±1.643)	0.067 (±0.254)	31.411 (±2.572)	13.934 (±0.711)
160	25	41.367 (±3.102)	19.833 (±4.075)	0.300 (±1.643)	0.000 (±0.000)	25.229 (±3.737)	21.521 (±0.193)
	50	27.433 (±6.912)	13.200 (±4.248)	0.300 (±1.643)	0.133 (±0.346)	28.732 (±3.078)	18.298 (±0.811)
	75	43.900 (±10.142)	21.767 (±5.741)	0.300 (±1.643)	0.000 (±0.000)	30.775 (±2.691)	15.417 (±1.322)
	100	66.033 (±19.817)	32.933 (±10.181)	0.300 (±1.643)	0.000 (±0.000)	31.442 (±2.564)	13.939 (±0.786)
214	25	42.267 (±2.791)	0.000 (±0.000)	0.300 (±1.643)	0.000 (±0.000)	25.211 (±3.741)	21.531 (±0.189)
	50	27.000 (±9.432)	0.000 (±0.000)	0.300 (±1.643)	0.067 (±0.254)	28.716 (±3.085)	18.313 (±0.815)
	75	39.400 (±10.559)	0.000 (±0.000)	0.300 (±1.643)	0.000 (±0.000)	30.799 (±2.688)	15.354 (±1.333)
	100	73.733 (±24.271)	0.000 (±0.000)	0.300 (±1.643)	0.000 (±0.000)	31.387 (±2.576)	14.064 (±0.924)

memory status. The ALCs misclassified an average of 0.000 patterns as tableware and 0.300 as not. Thus, $\#Misclassified = 0.000 + 0.300 = 0.300$ which gives a correct classification rate of 99.85%. Figure 7.12 shows that the average number of ALCs decreased from 30.233 to 30.2 and the average fitness of the ALC set decreased from 23.528 to 23.525 over five iterations. The average number of misclassifications increased from iteration one to iteration three and then decreased at iteration five.

Table 7.24 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=106$ and $W1=50$ since the average number of ALCs was the lowest for all IS and $W1$ with an $fNeg$ value of 0.000. An average number of 26.300 ALCs formed part of the active set of ALCs. An average number of 17.233 of the ALCs in the active set had memory status. The ALCs misclassified an average of 0.000 patterns as tableware and 0.300 as not. Thus, $\#Misclassified = 0.000 + 0.300 = 0.300$ which gives a correct classification rate of 99.85%. Figure 7.13 shows a decrease in the average number of ALCs and a decrease in the average fitness of the ALC set. The average number of misclassifications increased from iteration one to two and then drops to 0.0 in iteration three.

7.4.6 Vehicle-window-float

Table 7.25 shows the results for classifying the Glass data set with patterns of the vehicle-window-float class as the self set. The ALCs were trained with the negative selection method. The best classification result was obtained when $IS=106$ and $W1=25$. An average number of 39.989 ALCs formed part of the active set of ALCs. An average number of 25.289 of the ALCs in the active set had memory status. The ALCs misclassified an average of 2.267 patterns as vehicle-window-float and 0.567 as not. Thus, $\#Misclassified = 2.267 + 0.567 = 2.834$ which gives a correct classification rate of 98.675%. Figure 7.14 shows a decrease in the average number of ALCs, a decrease in the average fitness of the ALC set and a decrease in the average number of misclassified patterns over all the iterations.

Table 7.26 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=106$ and $W1=25$. An average number of 39.967 ALCs formed part of the active set of ALCs. An average number of 25.933 of the ALCs in the active set had memory status. The ALCs misclassified an average of 2.000 patterns as vehicle-window-float and 0.567 as not. Thus, $\#Misclassified = 2.000 + 0.567 = 2.567$ which gives a correct classification rate of 98.800%. Figure 7.15 also shows a decrease in the average

