

# Model assisted (1+1)ES

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## 1 Algorithms

### 1.1 Algorithm 1

Normal (1+1) ES

```
1:  $N \leftarrow 400$ 
2: function FIT( $x$ )
3:    $y \leftarrow \sum_{i < N} (x_i - 1)^2$ 
4:   return( $y$ )
5: end function
6: function DIST( $x$ )
7:    $y \leftarrow \sqrt{\sum_{i < N} (x_i - 1)^2}$ 
8:   return( $y$ )
9: end function
10: Initialize( $ind, \sigma^*, prate^* \leftarrow 0$ )
11: for  $i \leq MAXGen$  do
12:    $i++$ 
13:    $\sigma \leftarrow \frac{\sigma^* * ||ind - y||}{N}$ 
14:    $ind2 \leftarrow ind + \sigma * N(0, I)$ 
15:    $newfit \leftarrow FIT(ind2)$ 
16:   if  $newfit \leq bestfit$  then
17:      $prate^* \leftarrow prate^* + \frac{(DIST(ind) - DIST(ind2)) * N}{DIST(ind)}$ 
18:      $ind \leftarrow ind2$ 
19:      $bestfit \leftarrow newfit$ 
20:   end if
21: end for
22:  $prate^* \leftarrow prate^* / i$ 
```

## 1.2 Algorithm 2

Model Assisted (1+1)ES

```

1:  $N \leftarrow 400$ 
2: function FIT( $x$ )
3:    $y \leftarrow \sum_{i < N} (x_i - 1)^2$ 
4:   return( $y$ )
5: end function
6: function DIST( $x$ )
7:    $y \leftarrow \sqrt{\sum_{i < N} (x_i - 1)^2}$ 
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:   for  $j \leq MAXModel$  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 for
25:    $newfit = FIT(ind2)$ 
26:   if  $newfit \leq bestfit$  then
27:      $prate^* \leftarrow prate^* + \frac{(DIST(ind) - DIST(ind2)) * N}{DIST(ind)}$ 
