Model assisted (1+1)ES

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1 Algorithms

1.1 Algorithm 1

Normal (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
$Initialize(ind, \sigma^*, prate^* \leftarrow 0)$
for $i \leq MAXGen$ **do**
    $i++$
    $\sigma \leftarrow \frac{\sigma^* * ||ind - y||)}{N}$
    $ind2 \leftarrow ind + \sigma * N(0, I)$
    $newfit \leftarrow FIT(ind2)$
    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
$prate^* \leftarrow prate^*/i$

1.2 Algorithm 2

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
$initialize(ind, \sigma^*, \sigma_e^*, prate^* \leftarrow 0)$
for $i \leq MAXGen$ **do**
    $i++$
    $ind2 \leftarrow ind$
    while $j \leq MAXModel$ **do**
        $j++$
        $\sigma \leftarrow \frac{\sigma^* * Dist(ind)}{N}$
        $ind3 \leftarrow ind2 + \sigma * N(0, I)$
        $\sigma_e \leftarrow \frac{2 * \sigma_e^* * Dist(ind)^2}{N}$
        $fit3 \leftarrow FIT(ind2) + \sigma_e * N(0, 1)$
        if $fit3 \leq bestfit$ **then**
            $ind2 \leftarrow ind3$
            $Break$
        end if
    end while
    $newfit = FIT(ind2)$
    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
$prate^* \leftarrow prate^*/i$

1.3 Algorithm 3

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

```
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*, σ*_e, prate* ← 0)
for i ≤ MAXGen do
    i++
    ind2 ← ind
    while true do
        j++
        σ ← σ* ∗ Dist(ind) / N
        ind3 ← ind2 + σ ∗ N(0, I)
        σ_e ← 2∗σ*_e∗Dist(ind)^2 / N
        fit3 ← FIT(ind2) + σ_e ∗ N(0, 1)
        if fit3 ≤ bestfit then
            ind2 ← ind3
            Break
        end if
    end while
    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
```

