Model assisted (1+1)ES

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1 Algorithms

1.1 Algorithm 1

Normal (1+1) ES

```
N ← 400
function FIT(x)
    y ← Σ_{i<N}(x_i − 1)^2
    return(y)
end function
function DIST(x)
    y ← sqrt(Σ_{i<N}(x_i − 1)^2)
    return(y)
end function
Initialize(ind, σ*, prate* ← 0)
for i ≤ MAXGen do
    i++
    σ ← (σ* * ||ind − y||) / N
    ind2 ← ind + σ * N(0, I)
    newfit ← FIT(ind2)
    if newfit ≤ bestfit then
        prate* ← prate* − N * log DIST(ind2) / DIST(ind)
        ind ← ind2
        bestfit ← newfit
    end if
end for
prate* ← prate*/i
```

1.2 Algorithm 2

Model Assisted (1+1)ES

1: $N \leftarrow 400$
2: **function** FIT(x)
3: $y \leftarrow \Sigma_{i<N}(x_i - 1)^2$
4: $return(y)$
5: **end function**
6: **function** DIST(x)
7: $y \leftarrow \sqrt{\Sigma_{i<N}(x_i - 1)^2}$
8: $return(y)$
9: **end function**
10: $initialize(ind, \sigma^*, \sigma_e^*, prate^* \leftarrow 0)$
11: **for** $i \leq MAXGen$ **do**
12: $i++$
13: $ind2 \leftarrow ind$
14: **while** $j \leq MAXModel$ **do**
15: $j++$
16: $\sigma \leftarrow \frac{\sigma^* * Dist(ind)}{N}$
17: $ind3 \leftarrow ind2 + \sigma * N(0, I)$
18: $\sigma_e \leftarrow \frac{2 * \sigma_e^* * Dist(ind)^2}{N}$
19: $fit3 \leftarrow FIT(ind2) + \sigma_e * N(0, 1)$
20: **if** $fit3 \leq bestfit$ **then**
21: $ind2 \leftarrow ind3$
22: $Break$
23: **end if**
24: **end while**
25: $newfit = FIT(ind2)$
26: **if** $newfit \leq bestfit$ **then**
27: $prate^* \leftarrow prate^* - N * \log \frac{DIST(ind2)}{DIST(ind)}$
28: $ind \leftarrow ind2$
29: $bestfit \leftarrow newfit$
30: **end if**
31: **end for**
32: $prate^* \leftarrow prate^*/i$

1.3 Algorithm 3

Model Assisted (1+1)ES without model generation limit

```
1: N ← 400
2: function FIT(x)
3:     y ← Σ_{i<N}(x_i − 1)^2
4:     return(y)
5: end function
6: function DIST(x)
7:     y ← sqrt(Σ_{i<N}(x_i − 1)^2)
8:     return(y)
9: end function
10: initialize(ind, σ*, σ*_e, prate* ← 0)
11: for i ≤ MAXGen do
12:     i++
13:     ind2 ← ind
14:     while true do
15:         j++
16:         σ ← σ* * Dist(ind) / N
17:         ind3 ← ind2 + σ * N(0, I)
18:         σ_e ← 2 * σ*_e * Dist(ind)^2 / N
19:         fit3 ← FIT(ind2) + σ_e * N(0, 1)
20:         if fit3 ≤ bestfit then
21:             ind2 ← ind3
22:             Break
23:         end if
24:     end while
25:     newfit = FIT(ind2)
26:     if newfit ≤ bestfit then
27:         prate* ← prate* − N * log DIST(ind2) / DIST(ind)
28:         ind ← ind2
29:         bestfit ← newfit
30:     end if
31: end for
32: prate* ← prate*/i
```