28:      $ind \leftarrow ind2$ 
29:      $bestfit \leftarrow newfit$ 
30:   end if
31: end for
32:  $prate^* \leftarrow prate^* / i$ 

```

### 1.3 Algorithm 3

Step-size Adaptive 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:    $flag \leftarrow 0$ 
15:   for  $j \leq MAXModel$  do
16:      $j++$ 
17:      $\sigma \leftarrow \frac{\sigma^* * Dist(ind)}{N}$ 
18:      $ind3 \leftarrow ind2 + \sigma * N(0, I)$ 
19:      $\sigma_e \leftarrow \frac{2 * \sigma_e^* * Dist(ind)^2}{N}$ 
20:      $fit3 \leftarrow FIT(ind2) + \sigma_e * N(0, 1)$ 
21:     if  $fit3 \leq bestfit$  then
22:        $flag \leftarrow 1$ 
23:        $ind2 \leftarrow ind3$ 
24:       Break
25:     end if
26:   end for
27:    $newfit = FIT(ind2)$ 
28:    $\sigma^* \leftarrow \sigma^* * \exp^{\frac{1}{N}}(flag - 0.05)$ 
29:   if  $newfit \leq bestfit$  then
30:      $prate^* \leftarrow prate^* + \frac{(DIST(ind) - DIST(ind2)) * N}{DIST(ind)}$ 
31:      $ind \leftarrow ind2$ 
32:      $bestfit \leftarrow newfit$ 
33:   end if
34: end for
35:  $prate^* \leftarrow prate^* / i$ 

```

## 2 Results

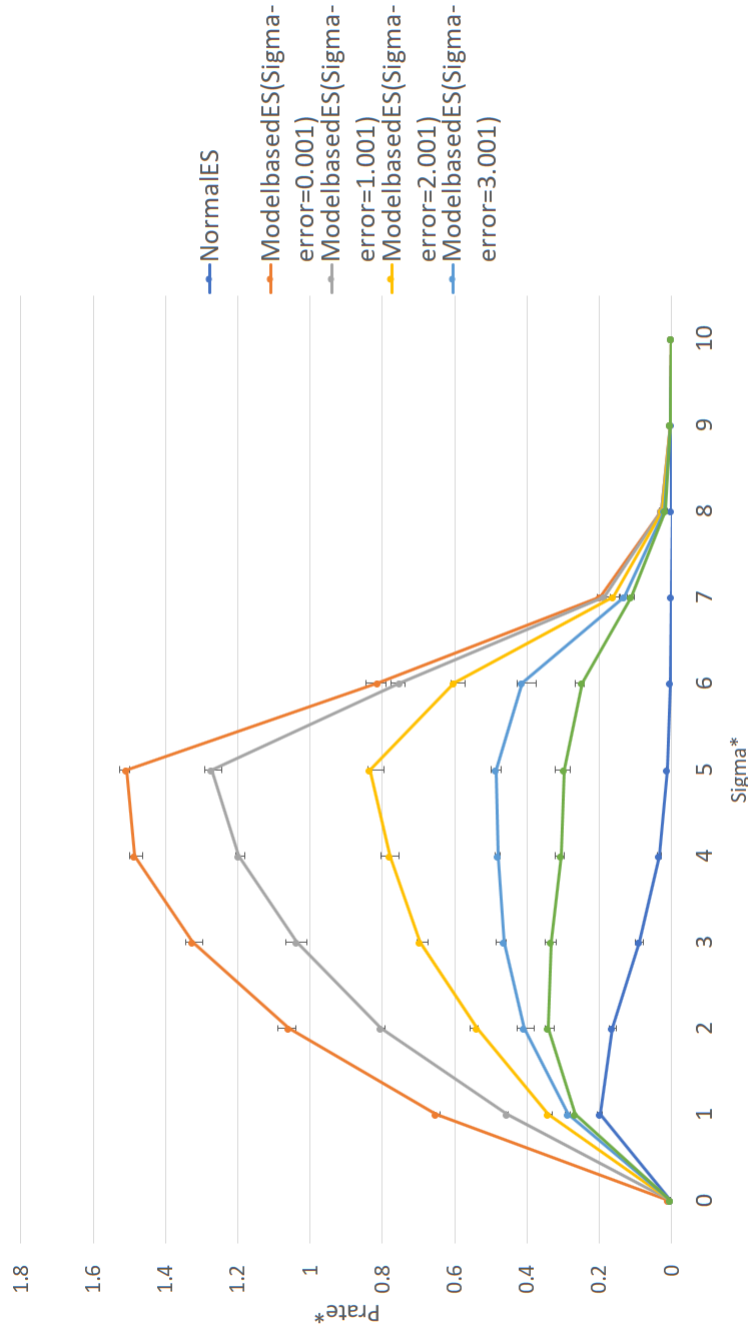


Figure 1: Normalized progress rate as a function of normalized mutation strength. Simple (1+1) ES fitness compared to Model assisted (1+1) ES, 400 Dimensions,  $Y = (X - 1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (5000 original fitness generations) (500 model-generation) 4