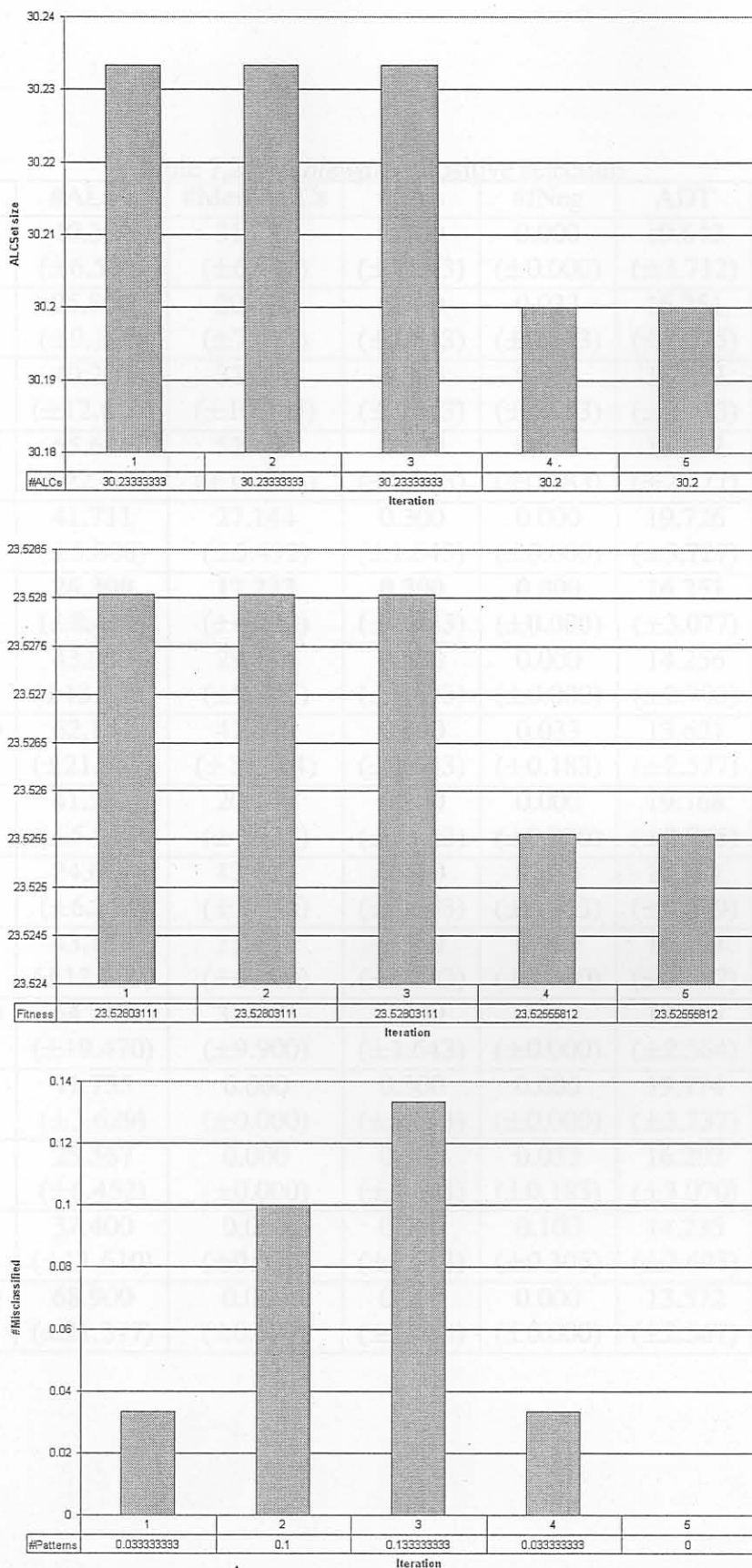


Figure 7.12: Tableware - Negative selection with IS=53 and W1=50

Table 7.24: *Tableware* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	40.380 (±6.503)	31.713 (±6.432)	0.300 (±1.643)	0.000 (±0.000)	19.643 (±3.712)	20.858 (±3.091)
	50	25.800 (±9.114)	20.420 (±7.743)	0.300 (±1.643)	0.033 (±0.183)	16.251 (±3.075)	17.656 (±2.496)
	75	40.207 (±12.660)	32.080 (±10.393)	0.300 (±1.643)	0.033 (±0.183)	14.227 (±2.693)	14.791 (±1.965)
	100	65.627 (±22.403)	52.453 (±18.065)	0.300 (±1.643)	0.033 (±0.183)	13.607 (±2.577)	13.558 (±1.898)
106	25	41.711 (±5.808)	27.144 (±5.492)	0.300 (±1.643)	0.000 (±0.000)	19.726 (±3.727)	21.005 (±2.552)
	50	26.300 (±8.422)	17.233 (±6.229)	0.300 (±1.643)	0.000 (±0.000)	16.251 (±3.077)	17.786 (±1.966)
	75	43.933 (±13.620)	29.156 (±9.485)	0.300 (±1.643)	0.000 (±0.000)	14.256 (±2.703)	14.945 (±1.450)
	100	62.144 (±21.347)	41.378 (±14.384)	0.300 (±1.643)	0.033 (±0.183)	13.621 (±2.577)	13.603 (±1.421)
160	25	41.233 (±5.211)	20.150 (±4.221)	0.300 (±1.643)	0.000 (±0.000)	19.768 (±3.735)	21.150 (±1.872)
	50	24.617 (±6.272)	12.033 (±3.796)	0.300 (±1.643)	0.033 (±0.183)	16.301 (±3.089)	17.970 (±1.300)
	75	43.150 (±12.229)	21.467 (±6.469)	0.300 (±1.643)	0.000 (±0.000)	14.197 (±2.687)	14.990 (±0.773)
	100	64.267 (±19.470)	32.083 (±9.900)	0.300 (±1.643)	0.000 (±0.000)	13.555 (±2.564)	13.647 (±0.870)
214	25	41.733 (±3.629)	0.000 (±0.000)	0.300 (±1.643)	0.000 (±0.000)	19.774 (±3.737)	21.535 (±0.187)
	50	25.567 (±6.452)	0.000 (±0.000)	0.300 (±1.643)	0.033 (±0.183)	16.203 (±3.070)	18.229 (±0.842)
	75	37.400 (±11.610)	0.000 (±0.000)	0.300 (±1.643)	0.100 (±0.305)	14.235 (±2.695)	15.331 (±1.349)
	100	68.900 (±21.377)	0.000 (±0.000)	0.300 (±1.643)	0.000 (±0.000)	13.572 (±2.567)	14.002 (±0.775)

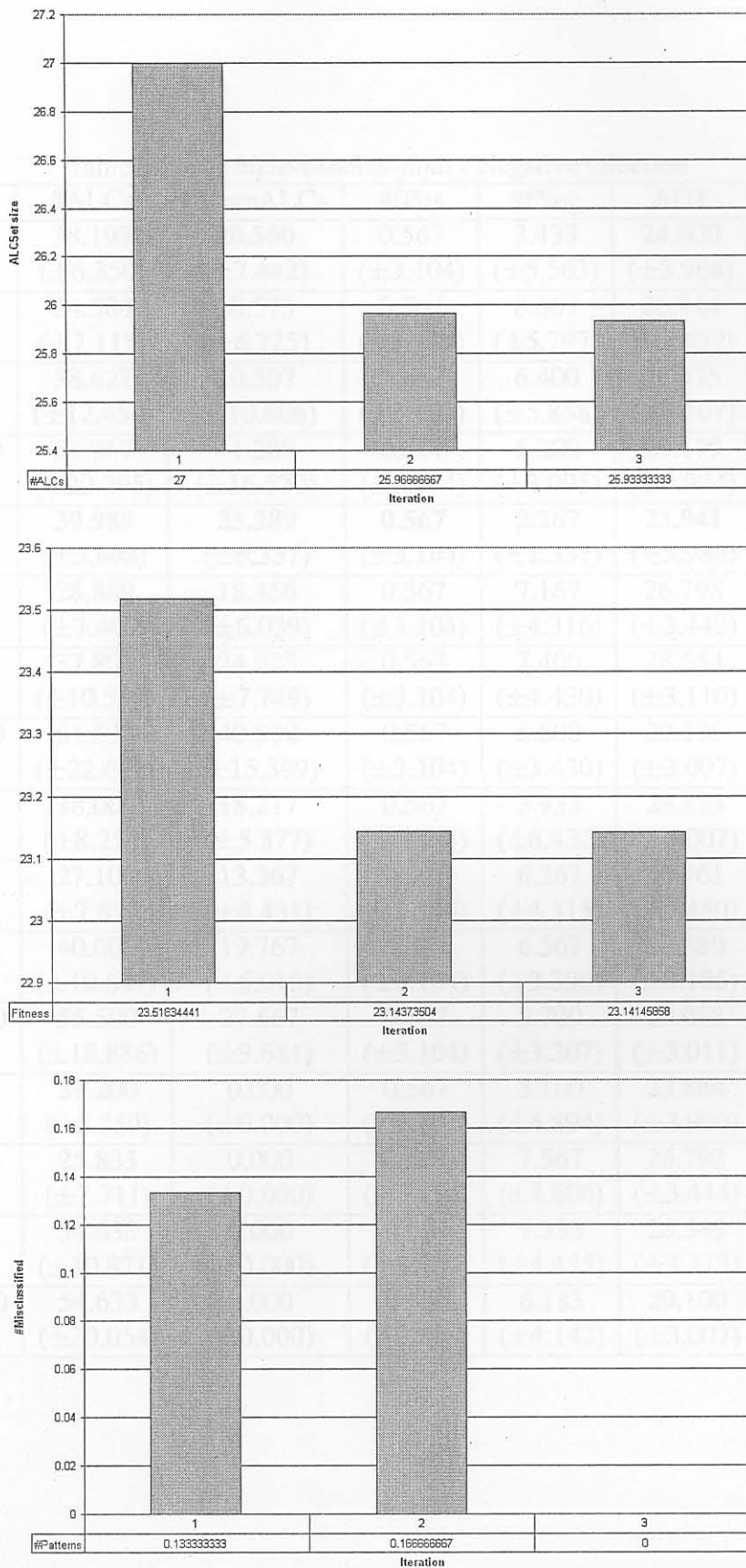


Figure 7.13: Tableware - Positive selection with IS=106 and W1=50

Table 7.25: *Vehicle-window-float* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	38.193 (±6.350)	28.560 (±7.442)	0.567 (±3.104)	3.433 (±5.563)	24.000 (±3.968)	21.687 (±0.226)
	50	24.580 (±7.115)	18.573 (±6.725)	0.567 (±3.104)	8.667 (±5.797)	26.744 (±3.457)	19.113 (±0.693)
	75	38.627 (±12.450)	30.507 (±10.806)	0.567 (±3.104)	6.400 (±5.858)	28.575 (±3.107)	16.350 (±1.163)
	100	51.967 (±20.295)	41.380 (±16.570)	0.567 (±3.104)	6.200 (±3.995)	29.179 (±2.994)	15.003 (±0.840)
106	25	39.989 (±3.608)	25.289 (±5.337)	0.567 (±3.104)	2.267 (±1.337)	23.941 (±3.980)	21.737 (±0.153)
	50	28.889 (±7.405)	18.456 (±6.039)	0.567 (±3.104)	7.167 (±4.316)	26.798 (±3.442)	19.191 (±0.646)
	75	37.800 (±10.535)	24.933 (±7.749)	0.567 (±3.104)	7.400 (±4.430)	28.554 (±3.110)	16.460 (±1.138)
	100	61.533 (±22.642)	40.900 (±15.399)	0.567 (±3.104)	5.600 (±3.430)	29.105 (±3.007)	15.114 (±0.733)
160	25	38.000 (±8.259)	18.217 (±5.377)	0.567 (±3.104)	3.933 (±6.432)	23.823 (±4.007)	21.754 (±0.147)
	50	27.100 (±7.893)	13.367 (±4.431)	0.567 (±3.104)	6.267 (±4.315)	26.761 (±3.450)	19.178 (±0.622)
	75	40.000 (±10.641)	19.767 (±6.018)	0.567 (±3.104)	6.567 (±3.390)	28.580 (±3.105)	16.440 (±1.149)
	100	55.500 (±18.886)	27.667 (±9.681)	0.567 (±3.104)	5.700 (±3.207)	29.088 (±3.011)	15.073 (±0.531)
214	25	39.200 (±6.359)	0.000 (±0.000)	0.567 (±3.104)	3.100 (±4.894)	23.884 (±3.990)	21.748 (±0.153)
	50	25.833 (±7.711)	0.000 (±0.000)	0.567 (±3.104)	7.567 (±4.606)	26.792 (±3.444)	19.150 (±0.670)
	75	34.633 (±10.871)	0.000 (±0.000)	0.567 (±3.104)	7.333 (±4.475)	28.549 (±3.113)	16.472 (±1.136)
	100	54.633 (±20.054)	0.000 (±0.000)	0.567 (±3.104)	6.133 (±4.142)	29.100 (±3.007)	15.081 (±0.626)

