SIG Proceedings Paper in LaTeX Format*

Extended Abstract†

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ABSTRACT

Operational maturity of biological control systems have fuelled the inspiration for a large number of mathematical and logical models for control, automation and optimisation. The human brain represents the most sophisticated control architecture known to us and is a central motivation for several research attempts across various domains. In the present work, we introduce an algorithm for mathematical optimisation that derives its intuition from the hierarchical and distributed operations of the human motor system. The system comprises global leaders, local leaders and an effector population that adapt dynamically to attain global optimisation via a feedback mechanism coupled with the structural hierarchy. The hierarchical system operation is distributed into local control for movement and global controllers that facilitate gross motion and decision making. We present our algorithm as a variant of the classical Differential Evolution algorithm, introducing a hierarchical crossover operation. The discussed approach is tested exhaustively on standard test functions as well as the CEC 2017 benchmark. Our algorithm significantly outperforms various standard algorithms as well as their popular variants as discussed in the results.

CCS CONCEPTS

•**Computer systems organization** → **Embedded systems;** *Redundancy;* Robotics; •**Networks** → Network reliability;

KEYWORDS

ACM proceedings, LaTeX, text tagging

*Produces the permission block, and copyright information
†The full version of the author's guide is available as acmart.pdf document
‡Dr. Trovato insisted his name be first.
§The secretary disavows any knowledge of this author's actions.
¶This author is the one who did all the really hard work.

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1 INTRODUCTION

Operational maturity of biological control systems have enamored researchers across various domains.Consequently, these have been the source of inspiration of various mathematical and logical models for control, automation and optimization. The behavioural characteristics observed at the Cellular level in E.Coli fueled the inspiration for the Bacterial Foraging Optimization algorithm.

The biological system most relevant to us is the human brain. It represents the most advanced control architecture and several research initiative seek to mimic its level of accuracy and precision in day-to-day activities. The brain activities can be distributed into two categories: sensory and motor operations. Sensory cortical functions have to an extent inspired the concept of neural networks that have been successfully scaled to a large number of domains.

While not always the case, it is at times useful and accurate to view a biological neural network as being arranged in a hierarchical fashion. As a naive example, consider a day-to-day activity of grasping a cup of coffee. One part of the brain that is clearly hierarchical is the human motor system. The hierarchical and distributed control of the human motor system can be classified as having local control functions for movement and higher level controllers that facilitate gross motion and decision making.

The optimal execution of any human motor operation, such as grasping a cup of coffee, involves distributed brain structures at different levels of hierarchy. It broadly includes the prefrontal cortex, motor cortex, spinal cord, anterior horn cells etc. In generating actions sequences, a sequence of actions is implemented by string of subsequences of actions, each possibly implemented in different parts of the body.

The hierarchy of the operations can be classified as:

1. Motivation and planning of the movement or task.
2. Generation of instructions for movement.

3. Refinement of instruction based on feedback from components.
4. Maintenance of posture and smooth execution of task.

Whenever a person plans to perform an action, electrical signal generated from the pyramidal neurons in the prefrontal cortex(global leaders, center for the decision making) are transmitted a supraspinal tract on the anterior horn cells(communicating to local leaders). Initially, these global leaders send inhibitory influence to the population over the local leaders. Efficient and optimal execution of tasks involves feedback based facilitation and inhibition of the effectors. These result in contraction and relaxation of the agonist and antagonist muscle fibers through the local leaders. The sequence of updation of the represents the optimal convergence of the system, leading to smooth motor operations.

2 DISTRIBUTED LEADER OPTIMIZATION

Taking inspiration from the human motor system, we model the hierarchical motor operations in our optimization agents, where we define a global leader which influences the action of several distributed local leaders and the particle agents which act as the effectors. The global leader is analogous to the decision making and planning section in the motor system hierarchy whilst, the local leaders correspond to motion generators acting under the influence of the global leader.

The position of each particle in the population is affected by the influence of global leaders and local leaders, while also being affected by a randomly chosen particle from the population to induce some stochasticity in the optimization pipeline. We first model the influence of the global leader on the local leaders and the influences of the local leaders on each population element using equation (1) and (2). We introduce a hierarchical crossover between the two influencing equations governed by a hierarchical crossover parameter.