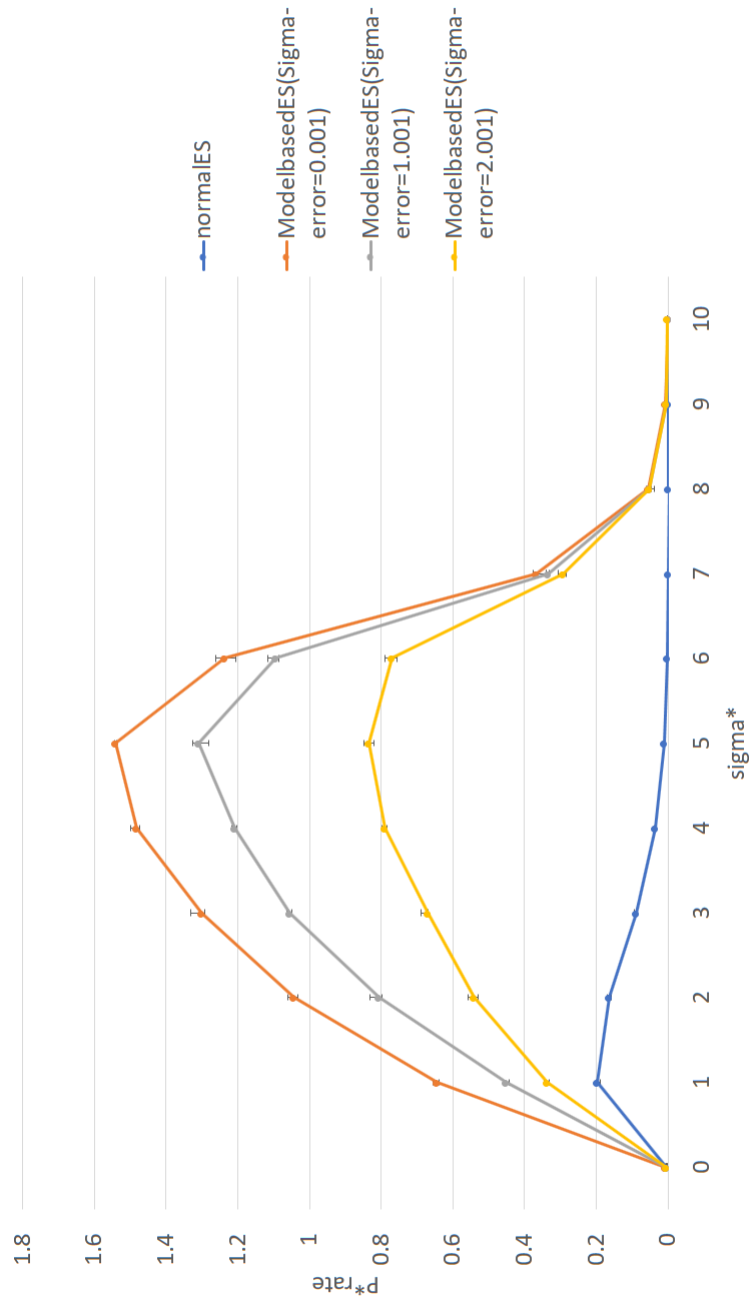


Figure 2: Normalized progress rate as a function of normalized mutation strength. Simple (1+1) ES fitness compared to Model assisted (1+1)ES, 400 Dimensions,  $Y = (X - 1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (10000 original fitness generations) (1000 model-generation)

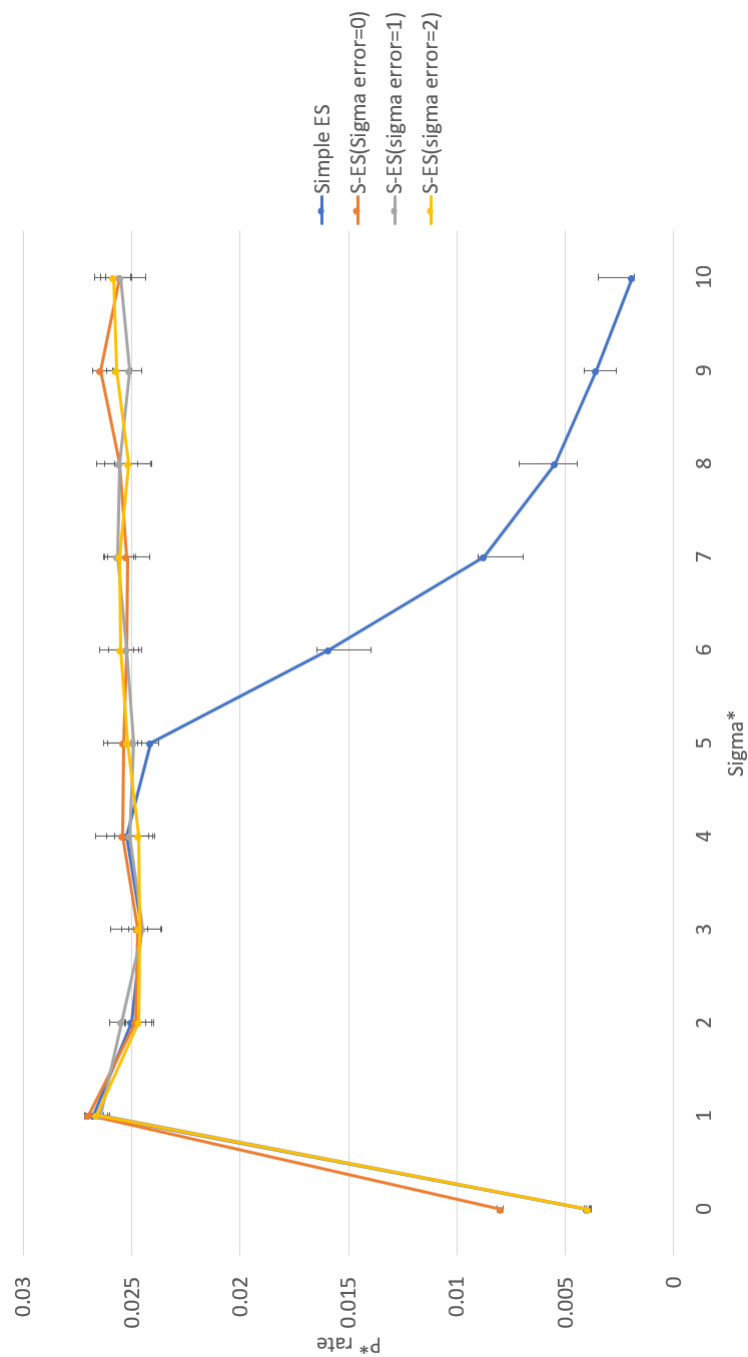


Figure 3: Normalized progress rate as a function of normalized mutation strength. Simple (1+1) ES fitness compared to Model assisted (1+1)ES, 4 Dimensions,  $Y = (X - 1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (5000 original fitness generations) (1000000 model-generation)

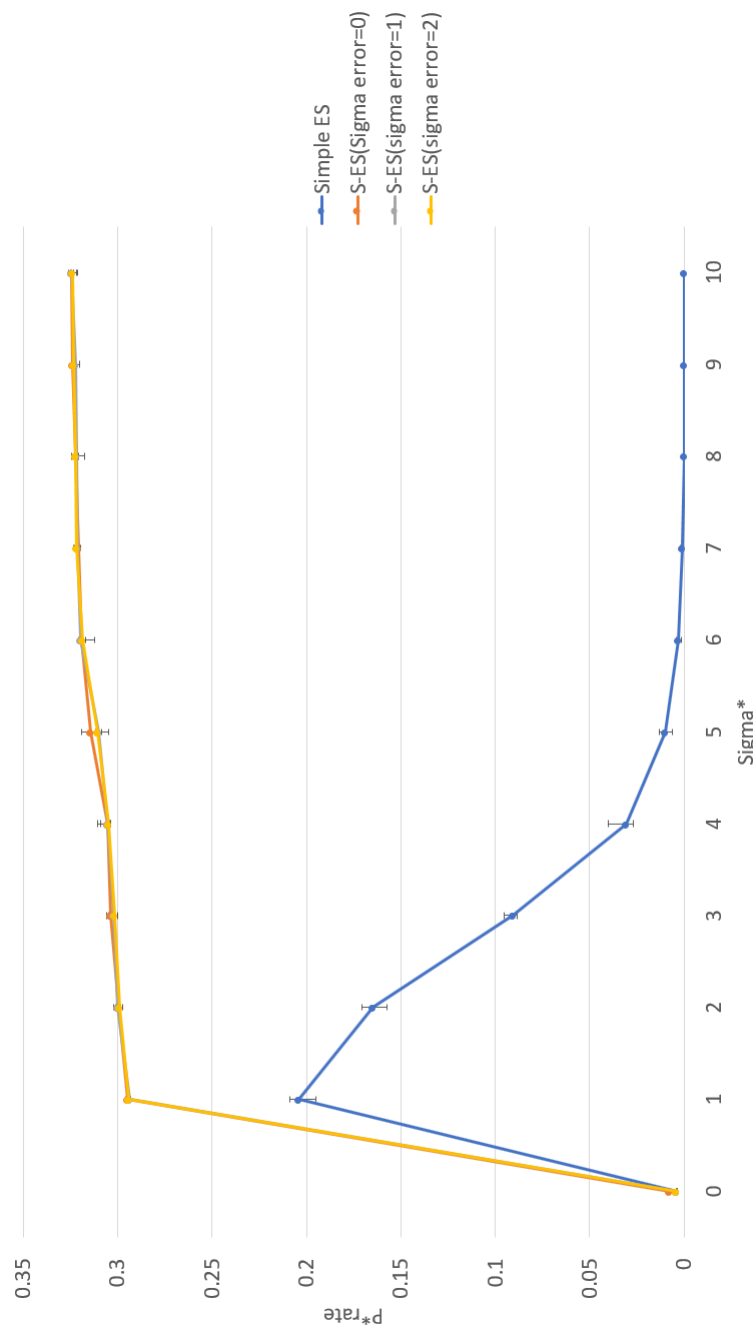