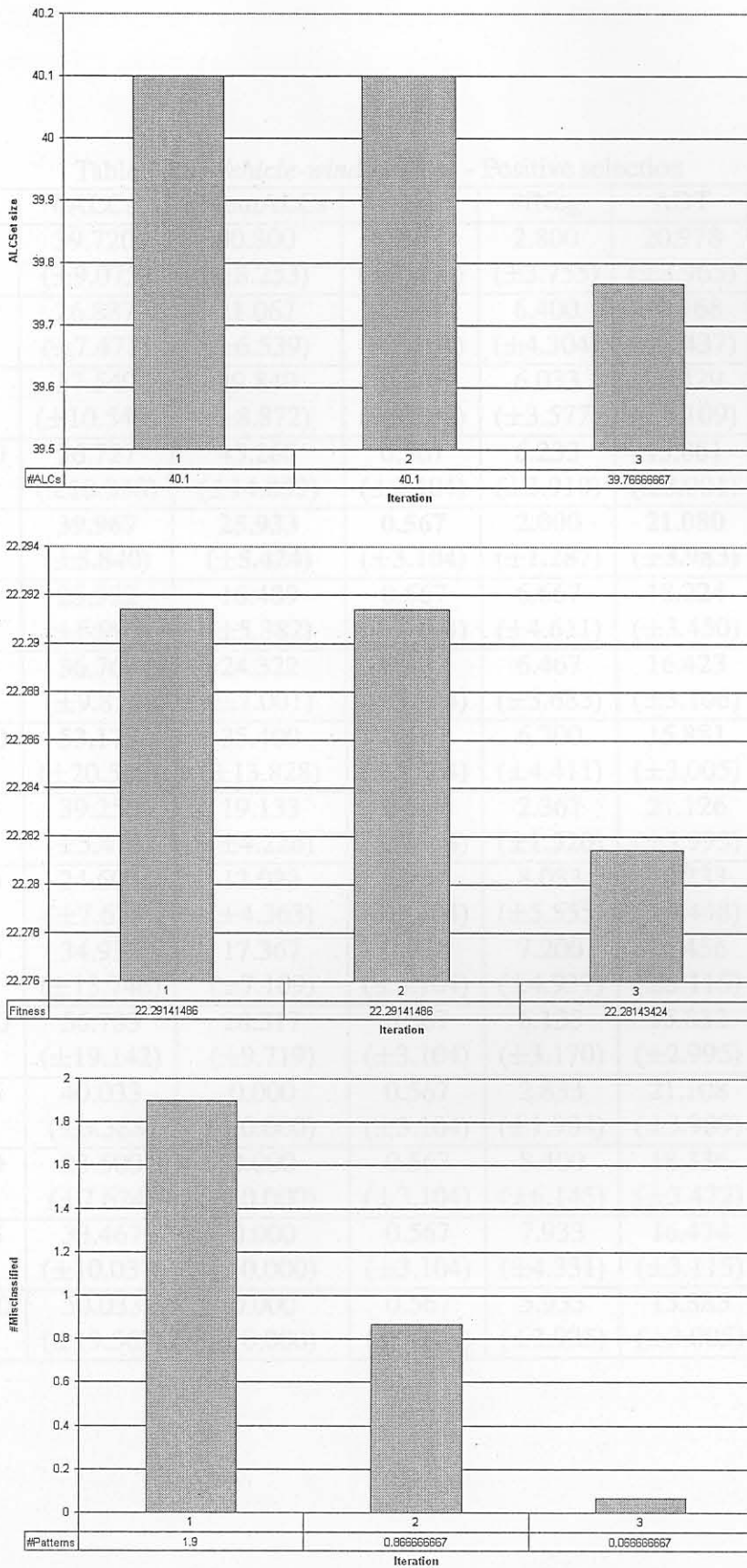
Figure 7.14: *Vehicle-window-float* - Negative selection with IS=106 and W1=25

Table 7.26: *Vehicle-window-float* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
53	25	39.720 (±9.075)	30.800 (±8.253)	0.567 (±3.104)	2.800 (±3.755)	20.978 (±3.965)	21.100 (±3.138)
	50	26.887 (±7.471)	21.067 (±6.539)	0.567 (±3.104)	6.400 (±4.304)	18.168 (±3.437)	18.547 (±2.661)
	75	37.540 (±10.544)	29.840 (±8.872)	0.567 (±3.104)	6.033 (±3.577)	16.429 (±3.109)	15.877 (±2.172)
	100	56.727 (±18.358)	45.260 (±14.859)	0.567 (±3.104)	6.233 (±3.910)	15.861 (±3.001)	14.547 (±2.072)
106	25	39.967 (±5.840)	25.933 (±5.424)	0.567 (±3.104)	2.000 (±1.287)	21.080 (±3.983)	21.239 (±2.596)
	50	25.322 (±6.997)	16.489 (±5.382)	0.567 (±3.104)	6.667 (±4.611)	18.224 (±3.450)	18.622 (±2.117)
	75	36.767 (±9.812)	24.322 (±7.001)	0.567 (±3.104)	6.467 (±3.683)	16.423 (±3.106)	15.971 (±1.629)
	100	53.178 (±20.539)	35.400 (±13.828)	0.567 (±3.104)	6.700 (±4.411)	15.881 (±3.005)	14.646 (±1.675)
160	25	39.250 (±5.415)	19.133 (±4.226)	0.567 (±3.104)	2.367 (±1.520)	21.126 (±3.993)	21.370 (±1.913)
	50	24.600 (±7.623)	12.033 (±4.363)	0.567 (±3.104)	8.033 (±5.555)	18.233 (±3.448)	18.762 (±1.439)
	75	34.933 (±13.746)	17.367 (±7.109)	0.567 (±3.104)	7.200 (±4.937)	16.456 (±3.115)	16.024 (±1.007)
	100	56.733 (±19.142)	28.317 (±9.719)	0.567 (±3.104)	6.133 (±3.170)	15.832 (±2.995)	14.666 (±1.094)
214	25	40.033 (±3.388)	0.000 (±0.000)	0.567 (±3.104)	2.833 (±1.984)	21.108 (±3.989)	21.758 (±0.146)
	50	23.500 (±7.624)	0.000 (±0.000)	0.567 (±3.104)	8.400 (±6.145)	18.336 (±3.472)	19.264 (±0.658)
	75	33.467 (±10.037)	0.000 (±0.000)	0.567 (±3.104)	7.933 (±4.331)	16.474 (±3.115)	16.464 (±1.164)
	100	50.033 (±19.567)	0.000 (±0.000)	0.567 (±3.104)	5.933 (±2.935)	15.885 (±3.005)	15.046 (±0.698)

number of ALCs, a decrease in the average fitness of the ALC set and a decrease in the average number of misclassified patterns over all the iterations.

7.4.7 Conclusion: Glass

The above results show that in most cases, except in the case of the *building-window-float* class as self, the positive selection method had better classification results than the negative selection method, though the parameter settings for IS and W1 were different for each case. In cases where the correct classification results were the same, as is the case with *containers* and *tableware* as self sets, the positive selection method had better performance compared to the negative selection method since the average number of ALCs in the active set was less for positive selection than for negative selection.

7.5 Car Evaluation

The car evaluation data set was derived from a simple hierarchical decision model that was developed by [8]. The model evaluates cars according to three concept structures, namely overall price, technical characteristics and comfort. The overall price concept is related to the buying price and price of maintenance, technical characteristics is related to the estimated safety of the car and the comfort which is related to the number of doors, the capacity in terms of persons to carry and the size of the luggage boot. The car evaluation data set contains examples with the structural concepts removed and directly relates a car to the six input attributes. All of these attributes are nominally valued. Since the car database has underlying concept structures, the database may be particularly useful for testing constructive induction and structure discovery methods. The car evaluation data set consists of 1728 patterns that are distributed between 4 car classes. These classes are acceptable, good, unacceptable and very good. 1210 patterns are of the unacceptable class, 384 are of the acceptable class, 69 are of the good class and 65 are of the very good class. The patterns were converted to binary strings of length 12.