1.4 Algorithm 4

Step-size Adaptive Model Assisted (1+1)ES

$N \leftarrow 400$
function FIT(x)
  $y \leftarrow \Sigma_{i<N}(x_i - 1)^2$
  $return(y)$
end function
function DIST(x)
  $y \leftarrow \sqrt{\Sigma_{i<N}(x_i - 1)^2}$
  $return(y)$
end function
$initialize(ind, \sigma_e^*, prate^* \leftarrow 0)$
for $i \leq MAXGen$ **do**
  $i++$
  $ind2 \leftarrow ind$
  $flag \leftarrow 0$
  for $j \leq MAXModel$ **do**
    $j++$
    $ind3 \leftarrow ind2 + \sigma * N(0, I)$
    $\sigma_e \leftarrow \frac{2*\sigma_e^**Dist(ind)^2}{N}$
    $fit3 \leftarrow FIT(ind2) + \sigma_e * N(0, 1)$
    if $fit3 \leq bestfit$ **then**
      $flag \leftarrow 1$
      $ind2 \leftarrow ind3$
      $Break$
    end if
  end for
  $newfit = FIT(ind2)$
  $\sigma \leftarrow \sigma * \exp^{\frac{1}{N}}(flag - \alpha)$
  if $newfit \leq bestfit$ **then**
    $prate^* \leftarrow prate^* - N * \log \frac{DIST(ind2)}{DIST(ind)}$
    $ind \leftarrow ind2$
    $bestfit \leftarrow newfit$
  end if
end for
$prate^* \leftarrow prate^*/i$

2 Results

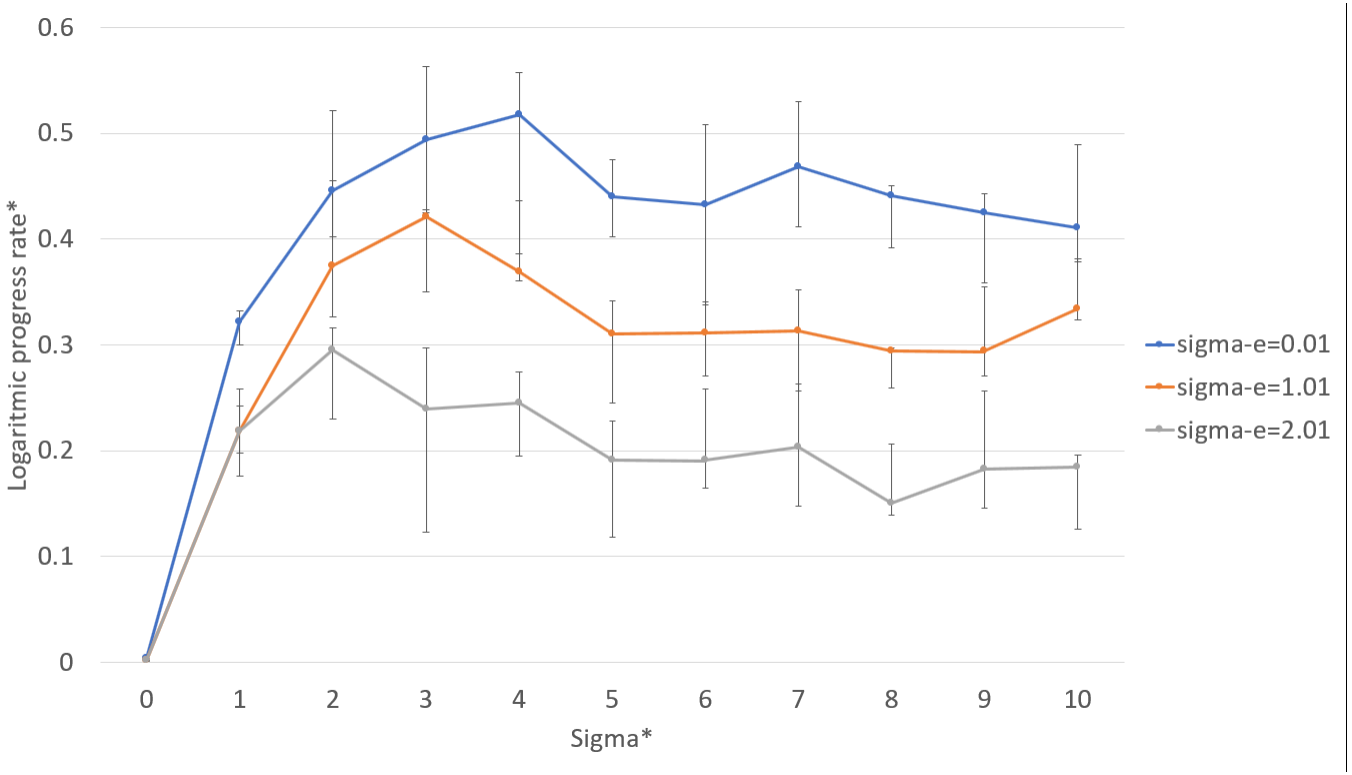

Figure 1: Normalized logarithmic progress rate as a function of normalized mutation strength.Algorithm 3 - Model assisted (1+1)ES without model generation limit, 4 Dimensions, $Y = (X - 1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (100 original fitness generations)