Figure 4: Normalized progress rate as a function of normalized mutation strength. Simple (1+1) ES fitness compared to Model assisted (1+1)ES, 40 Dimensions,  $Y = (X - 1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (5000 original fitness generations) (1000000 model-generation)

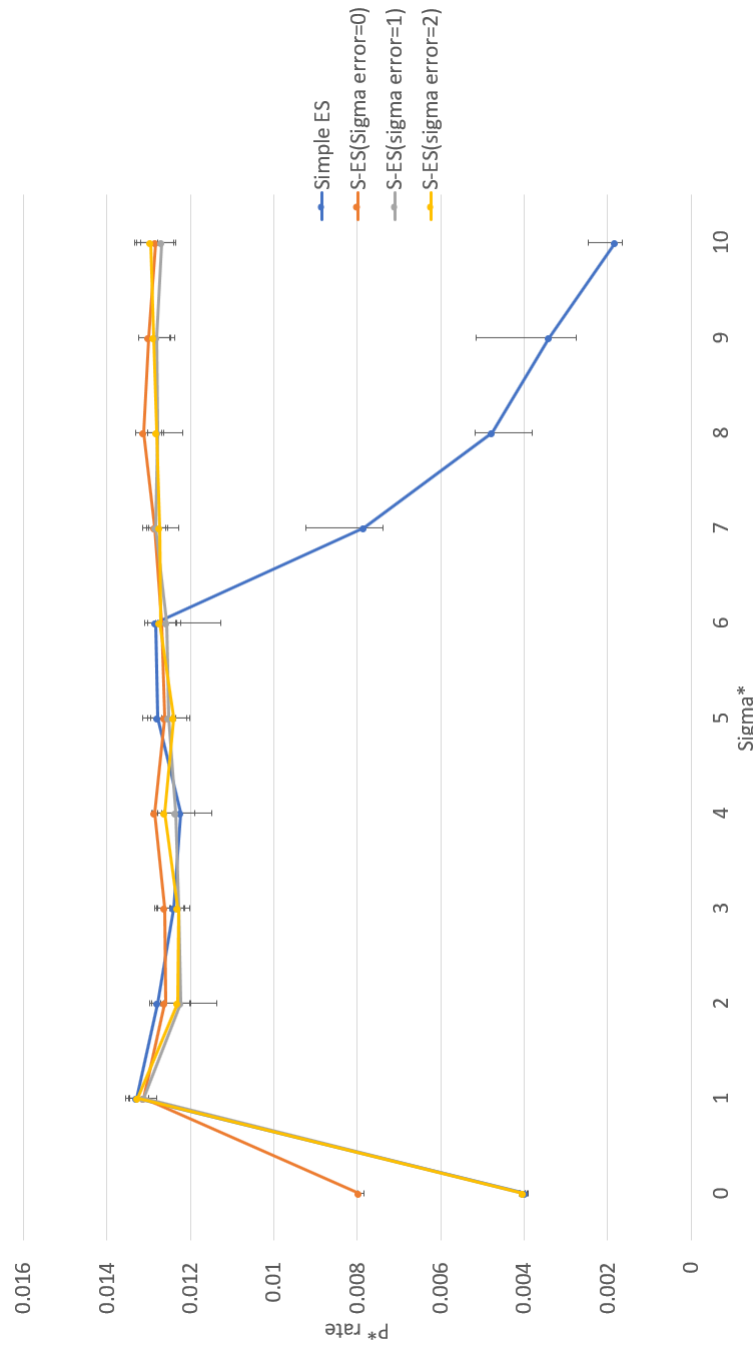


Figure 5: Normalized progress rate as a function of normalized mutation strength. Simple (1+1) ES fitness compared to Model assisted (1+1)ES, 4 Dimensions,  $Y = (X-1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (10000 original fitness generations)(1000 model-generation) 8



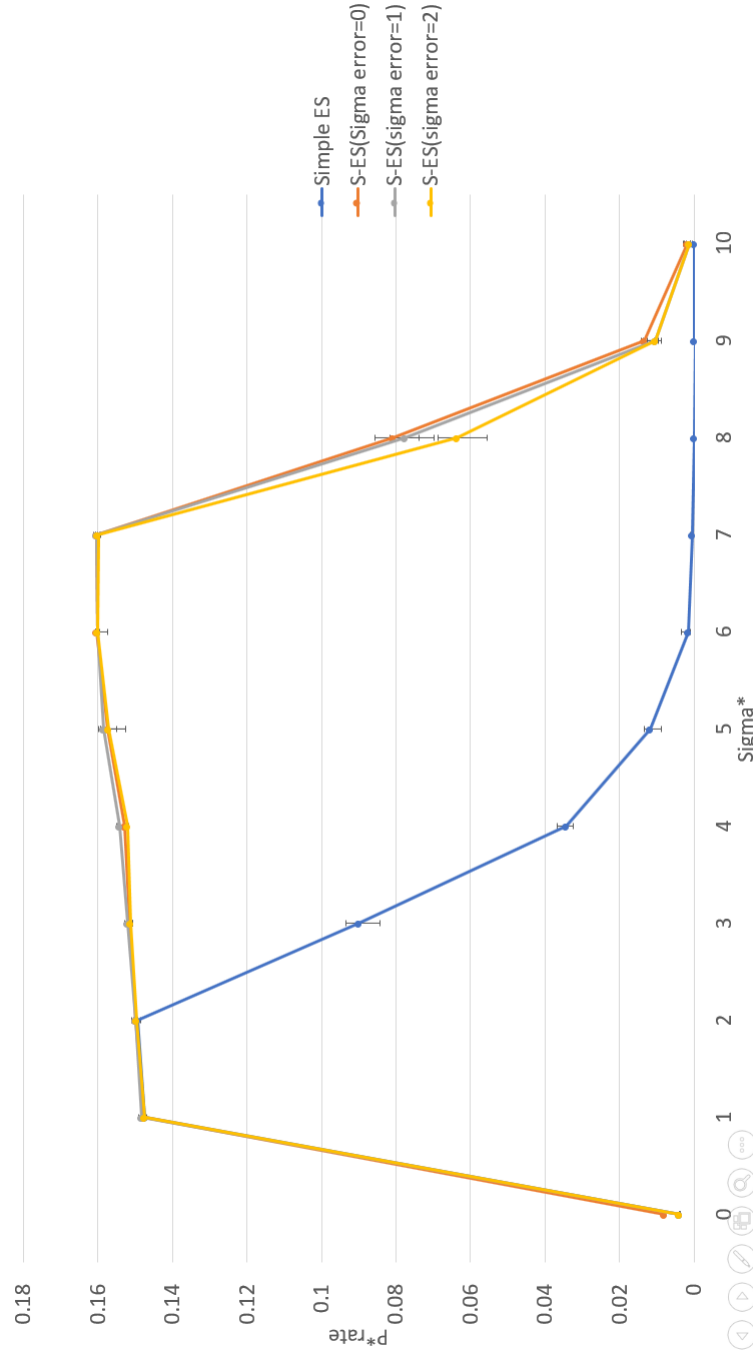