7.5.1 Acceptable

Table 7.27 shows that with IS=864 and W1=50 the lowest misclassification of 916.546 patterns ($\#Misclassified = 915.113 + 1.433 = 916.546$) was achieved when training the ALCs with negative selection on patterns of the acceptable class as self. This gives a correct classification of 46.959% with an average number of 11.967 ALCs in the active set. An average number of 5.900

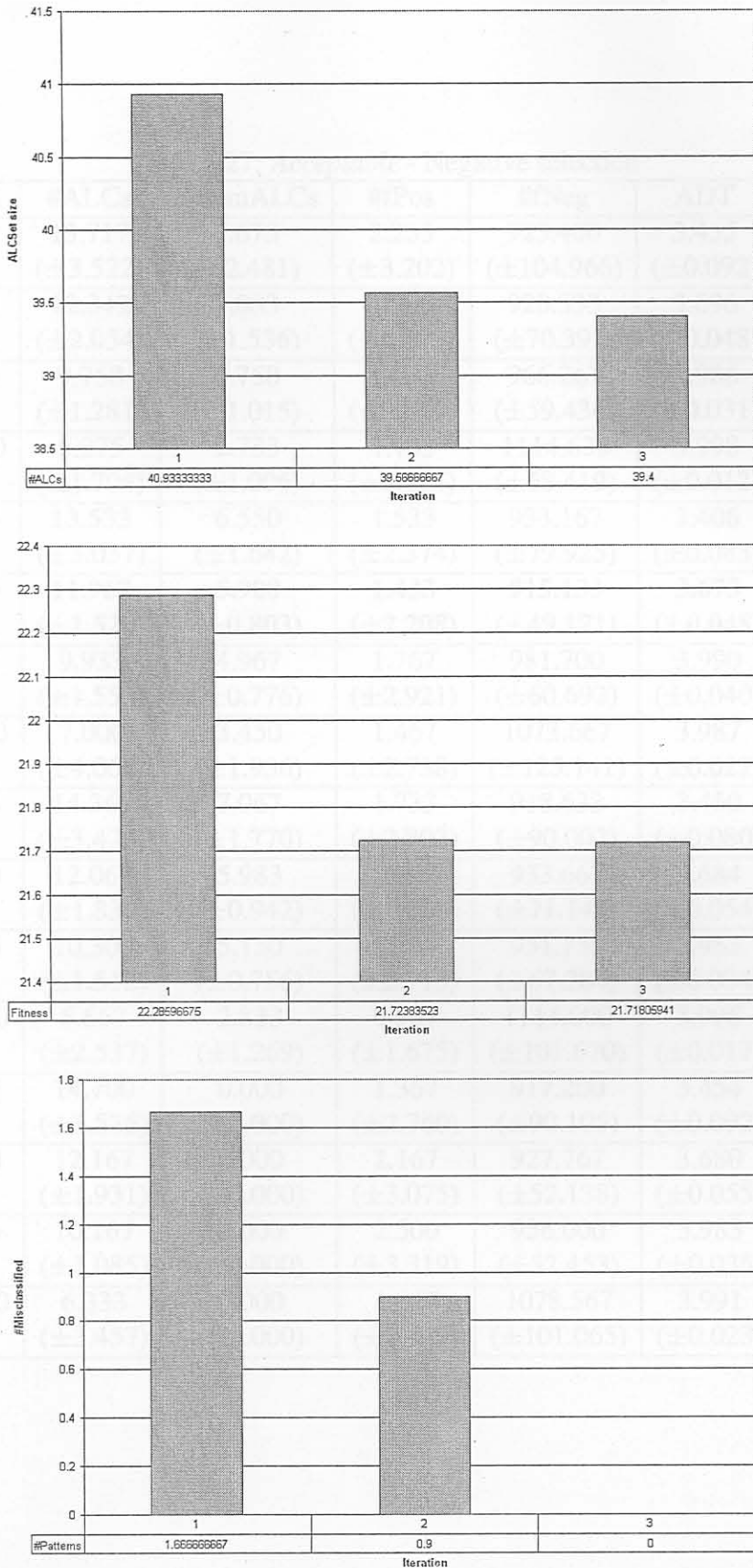


Figure 7.15: Vehicle-window-float - Positive selection with IS=106 and W1=25

Table 7.27: *Acceptable* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	13.717 (±3.522)	7.675 (±2.481)	2.233 (±3.202)	923.400 (±104.966)	3.455 (±0.092)	5.900 (±0.061)
	50	12.342 (±2.054)	7.083 (±1.536)	1.700 (±2.322)	920.533 (±70.391)	3.696 (±0.048)	5.732 (±0.063)
	75	9.758 (±1.281)	5.750 (±1.015)	1.533 (±2.849)	966.267 (±59.436)	3.986 (±0.031)	4.950 (±0.107)
	100	5.275 (±1.794)	2.733 (±1.006)	1.733 (±2.864)	1114.633 (±68.419)	3.998 (±0.012)	3.979 (±0.499)
864	25	13.533 (±3.037)	6.550 (±1.642)	1.533 (±2.374)	933.167 (±79.925)	3.406 (±0.083)	5.944 (±0.020)
	50	11.967 (±1.520)	5.900 (±0.803)	1.433 (±2.208)	915.133 (±49.171)	3.673 (±0.048)	5.747 (±0.037)
	75	9.933 (±1.552)	4.967 (±0.776)	1.767 (±2.921)	981.700 (±60.692)	3.990 (±0.040)	4.953 (±0.100)
	100	7.000 (±4.068)	3.450 (±1.936)	1.467 (±2.738)	1073.667 (±125.141)	3.987 (±0.027)	4.184 (±0.434)
1296	25	14.367 (±3.429)	7.067 (±1.770)	1.733 (±2.803)	918.633 (±90.002)	3.450 (±0.080)	5.949 (±0.018)
	50	12.067 (±1.837)	5.983 (±0.942)	1.667 (±2.708)	933.667 (±71.145)	3.684 (±0.054)	5.741 (±0.058)
	75	10.300 (±1.512)	5.150 (±0.756)	1.500 (±2.713)	951.733 (±67.284)	3.983 (±0.034)	4.967 (±0.098)
	100	5.667 (±2.537)	2.833 (±1.269)	0.567 (±1.675)	1114.000 (±101.670)	3.996 (±0.017)	3.974 (±0.582)
1728	25	14.700 (±3.525)	0.000 (±0.000)	1.367 (±2.760)	917.200 (±90.105)	3.454 (±0.092)	5.944 (±0.019)
	50	12.167 (±1.931)	0.000 (±0.000)	2.167 (±3.075)	927.767 (±52.138)	3.680 (±0.055)	5.747 (±0.053)
	75	10.167 (±1.085)	0.000 (±0.000)	2.500 (±3.319)	956.000 (±57.453)	3.983 (±0.035)	4.975 (±0.100)
	100	6.333 (±3.457)	0.000 (±0.000)	1.067 (±2.449)	1078.567 (±101.065)	3.991 (±0.023)	4.157 (±0.520)

of the ALCs in the active set had memory status.

Table 7.28 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=864$ and $W1=25$. An average number of 15.533 ALCs formed part of the active set of ALCs. An average number of 7.567 of the ALCs in the active set had memory status. The ALCs misclassified an average of 897.733 patterns as acceptable and 1.367 as not. Thus, $\#Misclassified = 897.733 + 1.367 = 899.100$ which gives a correct classification rate of 47.968%.

7.5.2 Good

The classification results for training the ALCs with negative selection on patterns of the good class as self is shown in table 7.29. The lowest misclassification of 230.233 patterns falsely as good and 0.433 as not ($\#Misclassified = 230.233 + 0.433 = 230.666$) was achieved with $IS=432$ and $W1=50$. This gives a correct classification of 86.651% with an average number of 17.642 ALCs in the active set of ALCs. The average number of ALCs with memory status in the active set was 12.675. Figure 7.16 shows that the average number of ALCs decreased over the iterations from 17.766 to 17.333 and the average fitness of the ALC set also decreased from 5.085 to 5.058 over the iterations. The number of misclassified patterns had an average decrease from 68.433 to 48.9.

Table 7.30 shows the results when the ALCs were trained with the positive selection method. The best classification result was achieved when $IS=1296$ and $W1=50$ which gave an average number of 16.833 ALCs in the active set of ALCs. An average number of 8.383 of the ALCs in the active set had memory status. The ALCs classified 243.000 patterns falsely as good and 0.367 as not, which gave a misclassification of 243.367 patterns ($\#Misclassified = 243.000 + 0.367 = 243.367$) and a correct classification rate of 85.916%.