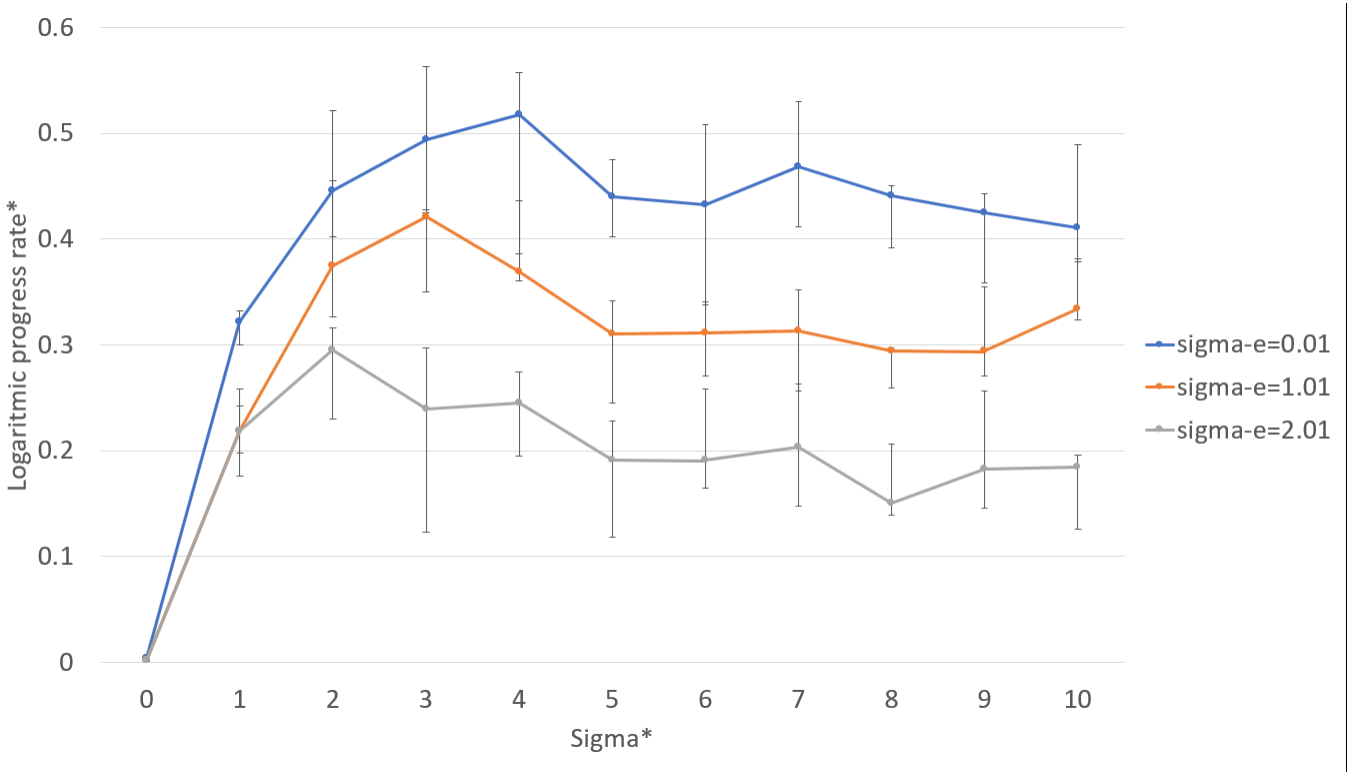

Figure 2: Normalized logarithmic progress rate as a function of normalized mutation strength.Algorithm 3 - Model assisted (1+1)ES without model generation limit, 40 Dimensions, $Y = (X - 1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (900 original fitness generations)