1.4 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

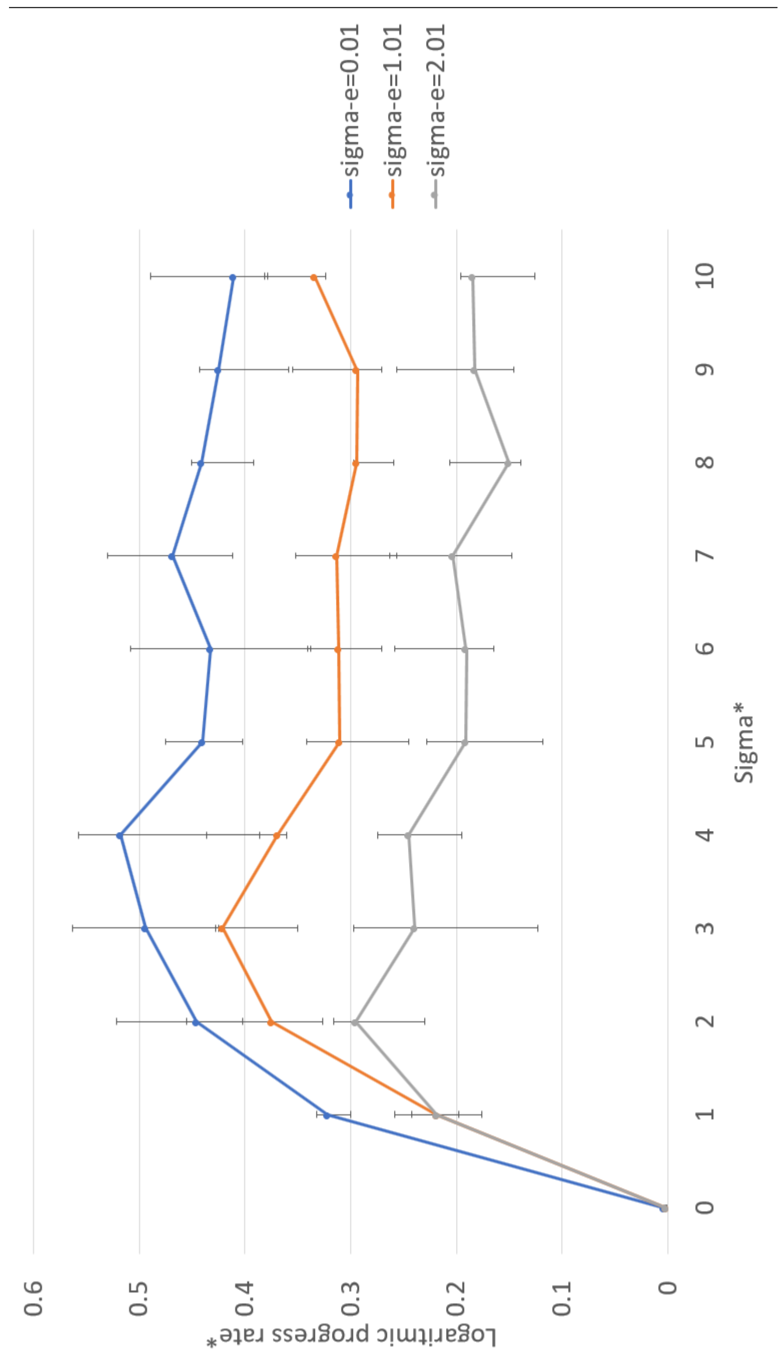

Figure 1: Normalized logarithmic progress rate as a function of normalized mutation strength.Algorithm 3 - Model assisted (1+1)ES without model generation limit, 4 Dimensions, $Y = (X - 1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails)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