Figure 6: Normalized progress rate as a function of normalized mutation strength. Simple (1+1) ES fitness compared to Model assisted (1+1)ES, 40 Dimensions,  $Y = (X-1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (10000 original fitness generations) (1000 model-generation) 9

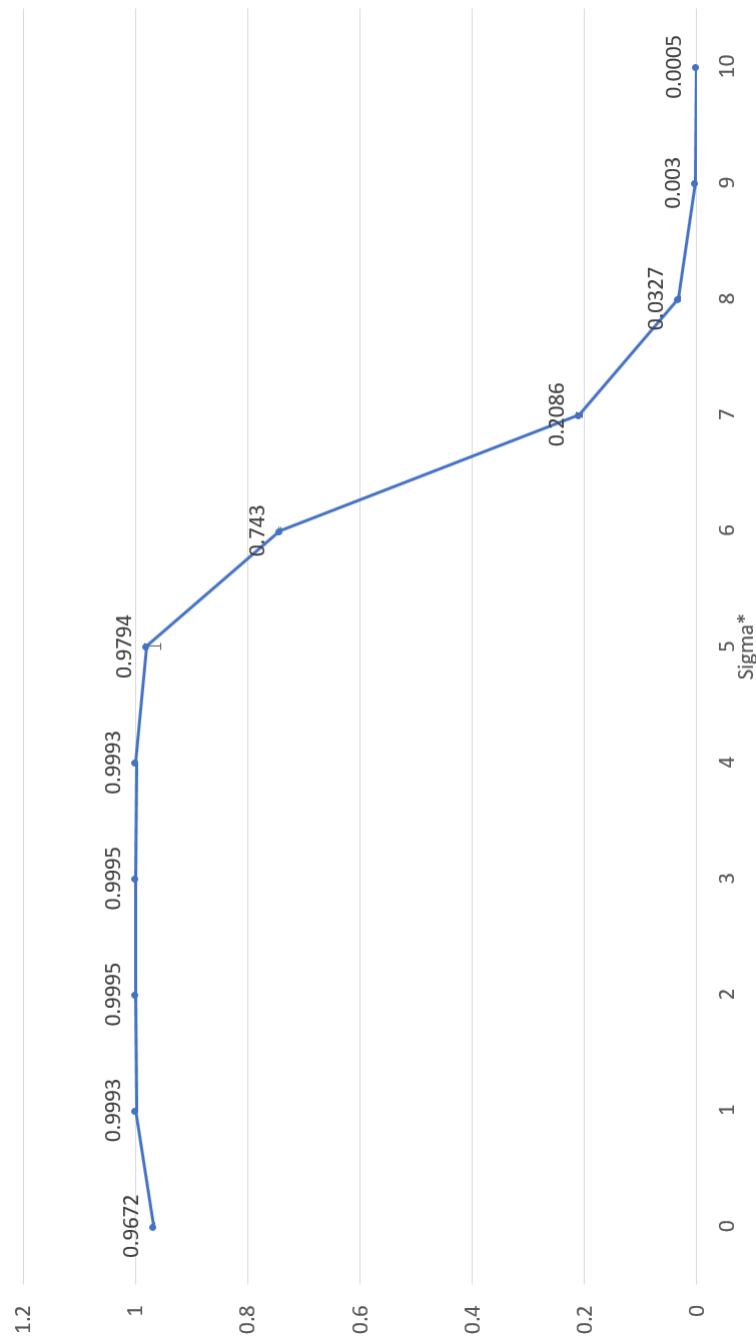


Figure 7: Number of generations that in less than 1000 model generations the algorithm finds a better model and exists the modeling loop in proportion to the 10000 original fitness generations. Model assisted (1+1)ES, 400 Dimensions,  $Y = (X - 1)^2$ . Each point represents the median result of 5 trails, error bars show the range of results for each point. (5 trails) (10000 original fitness generations) (1000 model-generation)