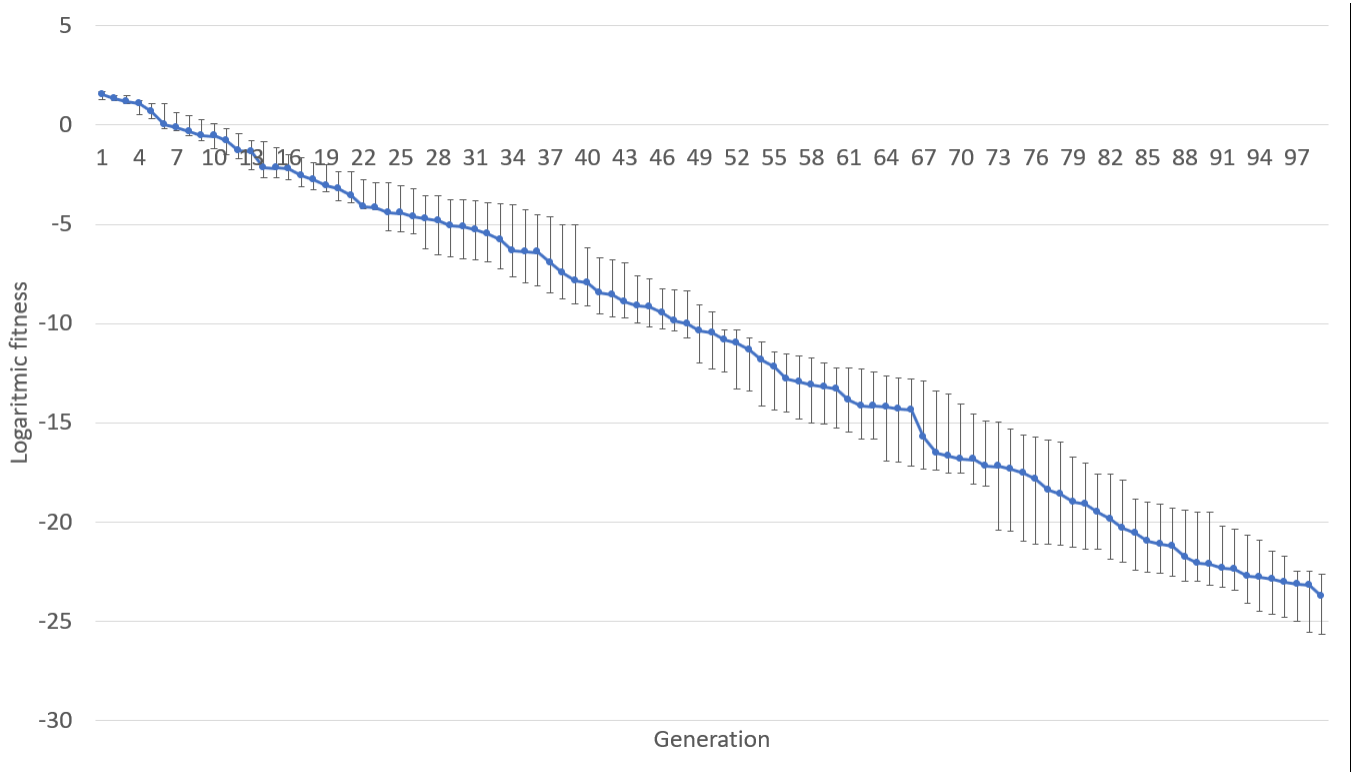

Figure 3: Normalized fitness as a function of normalized mutation strength. Algorithm 3- Model assisted (1+1)ES without model generation limit, 4 Dimensions, $Y = (X - 1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (100 original fitness generations)