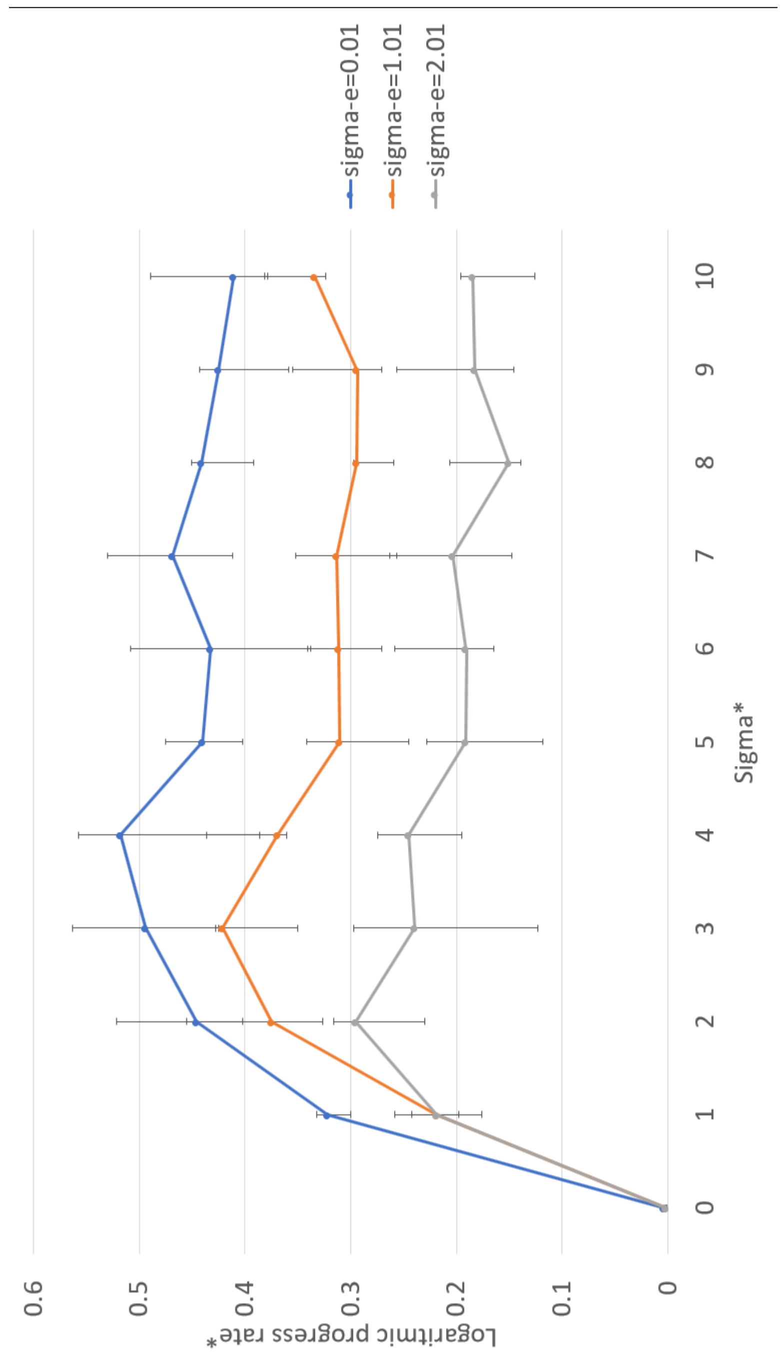

Figure 2: Normalized logarithmic progress rate as a function of normalized mutation strength.Algorithm 3 - Model assisted (1+1)ES without model generation limit, 40 Dimensions, $Y = (X-1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails)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

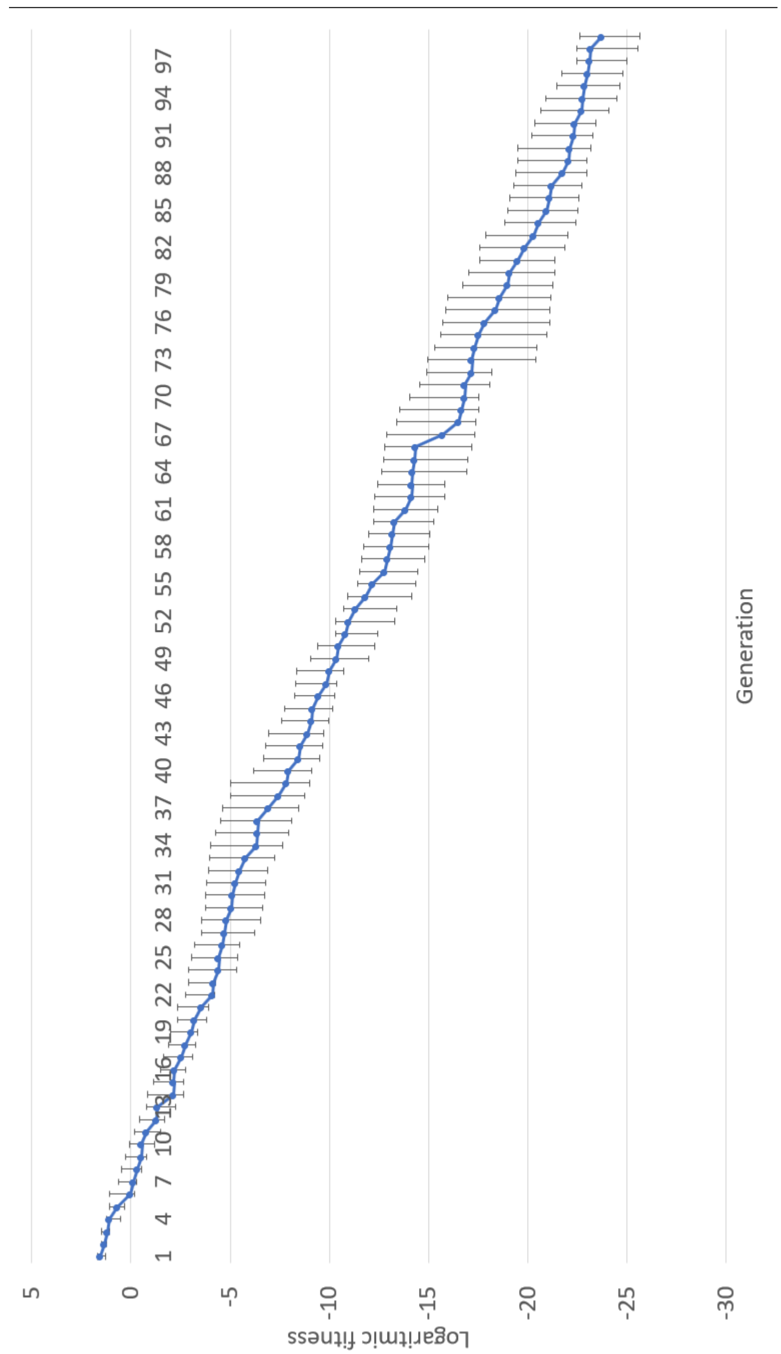

Figure 3: Normalized fitness as a function of normalized mutation strength. Algorithm 3- Model assisted (1+1)ES without model generation limit, 4 Dimensions, $Y = (X-1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (100 original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