7.5.3 Unacceptable

Table 7.31 shows that with $IS=864$ and $W1=75$ the lowest misclassification of 433.800 patterns ($\#Misclassified = 426.733 + 7.067 = 433.800$) was achieved when training the ALCs with negative selection on patterns of the unacceptable class as self. The ALCs misclassified an average of 426.733 patterns as unacceptable and 7.067 as not. This gives a correct classification of 74.895% with an average number of 11.567 ALCs in the active set. An average number of 5.783 of the

CHAPTER 7. EXPERIMENTAL RESULTS

Table 7.28: *Acceptable* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	13.508 (±3.531)	7.550 (±2.559)	1.900 (±2.510)	927.267 (±91.816)	8.537 (±0.090)	5.896 (±0.063)
	50	11.908 (±1.725)	6.717 (±1.243)	1.867 (±2.825)	928.567 (±71.491)	8.315 (±0.039)	5.727 (±0.063)
	75	9.508 (±1.172)	5.375 (±0.801)	1.867 (±2.933)	965.667 (±59.833)	8.008 (±0.023)	4.923 (±0.069)
	100	5.500 (±2.288)	3.008 (±1.505)	1.100 (±2.496)	1075.233 (±84.297)	8.002 (±0.008)	3.934 (±0.446)
864	25	15.533 (±3.767)	7.567 (±1.870)	1.367 (±2.157)	897.733 (±88.295)	8.542 (±0.070)	5.950 (±0.012)
	50	11.667 (±1.373)	5.783 (±0.703)	1.500 (±2.177)	933.700 (±54.525)	8.318 (±0.053)	5.736 (±0.048)
	75	10.100 (±1.213)	5.050 (±0.607)	1.867 (±2.886)	944.933 (±57.878)	8.027 (±0.046)	5.001 (±0.139)
	100	5.667 (±2.537)	2.833 (±1.269)	1.367 (±3.068)	1108.967 (±95.542)	8.004 (±0.017)	3.921 (±0.539)
1296	25	14.333 (±3.745)	7.050 (±1.882)	2.233 (±2.712)	922.100 (±92.388)	8.555 (±0.089)	5.944 (±0.027)
	50	11.900 (±1.494)	5.933 (±0.763)	2.367 (±3.347)	941.367 (±60.738)	8.316 (±0.053)	5.750 (±0.046)
	75	10.167 (±1.289)	5.083 (±0.644)	2.333 (±3.336)	941.767 (±54.185)	8.008 (±0.026)	4.965 (±0.092)
	100	5.000 (±0.000)	2.500 (±0.000)	0.900 (±2.074)	1135.233 (±68.284)	8.000 (±0.000)	3.840 (±0.554)
1728	25	14.067 (±3.463)	0.000 (±0.000)	1.633 (±2.710)	936.267 (±83.779)	8.562 (±0.070)	5.943 (±0.024)
	50	12.467 (±2.345)	0.000 (±0.000)	1.633 (±2.619)	917.800 (±59.883)	8.306 (±0.043)	5.750 (±0.053)
	75	10.300 (±1.088)	0.000 (±0.000)	1.233 (±2.528)	954.800 (±48.170)	8.020 (±0.041)	4.987 (±0.090)
	100	6.667 (±3.790)	0.000 (±0.000)	1.000 (±2.729)	1112.967 (±119.664)	8.011 (±0.025)	3.838 (±0.672)

Table 7.29: *Good* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	17.275 (±3.736)	10.683 (±2.391)	0.467 (±1.502)	311.233 (±94.128)	4.562 (±0.105)	5.725 (±0.090)
	50	17.642 (±4.835)	12.675 (±3.657)	0.433 (±1.832)	230.233 (±75.159)	5.320 (±0.086)	4.836 (±0.135)
	75	11.158 (±1.765)	8.358 (±1.327)	0.333 (±1.470)	378.533 (±58.707)	5.910 (±0.082)	3.291 (±0.339)
	100	8.267 (±5.159)	6.200 (±3.869)	0.133 (±0.730)	495.200 (±107.094)	5.977 (±0.036)	2.614 (±0.304)
864	25	18.733 (±3.759)	9.117 (±1.888)	0.467 (±1.833)	296.600 (±88.853)	4.463 (±0.064)	5.853 (±0.030)
	50	17.500 (±4.265)	8.750 (±2.132)	0.400 (±1.476)	244.933 (±74.043)	5.305 (±0.085)	4.870 (±0.101)
	75	10.333 (±1.729)	5.167 (±0.864)	0.367 (±1.474)	395.033 (±62.126)	5.930 (±0.076)	3.232 (±0.338)
	100	7.667 (±4.498)	3.833 (±2.249)	0.133 (±0.730)	555.633 (±160.979)	5.982 (±0.030)	2.511 (±0.474)
1296	25	18.600 (±3.001)	9.067 (±1.654)	0.433 (±1.501)	292.033 (±79.156)	4.447 (±0.104)	5.850 (±0.025)
	50	16.733 (±4.593)	8.367 (±2.297)	0.433 (±1.832)	244.467 (±75.462)	5.296 (±0.086)	4.862 (±0.121)
	75	10.900 (±1.845)	5.450 (±0.922)	0.367 (±1.474)	395.600 (±61.482)	5.931 (±0.064)	3.220 (±0.305)
	100	9.000 (±4.983)	4.500 (±2.491)	0.267 (±1.461)	511.267 (±167.143)	5.973 (±0.033)	2.583 (±0.498)
1728	25	18.233 (±3.674)	0.000 (±0.000)	0.500 (±1.526)	300.800 (±110.290)	4.453 (±0.137)	5.848 (±0.028)
	50	17.600 (±4.546)	0.000 (±0.000)	0.533 (±1.852)	244.567 (±66.496)	5.319 (±0.065)	4.849 (±0.120)
	75	10.167 (±1.289)	0.000 (±0.000)	0.333 (±1.470)	409.600 (±58.785)	5.948 (±0.060)	3.159 (±0.287)
	100	8.000 (±4.661)	0.000 (±0.000)	0.167 (±0.747)	518.967 (±140.424)	5.980 (±0.031)	2.663 (±0.316)

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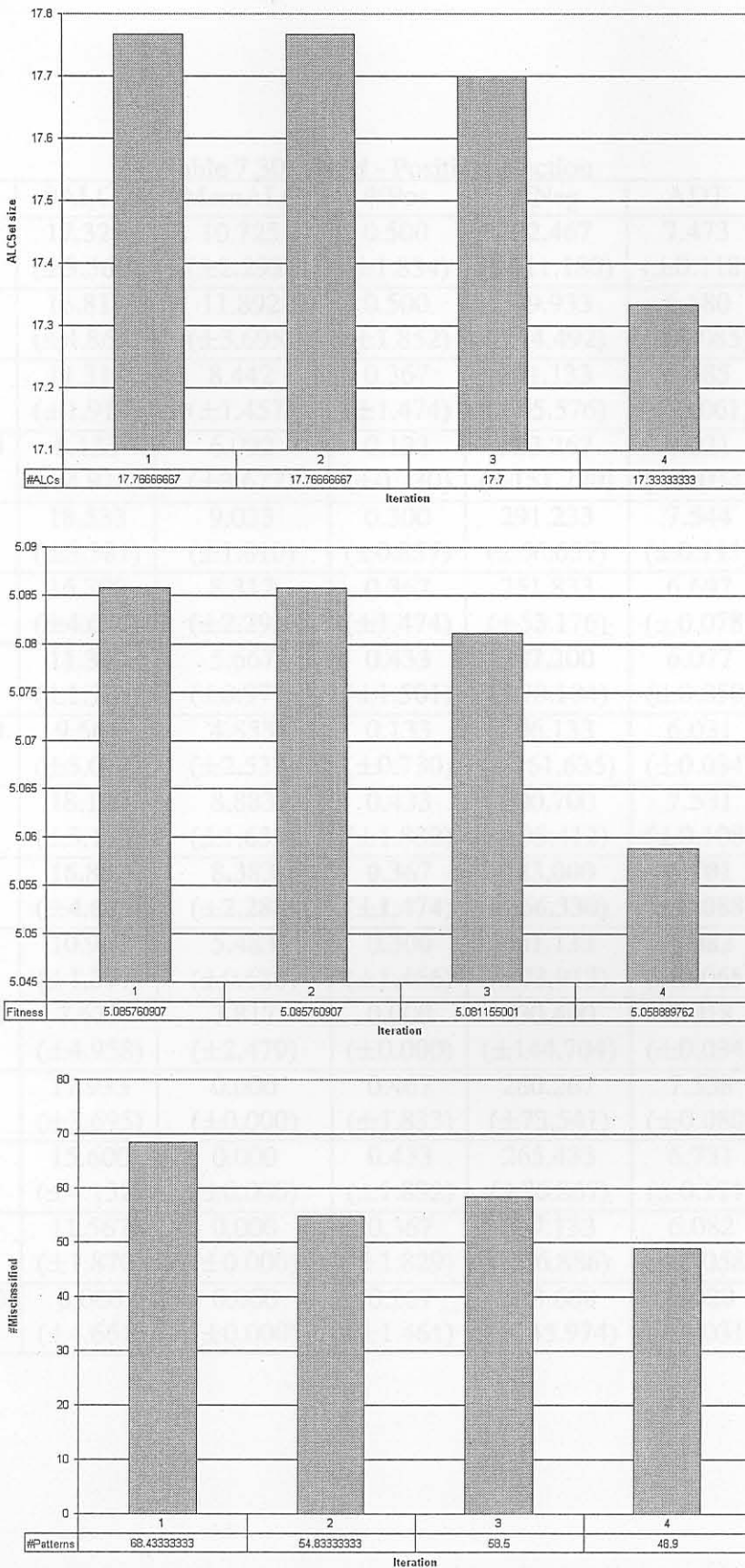
Figure 7.16: *Good* - Negative selection with IS=432 and W1=50