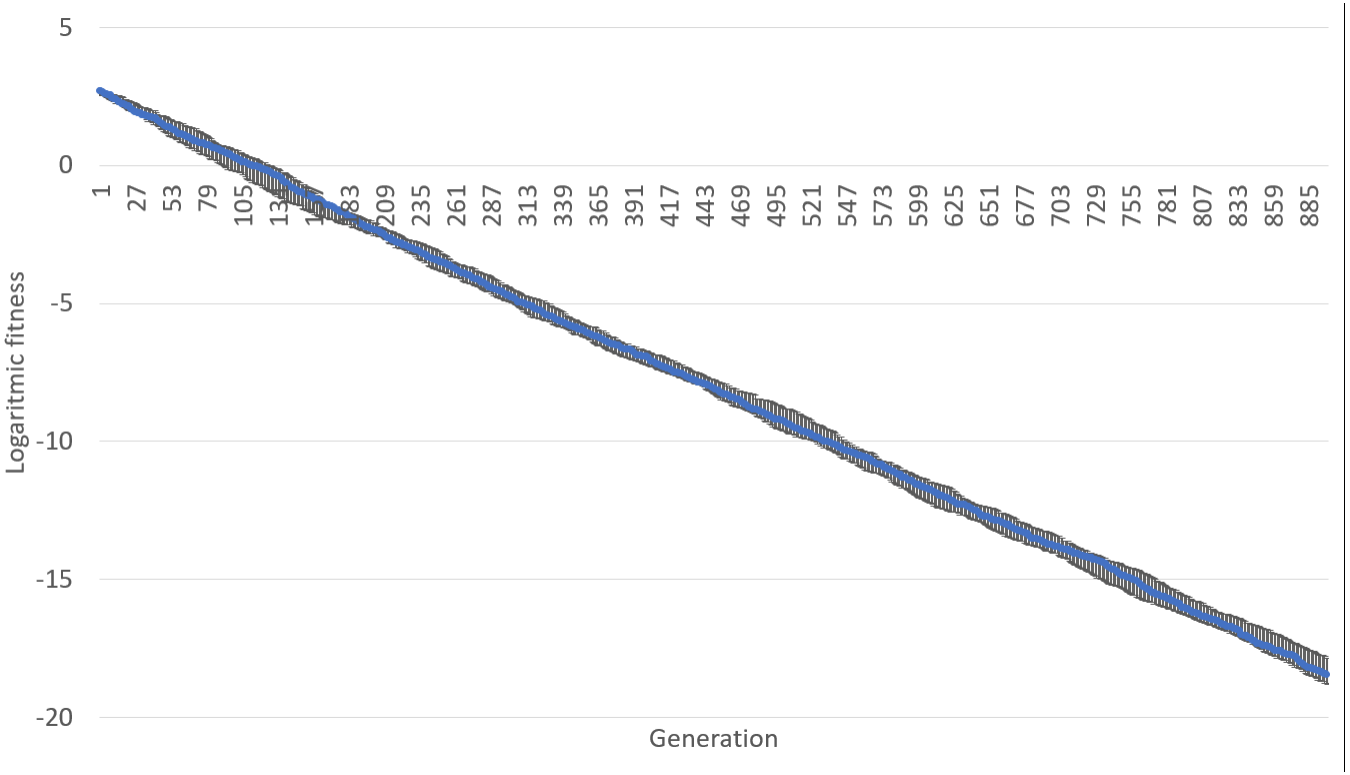

Figure 4: Normalized fitness as a function of normalized mutation strength. Algorithm 3- Model assisted (1+1)ES without model generation limit, 40 Dimensions, $Y = (X-1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (900 original fitness generations)