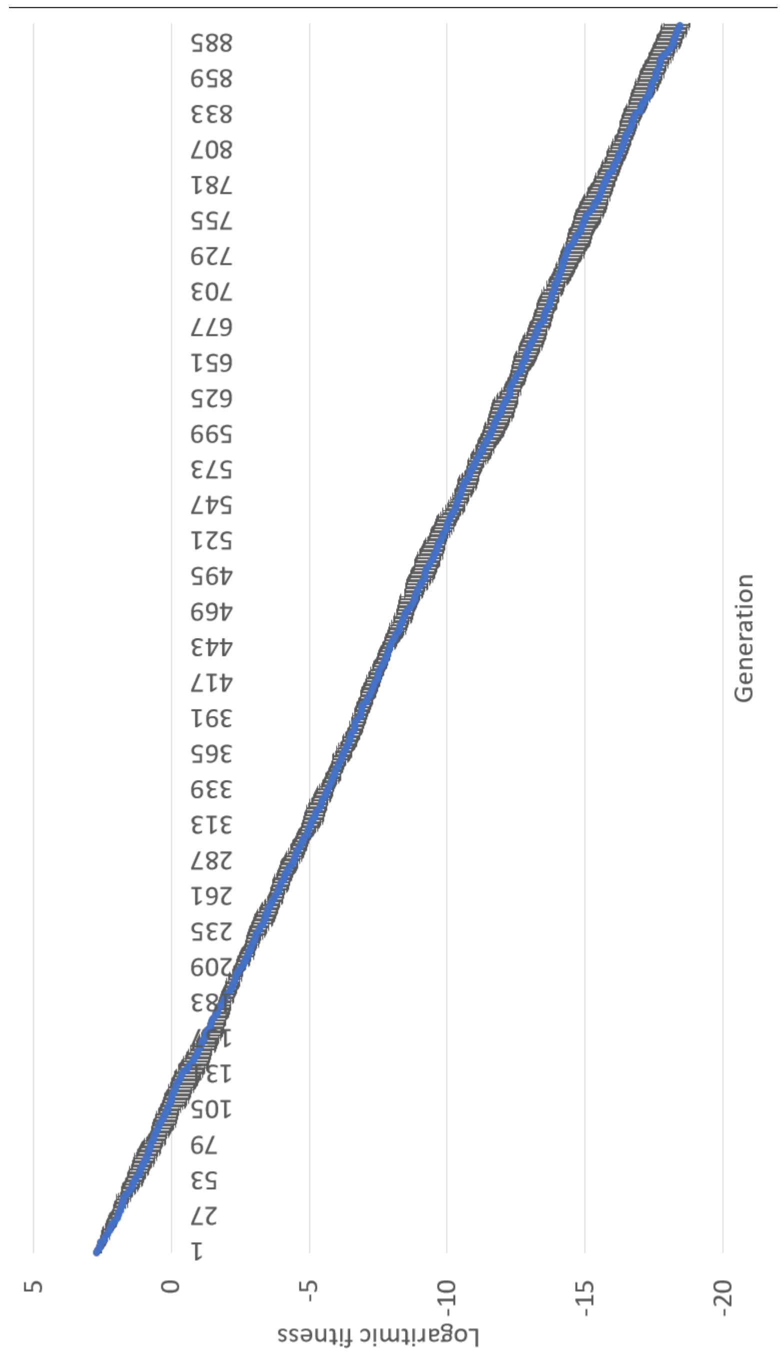

Figure 4: Normalized fitness as a function of normalized mutation strength. Algorithm 3- Model assisted (1+1)ES without model generation limit, 40 Dimensions, $Y = (X-1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (900 original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