Table 7.30: *Good* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	17.325 (±3.366)	10.725 (±2.293)	0.500 (±1.834)	322.467 (±111.180)	7.473 (±0.118)	5.775 (±0.054)
	50	16.817 (±4.862)	11.892 (±3.695)	0.500 (±1.852)	249.933 (±74.492)	6.680 (±0.085)	4.833 (±0.103)
	75	11.317 (±1.917)	8.442 (±1.457)	0.367 (±1.474)	391.133 (±65.576)	6.085 (±0.061)	3.276 (±0.290)
	100	8.133 (±4.918)	6.092 (±3.677)	0.133 (±0.730)	533.267 (±151.720)	6.021 (±0.034)	2.608 (±0.415)
864	25	18.533 (±3.381)	9.033 (±1.810)	0.300 (±0.837)	291.233 (±66.657)	7.544 (±0.111)	5.846 (±0.028)
	50	16.700 (±4.617)	8.317 (±2.291)	0.367 (±1.474)	251.833 (±53.176)	6.697 (±0.078)	4.882 (±0.125)
	75	11.333 (±1.953)	5.667 (±0.977)	0.433 (±1.501)	387.200 (±70.104)	6.077 (±0.050)	3.257 (±0.307)
	100	9.667 (±5.074)	4.833 (±2.537)	0.133 (±0.730)	506.133 (±161.635)	6.031 (±0.034)	2.606 (±0.538)
1296	25	18.100 (±3.155)	8.883 (±1.633)	0.433 (±1.832)	300.700 (±93.412)	7.531 (±0.108)	5.849 (±0.029)
	50	16.833 (±4.609)	8.383 (±2.288)	0.367 (±1.474)	243.000 (±66.330)	6.701 (±0.088)	4.874 (±0.085)
	75	10.967 (±1.377)	5.483 (±0.688)	0.300 (±1.466)	401.133 (±73.913)	6.082 (±0.065)	3.238 (±0.283)
	100	7.633 (±4.958)	3.817 (±2.479)	0.000 (±0.000)	530.400 (±144.704)	6.018 (±0.034)	2.632 (±0.392)
1728	25	17.933 (±3.695)	0.000 (±0.000)	0.467 (±1.833)	280.267 (±73.541)	7.538 (±0.080)	5.851 (±0.028)
	50	15.600 (±4.132)	0.000 (±0.000)	0.433 (±1.832)	265.433 (±76.867)	6.731 (±0.111)	4.890 (±0.115)
	75	11.567 (±1.870)	0.000 (±0.000)	0.367 (±1.829)	387.133 (±56.886)	6.082 (±0.058)	3.250 (±0.321)
	100	8.000 (±4.661)	0.000 (±0.000)	0.267 (±1.461)	513.600 (±145.974)	6.020 (±0.031)	2.562 (±0.427)

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Table 7.31: *Unacceptable* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	13.033 (± 3.770)	5.533 (± 1.682)	7.533 (± 5.734)	450.300 (± 29.880)	3.042 (± 0.235)	5.119 (± 0.440)
	50	15.300 (± 3.723)	7.808 (± 2.472)	11.667 (± 5.990)	428.767 (± 31.704)	3.468 (± 0.195)	4.672 (± 0.344)
	75	12.008 (± 4.186)	6.808 (± 3.145)	6.267 (± 6.863)	429.033 (± 32.505)	4.060 (± 0.212)	2.942 (± 0.347)
	100	9.983 (± 9.282)	5.900 (± 6.833)	3.600 (± 5.512)	456.533 (± 39.923)	4.100 (± 0.250)	2.191 (± 0.457)
864	25	17.617 (± 3.854)	6.733 (± 1.524)	10.033 (± 5.346)	443.133 (± 30.016)	2.773 (± 0.156)	5.602 (± 0.157)
	50	14.550 (± 3.171)	6.517 (± 1.600)	10.667 (± 5.933)	432.600 (± 34.523)	3.342 (± 0.179)	4.926 (± 0.297)
	75	11.567 (± 2.622)	5.783 (± 1.311)	7.067 (± 6.746)	426.733 (± 33.595)	4.044 (± 0.133)	3.005 (± 0.241)
	100	10.600 (± 9.471)	5.283 (± 4.728)	3.000 (± 5.766)	452.867 (± 44.584)	4.068 (± 0.227)	2.276 (± 0.423)
1296	25	14.883 (± 4.413)	6.050 (± 1.945)	8.833 (± 6.114)	449.067 (± 33.783)	2.794 (± 0.177)	5.515 (± 0.243)
	50	15.100 (± 3.294)	7.083 (± 1.727)	12.033 (± 5.887)	435.967 (± 32.905)	3.325 (± 0.182)	4.956 (± 0.249)
	75	11.767 (± 2.582)	5.867 (± 1.273)	7.133 (± 6.872)	428.800 (± 33.455)	4.042 (± 0.161)	3.034 (± 0.284)
	100	8.867 (± 8.055)	4.433 (± 4.027)	3.067 (± 5.558)	455.600 (± 46.120)	4.086 (± 0.215)	2.275 (± 0.410)
1728	25	18.100 (± 4.413)	0.000 (± 0.000)	10.767 (± 6.484)	443.367 (± 32.557)	2.536 (± 0.088)	5.854 (± 0.035)
	50	14.333 (± 2.905)	0.000 (± 0.000)	10.733 (± 5.789)	438.500 (± 34.400)	3.230 (± 0.147)	5.129 (± 0.181)
	75	12.000 (± 3.151)	0.000 (± 0.000)	7.167 (± 6.869)	428.533 (± 31.059)	4.038 (± 0.184)	3.033 (± 0.341)
	100	8.567 (± 7.592)	0.000 (± 0.000)	4.533 (± 5.964)	456.800 (± 43.608)	4.076 (± 0.199)	2.327 (± 0.397)

ALCs in the active set had memory status.

Table 7.32 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=1296$ and $W1=75$. An average number of 12.400 ALCs formed part of the active set of ALCs. An average number of 6.200 of the ALCs in the active set had memory status. The ALCs misclassified an average of 425.233 patterns as unacceptable and 6.467 as not which gave a misclassification of 431.700 patterns ($\#Misclassified = 425.233 + 6.467 = 431.700$) and a correct classification rate of 75.017%.

7.5.4 Very Good

Table 7.33 shows the results for classifying the Car evaluation data set with patterns of the very good class as the self set. The ALCs were trained with the negative selection method. The best classification result was obtained when $IS=432$ and $W1=50$. An average number of 17.992 ALCs formed part of the active set of ALCs. An average number of 13.200 of the ALCs in the active set had memory status. The ALCs misclassified an average of 129.133 patterns as very good and 0.333 as not. Thus, $\#Misclassified = 129.133 + 0.333 = 129.466$ which gives a correct classification rate of 92.507%. Figure 7.17 shows a decrease in the average number of ALCs over the iterations from 18.1 to 17.8. The average fitness of the ALC set also decreased from 5.133 to 5.114. The average number of misclassified patterns decreased from iteration one to two, but then increased at iteration four.

Table 7.32 shows the results when the ALCs were trained with the positive selection method. The best classification result was obtained when $IS=864$ and $W1=50$. An average number of 18.233 ALCs formed part of the active set of ALCs. An average number of 9.067 of the ALCs in the active set had memory status. The ALCs misclassified an average of 130.033 patterns as unacceptable and 0.333 as not. Thus, $\#Misclassified = 130.033 + 0.333 = 130.366$ which gives a correct classification rate of 92.455%.