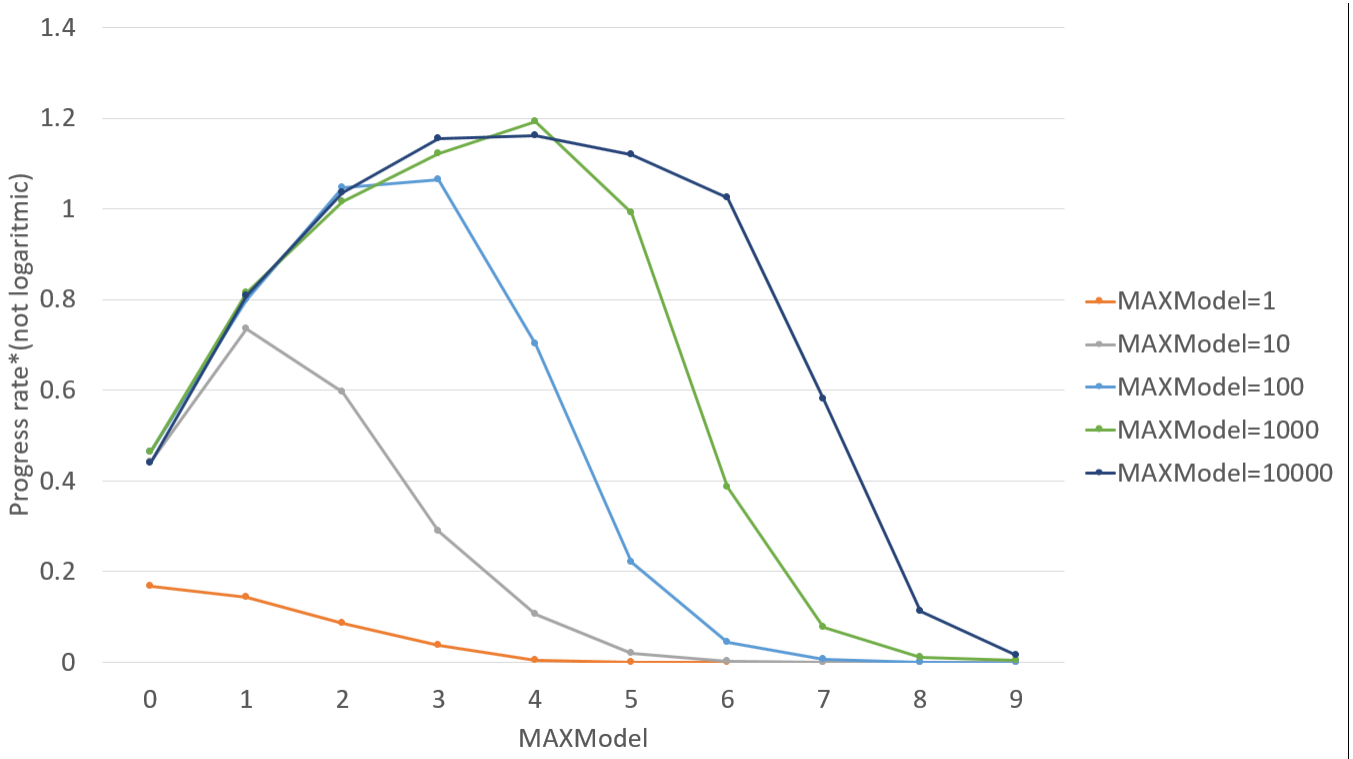

Figure 5: Normalized progress rate as a function of maximum number of model generations.Algorithm 2-Model assisted (1+1)ES, 40 Dimensions, $Y = (X-1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (900 original fitness generations)

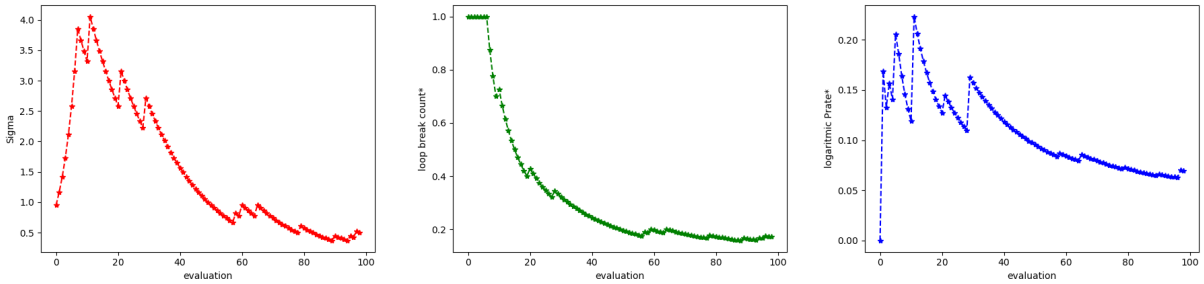

Figure 6: Sigma, logarithmic progress rate and number of generations that in less than 1000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 4 Dimensions, $Y = (X - 1)^2$. $(\sigma^*_{initialvalue} = 1)(\alpha = 0.2)$(100 original fitness generations)(1000 model-generation)