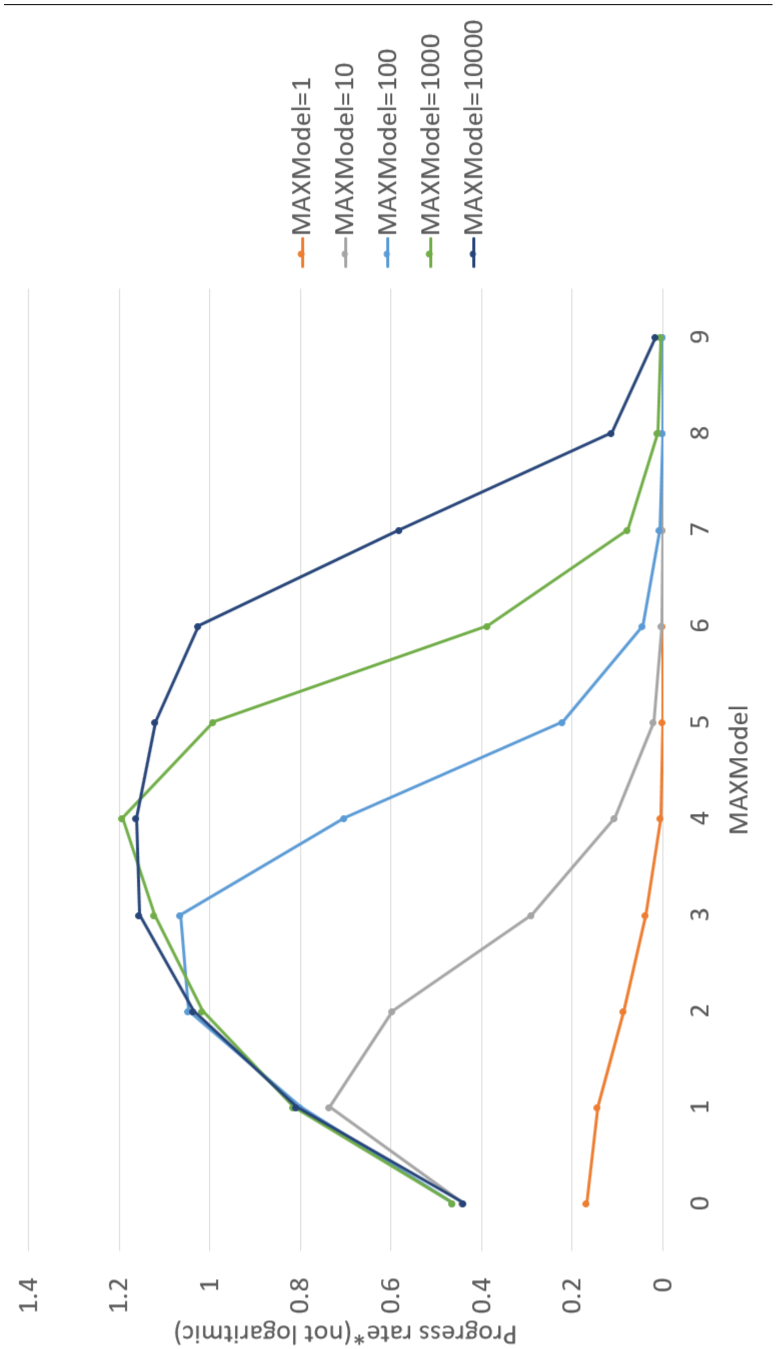

Figure 5: Normalized progress rate as a function of maximum number of model generations.Algorithm 2-Model assisted (1+1)ES, 40 Dimensions, $Y = (X - 1)^2$.Each point represents the median result of 5 trails, error bars show the range of results for each point.(5 trails) (900 original fitness generations)

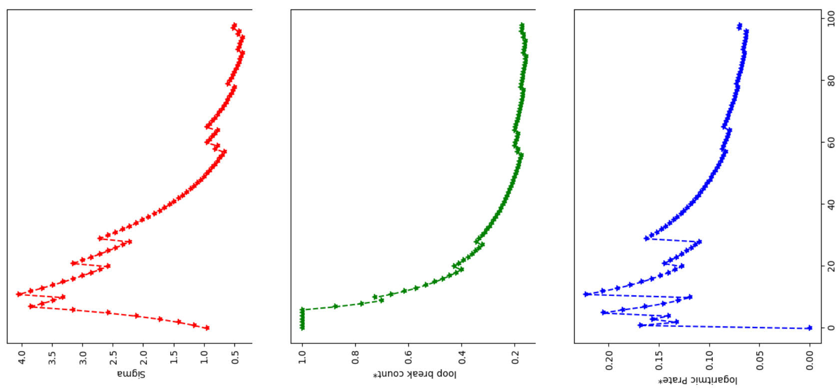

Figure 6: Sigma, logarithmic progress rate and number of generations that in less than 1000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 4 Dimensions, $Y = (X-1)^2$. $(\sigma^*_{initialvalue}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