7.5.5 Conclusion: Car Evaluation

The above results show that different parameter settings for IS and $W1$ are necessary to obtain the best classification results for different classes as self. When comparing the best results of the above classes from both negative and positive selection as training methods, the average HD between the ALCs in the active set for the *acceptable* class as self is the highest for all the classes

Table 7.32: *Unacceptable* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	14.917 (±4.141)	6.500 (±2.121)	9.500 (±5.264)	447.200 (±30.398)	9.077 (±0.176)	5.267 (±0.310)
	50	13.258 (±3.529)	6.417 (±2.364)	10.600 (±6.360)	436.867 (±38.115)	8.577 (±0.194)	4.681 (±0.331)
	75	11.283 (±2.683)	6.158 (±2.148)	7.200 (±6.504)	429.867 (±33.360)	7.937 (±0.178)	2.982 (±0.323)
	100	10.292 (±10.352)	6.092 (±7.629)	3.700 (±6.221)	453.167 (±46.268)	7.920 (±0.216)	2.271 (±0.412)
864	25	15.800 (±4.656)	5.300 (±1.648)	7.733 (±5.401)	451.400 (±28.165)	9.513 (±0.111)	5.874 (±0.035)
	50	15.767 (±4.014)	6.767 (±1.851)	11.767 (±6.290)	433.967 (±35.004)	8.770 (±0.107)	5.147 (±0.121)
	75	12.067 (±3.999)	6.017 (±1.941)	5.400 (±7.040)	427.800 (±32.190)	7.933 (±0.203)	2.967 (±0.367)
	100	9.867 (±11.933)	4.933 (±5.966)	3.567 (±5.685)	459.800 (±47.640)	7.900 (±0.239)	2.236 (±0.399)
1296	25	19.633 (±3.961)	7.367 (±1.676)	10.067 (±6.203)	438.133 (±31.181)	9.461 (±0.099)	5.860 (±0.037)
	50	15.633 (±3.873)	7.100 (±1.927)	11.700 (±6.204)	430.333 (±38.301)	8.769 (±0.109)	5.148 (±0.122)
	75	12.400 (±4.407)	6.200 (±2.203)	6.467 (±7.281)	425.233 (±36.141)	7.956 (±0.154)	3.034 (±0.245)
	100	9.500 (±10.153)	4.750 (±5.077)	3.100 (±5.592)	457.100 (±42.542)	7.923 (±0.218)	2.255 (±0.409)
1728	25	16.833 (±4.836)	0.000 (±0.000)	8.933 (±5.426)	449.467 (±32.126)	9.492 (±0.103)	5.862 (±0.029)
	50	15.000 (±3.677)	0.000 (±0.000)	9.500 (±6.318)	431.400 (±35.091)	8.743 (±0.121)	5.102 (±0.153)
	75	12.167 (±4.395)	0.000 (±0.000)	6.333 (±6.825)	425.467 (±34.767)	7.945 (±0.178)	2.975 (±0.244)
	100	10.267 (±10.044)	0.000 (±0.000)	3.200 (±5.561)	449.433 (±48.340)	7.937 (±0.179)	2.357 (±0.340)

Table 7.33: *Very Good* - Negative selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	17.650 (±2.573)	10.983 (±1.838)	0.367 (±0.928)	157.833 (±49.543)	4.750 (±0.117)	5.681 (±0.088)
	50	17.992 (±5.647)	13.200 (±4.251)	0.333 (±0.884)	129.133 (±45.808)	5.719 (±0.113)	4.532 (±0.191)
	75	9.633 (±0.850)	7.225 (±0.638)	0.333 (±0.922)	193.900 (±36.771)	6.016 (±0.125)	3.972 (±0.174)
	100	6.667 (±4.611)	5.000 (±3.458)	0.233 (±0.626)	370.933 (±125.691)	6.021 (±0.156)	3.047 (±0.482)
864	25	18.683 (±3.573)	8.817 (±1.836)	0.400 (±0.932)	163.433 (±48.846)	4.627 (±0.108)	5.801 (±0.028)
	50	17.900 (±4.581)	8.950 (±2.291)	0.300 (±0.877)	129.900 (±49.694)	5.707 (±0.083)	4.562 (±0.148)
	75	9.700 (±0.988)	4.850 (±0.494)	0.333 (±0.922)	186.200 (±31.196)	6.022 (±0.170)	3.939 (±0.297)
	100	8.100 (±5.695)	4.050 (±2.848)	0.300 (±0.877)	346.867 (±137.375)	6.012 (±0.156)	3.240 (±0.423)
1296	25	18.267 (±3.194)	8.833 (±1.544)	0.367 (±0.928)	165.367 (±44.187)	4.620 (±0.094)	5.805 (±0.025)
	50	17.333 (±5.128)	8.633 (±2.569)	0.333 (±0.922)	136.700 (±44.319)	5.690 (±0.092)	4.575 (±0.161)
	75	10.200 (±1.669)	5.100 (±0.835)	0.333 (±0.922)	192.967 (±36.416)	6.010 (±0.124)	3.976 (±0.153)
	100	6.067 (±4.354)	3.033 (±2.177)	0.133 (±0.507)	365.867 (±119.465)	6.021 (±0.129)	3.109 (±0.460)
1728	25	19.600 (±2.568)	0.000 (±0.000)	0.400 (±0.932)	154.400 (±33.757)	4.641 (±0.078)	5.799 (±0.029)
	50	16.833 (±5.004)	0.000 (±0.000)	0.333 (±0.922)	144.667 (±56.804)	5.695 (±0.118)	4.572 (±0.192)
	75	9.967 (±1.402)	0.000 (±0.000)	0.333 (±0.922)	186.300 (±40.623)	6.014 (±0.126)	3.976 (±0.167)
	100	6.800 (±6.588)	0.000 (±0.000)	0.200 (±0.805)	344.233 (±115.088)	6.019 (±0.128)	3.300 (±0.353)