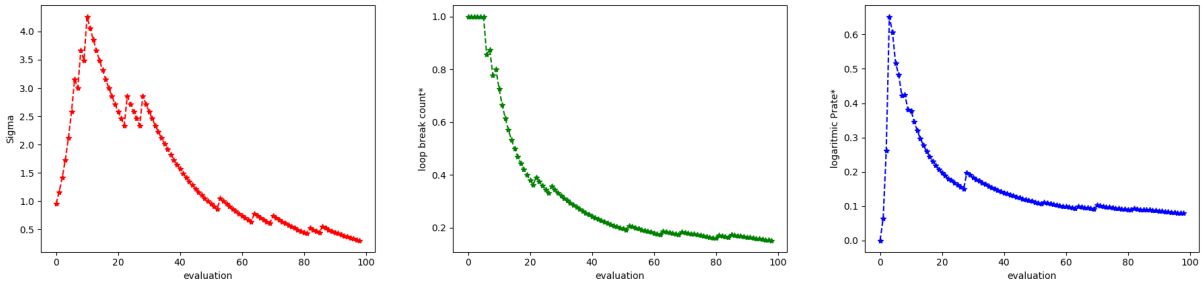

Figure 7: Sigma, logarithmic progress rate and number of generations that in less than 10000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 4 Dimensions, $Y = (X - 1)^2$. $(\sigma^*_{initialvalue} = 1)(\alpha = 0.2)$(100 original fitness generations)(10000 model-generation)

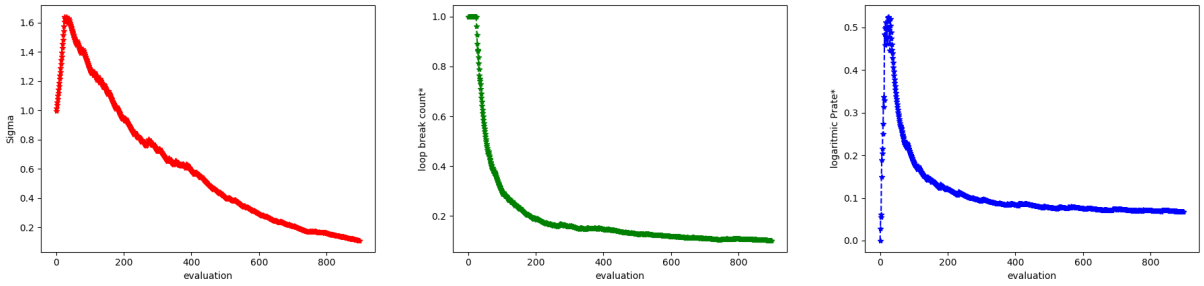

Figure 8: Sigma, logarithmic progress rate and number of generations that in less than 1000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 40 Dimensions, $Y = (X - 1)^2$. $(\sigma^*_{initialvalue} = 1)(\alpha = 0.2)$(100 original fitness generations)(1000 model-generation)

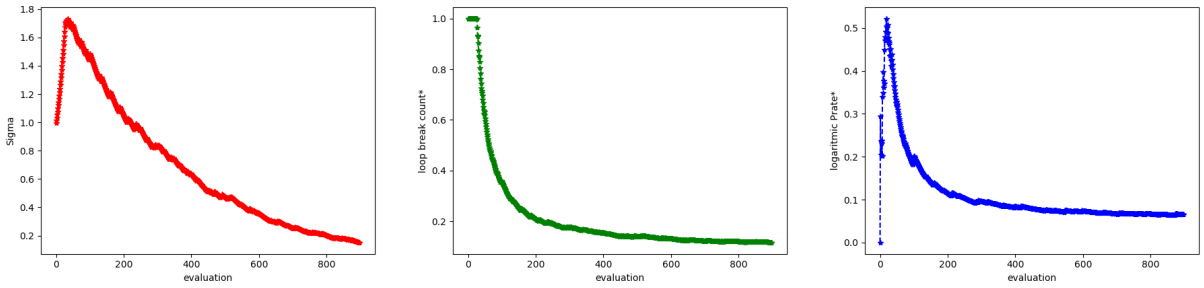

Figure 9: Sigma, logarithmic progress rate and number of generations that in less than 10000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 40 Dimensions, $Y = (X - 1)^2$. $(\sigma^*_{initialvalue} = 1)(\alpha = 0.2)$(100 original fitness generations)(10000 model-generation)