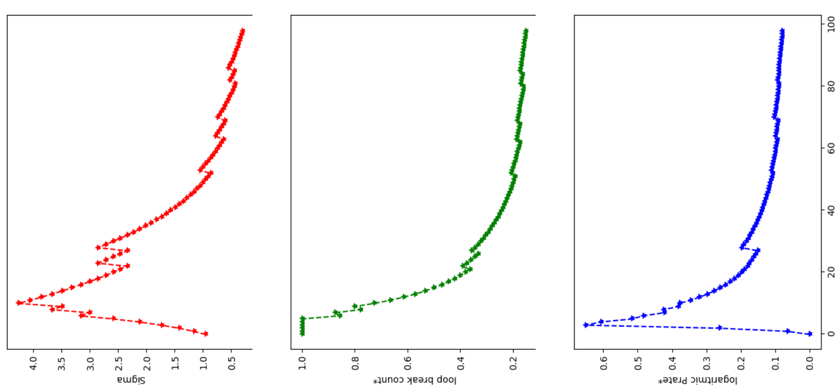

Figure 7: Sigma, logarithmic progress rate and number of generations that in less than 10000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 4 Dimensions, $Y = (X-1)^2$. $(\sigma^*_{initialvalue}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

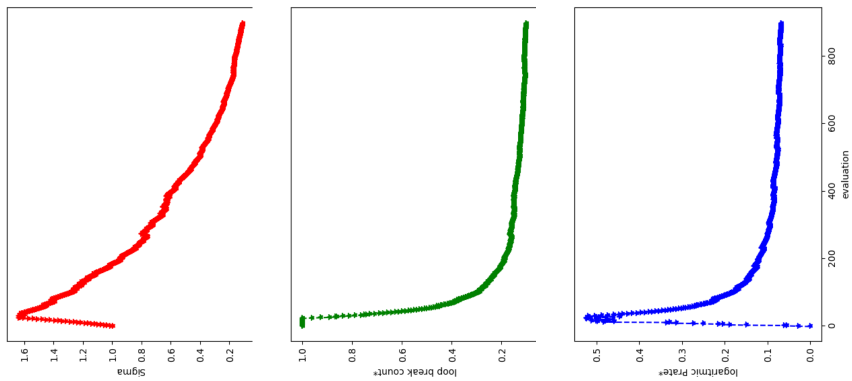

Figure 8: Sigma, logarithmic progress rate and number of generations that in less than 1000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 40 Dimensions, $Y = (X-1)^2$. $(\sigma^*_{initialvalue}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

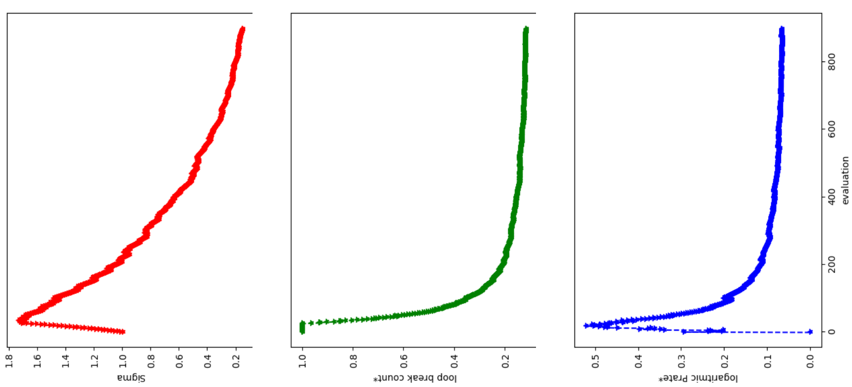

Figure 9: Sigma, logarithmic progress rate and number of generations that in less than 10000 model generations the algorithm finds a better model and exits the modeling loop in proportion to the number of original fitness generations. Model assisted (1+1)ES, 40 Dimensions, $Y = (X-1)^2$. $(\sigma^*_{initialvalue}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