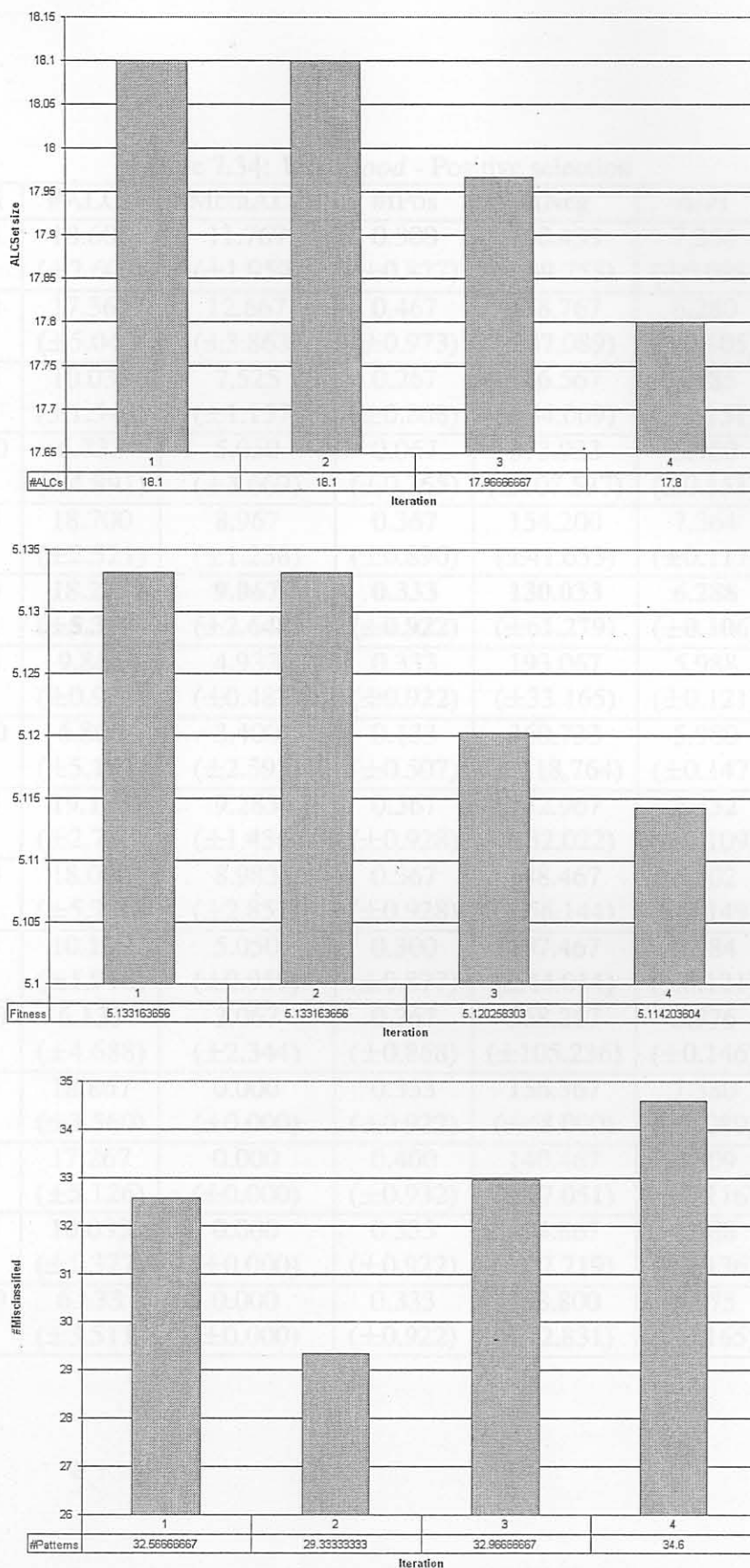


Figure 7.17: Very Good - Negative selection with IS=432 and W1=50

Table 7.34: *Very Good* - Positive selection

IS	W1	#ALCs	#MemALCs	#fPos	#fNeg	ADT	HD
432	25	18.608 (±2.603)	11.767 (±1.959)	0.300 (±0.877)	150.433 (±39.753)	7.254 (±0.088)	5.696 (±0.062)
	50	17.367 (±5.042)	12.667 (±3.863)	0.467 (±0.973)	138.767 (±47.089)	6.280 (±0.105)	4.524 (±0.176)
	75	10.033 (±1.542)	7.525 (±1.157)	0.267 (±0.868)	186.567 (±34.069)	5.985 (±0.151)	3.970 (±0.218)
	100	6.733 (±4.891)	5.050 (±3.669)	0.067 (±0.365)	373.933 (±107.537)	5.980 (±0.151)	3.202 (±0.386)
864	25	18.700 (±2.521)	8.967 (±1.238)	0.367 (±0.890)	154.200 (±41.633)	7.364 (±0.117)	5.794 (±0.025)
	50	18.233 (±5.399)	9.067 (±2.648)	0.333 (±0.922)	130.033 (±61.279)	6.288 (±0.106)	4.553 (±0.181)
	75	9.867 (±0.973)	4.933 (±0.487)	0.333 (±0.922)	193.067 (±33.165)	5.988 (±0.121)	3.978 (±0.187)
	100	6.800 (±5.182)	3.400 (±2.591)	0.133 (±0.507)	360.733 (±118.764)	5.980 (±0.147)	3.185 (±0.377)
1296	25	19.133 (±2.700)	9.283 (±1.436)	0.367 (±0.928)	152.967 (±32.022)	7.352 (±0.109)	5.792 (±0.023)
	50	18.000 (±5.736)	8.983 (±2.851)	0.367 (±0.928)	148.467 (±56.144)	6.302 (±0.149)	4.566 (±0.195)
	75	10.100 (±1.918)	5.050 (±0.959)	0.300 (±0.877)	197.467 (±44.014)	5.984 (±0.121)	3.970 (±0.150)
	100	6.133 (±4.688)	3.067 (±2.344)	0.267 (±0.868)	368.267 (±105.236)	5.976 (±0.146)	3.161 (±0.514)
1728	25	18.867 (±3.560)	0.000 (±0.000)	0.333 (±0.922)	156.367 (±48.000)	7.380 (±0.089)	5.805 (±0.032)
	50	17.267 (±5.126)	0.000 (±0.000)	0.400 (±0.932)	140.467 (±47.051)	6.309 (±0.116)	4.573 (±0.157)
	75	10.033 (±1.377)	0.000 (±0.000)	0.333 (±0.922)	194.867 (±27.719)	5.988 (±0.136)	3.979 (±0.184)
	100	6.133 (±3.511)	0.000 (±0.000)	0.333 (±0.922)	338.800 (±72.831)	5.975 (±0.165)	3.248 (±0.409)

The classification results obtained from CAIS with negative and positive selection is summarized and compared with CA5 in Table 7.33. CA5 was trained different from CAIS. The experiments with CA5 also used a 30-fold cross validation training set, but the training set consisted out of

DATA SET	CLASS AS SELF	GAIS NEGATIVE SELECTION	GAIS POSITIVE SELECTION	C4.5
IRIS	<i>Setosa</i>	99.66%	99.62%	99.3%
	<i>Versicolor</i>	97.13%	97.0%	96.0%
	<i>Virginica</i>	94.6%	94.62%	97.3%
WISCONSIN	<i>Benign</i>	98.907%	98.798%	96.3%
BREAST CANCER	<i>Malignant</i>	93.395%	93.948%	96.3%
MUSHROOM	<i>Edible</i>	88.502%	87.438%	99.9%
	<i>Poisonous</i>	80.383%	79.105%	99.9%
GLASS	<i>Building-window-float</i>	92.741%	92.357%	79.3%
	<i>Building-window-nonfloat</i>	83.816%	84.454%	79.7%
	<i>Containers</i>	99.797%	99.797%	95.9%
	<i>Headlamps</i>	99.376%	99.329%	94.9%
	<i>Tableware</i>	99.85%	99.85%	97.7%
	<i>Vehicle-window-float</i>	98.675%	98.8%	91.7%
CAR EVALUATION	<i>Acceptable</i>	46.959%	47.968%	95.1%
	<i>Good</i>	86.651%	85.916%	98.7%
	<i>Unacceptable</i>	74.895%	75.017%	99.5%
	<i>Very Good</i>	92.507%	92.455%	100%

Table 7.35: Summarised results

as the self set. The average ADT in the active set of ALCs with *acceptable* as the self set is the lowest with negative selection and the highest with positive selection for all the classes as the self set. These deductions support the bad classification result with *acceptable* as the self set, since the ALCs are widely distributed in problem space (the high average HD) with the lowest space coverage (the low average ADT for negative selection and the high average ADT for positive selection). For *acceptable* or *unacceptable* as the self set the positive selection method had better classification results than the negative selection method and for *good* or *very good* as the self set the negative selection method had better classification results than the positive selection method.

7.6 Comparing the Results

The classification results obtained from GAIS with negative and positive selection is summarised and compared with C4.5 in table 7.35. C4.5 was trained different from GAIS. The experiments with C4.5 also used a 30-fold cross validation training set, but the training set consisted out of

self and non-self patterns. The results show that GAIS had on average better classification than C4.5 in classifying the Iris data set, except for *virginica* as self. C4.5 had better classification for the Mushroom data set and the Car evaluation data set, where GAIS had better classification with the Glass data set. C4.5 had better classification with *malignant* as self and GAIS had better classification with *benign* as self in classifying the Wisconsin breast cancer data set. The high misclassification rate of GAIS on the Mushroom and Car Evaluation data sets is due to the low number of ALCs evolved by the GA. The evolved ALCs are widely distributed in space (refer to the high average HD) with a low space coverage (refer to the low average ADT for negative selection and the high average ADT for positive selection). These deductions indicate that better classification results can be obtained when more ALCs are evolved, but with a higher degree of average overlap (lower average HD) among the evolved ALCs. GAIS only evolves an optimal initial set of ALCs. The initial set is kept static during the training process to determine the status of each ALC in the set. Classification performance of GAIS could be improved by replacing the annihilated ALCs with newly evolved ALCs by the GA. When there is overlap among the self patterns and the non-self patterns, the GA needs to evolve a higher number of ALCs to optimally cover the highly distributed non-self space between the self patterns. From these results it can be concluded that depending on the problem that needs to be classified and the selected class as the self set, there are cases that GAIS performs better than C4.5. This deduction supports the *no free lunch theorem* [84].

7.1 Conclusion

The main objective of this dissertation - to evolve ALCs that have the maximum coverage of self space with the least overlap among the ALCs - is addressed. The dissertation starts with an overview of the functioning of the natural immune system (NIS) - the biological system that protects the body against harmful pathogenic material. The different states of a lymphocyte are also introduced. The dissertation gave an overview of evolutionary computation, focusing on genetic algorithms. A new artificial immune system (namely GAIS) was developed for classification. GAIS uses a genetic algorithm to evolve artificial lymphocytes (ALCs). The GA evolved the grand ALCs sequentially. Each evolved ALC was added to the set of ALCs. The GA was forced with the least overlap restriction to explore different regions of the search space that was not covered by the existing set of ALCs. The evolved ALCs were trained with negative or positive selection to ensure that the ALCs did not cover the patterns in the predetermined self set. The active set of evolved ALCs was used to classify patterns. The status of the ALCs was evaluated at predetermined time steps.