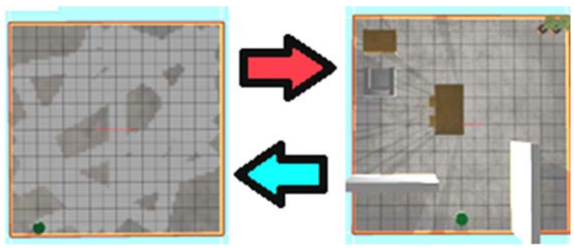

Fig. 2. Experimental setup consisting in two sample scenes: without- (left) and with obstacles (right), respectively. The robot evolves the ability to clean these two rooms consecutively, at two consecutive stages of an incremental evolution.

## 4. Experiments

To verify the feasibility of incorporating histones, we performed two experiments. These two experiments were intended to allow us to compare the efficiency of evolution via LEP and canonical GP, respectively.

### 4.1. *Exploring evolution characteristic of LEP*

In this experiment, we explore how histones influence the efficiency of evolution. The controller of the robot is evolved in the first stage (i.e., room without obstacles) of LEP under the same conditions as GP. We believed that introducing histone would facilitate a faster evolution in that it would require lower computational effort (i.e., would feature a reduced number of evolved generations).

### 4.2. *Two-staged incremental evolution*

During the first stage of the incremental evolution, the robot evolves via GP its ability to efficiently clean the room without obstacles. Then, the best controllers are used to seed the second stage of the evolution which involves an evolution (via GP) of the ability to clean the room with obstacles. The same two-staged incremental evolution is used applying LEP with histone-modification at both stages.

After that, the best controllers of second stage are evaluated again in the room without obstacles (i.e., the same environment that is used during the first stage) to investigate their abilities to adapt to the "new" environment. Because of changing environment, the controllers would need to evolve new features in order to perform well in it. We believe that individual used applying LEP can adapt to the new environment by just switching some of their genes *on* and *off* instead of evolving new genotype from scratch.

## 5. Experimental Results

### 5.1. *Result of one-staged evolution*

The results of applying LEP or GP on individuals evolved are shown in Figure 3.

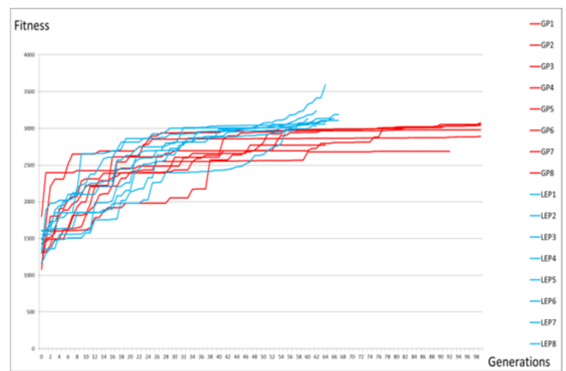


Fig. 3. Fitness convergence of LEP (blue) and GP (red), respectively. The maximum number of generations is 100. The number of evaluations per one generation of individuals applying LEP is two times as many as GP.

As Figure 3 indicates, the controllers, evolved via LEP have better fitness and evolve faster (with lower number of generations) than canonical GP. On the other hand, the average complexity of genotype (in number of nodes in their DOM-trees) is higher in LEP, which, in turn result in an increased computational overhead because of slower evaluation of these genotypes. This finding implies that the improvement of computational effort due to the incorporation of histones in LEP comes at the cost of some degradation of computational performance. This degradation, however, is rather negligible, because, in the considered application of LEP, the runtime, needed to simulate the physics of the Khepera robot is much longer than the time spent for evaluating the DOM-tree of the genotype.

### 5.2. *Result of two-staged incremental evolution*

In second stage, even if there is no difference in the efficiency of the first stage, performance of controllers applying LEP was better than GP. LEP's individual tended to live but GP's individual easy to be weeded out difficult stage. However, some individuals tended to not adapt in first stage when the best individuals in the second stage are returned.

## 6. Discussion

The experimental results suggest that introducing histones as genetic switches facilitates a faster evolution of a simulated Khepera robot. The simulated evolution is relatively fast anyway, and, features about the same runtime overhead as the adaptation via changing of histones. In the real biological world however, the evolution of one generation requires years of time, while the effect of modifications to histones could be observed much sooner. Therefore, we believe that histones incorporated in the genotypes are capable of facilitating the biological evolution.

In addition, in latter experiment, we discovered that some of the controllers could not adapt well to the old "new" environment (room without obstacles), because the parts of their respective genotypes that are responsible for dealing with that environment, was lost during the second stage of evolution (in a room with obstacles). Therefore, it could be interesting to investigate such a genetic mechanism during the second stage of LEP that could protect the useful features (e.g., ability to move and clean a room without obstacles) evolved at the first stage of evolution, from the destructive effect of crossover and mutation operations. One possibility is to allow the inactivated histones to repel the crossover and mutation operations, in order to preserve the inactivated code from destruction. This code could be deactivated later, when an old "new" environment arises.

## 7. Conclusion

We proposed an approach of LEP and verified the feasibility of incorporating histones. In order to implement histone, we introduced genetic "switches" that modify the gene expression by activating and deactivating the nodes in the tree representations (i.e., the "genotype") of the evolved individuals in GP. In our approach we propose LEP in that the modified genetic switches are inherited back in the evolving genotypes.

Also, we verified the effect of epigenesis on the efficiency of evolution of controllers of simulated Khepera cleaning robot in two experiments. From the results of the former experiment we concluded that applying LEP facilitates an earlier adaptation compared to canonical GP. The results of the latter experiment - with two-staged incremental evolution – indicate that using LEP contributes to the efficiency of evolution to old "new" environment. We think these results suggest that histones could be seen as a mechanism to "store" dormant abilities once needed to deal with challenging environments. These abilities could be activated again when the organisms face "new" environments that have been already explored in their evolutionary past.

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