Analogously to [step 3] in the brain motor operation, the updation of particle positions requires generating feedback for the leaders as a part of the optimization procedure, and hence the local leaders and the global leader are updated based onn their objective function value generated from the perturbations in population particles. This series of events comprise of one optimization pass (one loop step). On execution of several optimization passes as described, the system is able to converge to an optimal configuration, analogous to the successful execution of the required task as shown in [step 4].

The updated position of the particle x is governed by the hierarchical crossover operation and a mutation operation. The hierarchical operation is affected by the global leader g_L and the local leader l through the parametric equations (1) and (2). Switching between the two is governed by the hierarchical crossover parameter $P_H C$.

The new position of particle x is governed by the position of the global leader g_L and the corresponding local leader l of the particle. We introduce two parametric equations governing the generation of new position vector. The first equation (1), regulates the co-operative influences of the global leader g_L and the local leader l, where their influences are governed by leadership intensity parameters λ_1 and λ_2. Equation (2) deals with the influence of local leader on the particle x governed by the influential parameters λ_3 (controlling influence of leader on particle) and k_1 (controlling degree of co-operation of particle). The given equations are as follows:

$$E_g = \lambda_1 g_L + \lambda_2 l \tag{1}$$

$$E_g = \lambda_3 l + k_1 x \tag{2}$$

Finally, a new particle position is determined using the unified effect of (1) and (2) as shown:

$$y = E_g + E_l - kc \tag{3}$$

Where, c is a randomly chosen particle from the population to induce stochasticity in the system, and k is a normalized parameter controlling the extent of stochastic influence.

Algorithm 1 Distributed Leader Optimization Algorithm

procedure START
  Initialize parameters.
  Generate initial global leader g_L as a random point.
  Generate N_l local leader points around g_L.
  Using a Normal distribution, generate N points for population P around the local leaders.
  while termination criteria is not met **do**
    for each individual x_i in P **do**
      compute the corresponding local leader l based on nearest position.
      Generate E_g and E_l as shown in (1) and (2).
      Compute new position vector y using (3).
      if $f(y)<f(x)$ **then**
        Replace x with y in the population.
      end if
    end for
    Alter local leaders in each population cluster based on objective function value.
    Compute updated global leader g_L.
  end while
end procedure

2.1 Type Changes and *Special* Characters

We have already seen several typeface changes in this sample. You can indicate italicized words or phrases in your text with the command `\textit`; emboldening with the command `\textbf` and typewriter-style (for instance, for computer code) with `\texttt`. But remember, you do not have to indicate typestyle changes when such changes are part of the *structural* elements of your article; for instance, the heading of this subsection will be in a sans serif[1] typeface, but that is handled by the document class file. Take care with the use of[2] the curly braces in typeface changes; they mark the beginning and end of the text that is to be in the different typeface.

You can use whatever symbols, accented characters, or non-English characters you need anywhere in your document; you can find a complete list of what is available in the LaTeX *User's Guide* [**?**].

[1] Another footnote, here. Let's make this a rather short one to see how it looks.
[2] A third, and last, footnote.

2.2 Math Equations

You may want to display math equations in three distinct styles: inline, numbered or non-numbered display. Each of the three are discussed in the next sections.

2.2.1 Inline (In-text) Equations. A formula that appears in the running text is called an inline or in-text formula. It is produced by the **math** environment, which can be invoked with the usual `\begin . . . \end` construction or with the short form `$ . . . $`. You can use any of the symbols and structures, from α to ω, available in LaTeX [?]; this section will simply show a few examples of in-text equations in context. Notice how this equation: $\lim_{n\rightarrow \infty}x = 0$, set here in in-line math style, looks slightly different when set in display style. (See next section).

2.2.2 Display Equations. A numbered display equation—one set off by vertical space from the text and centered horizontally—is produced by the **equation** environment. An unnumbered display equation is produced by the **displaymath** environment.

Again, in either environment, you can use any of the symbols and structures available in LaTeX; this section will just give a couple of examples of display equations in context. First, consider the equation, shown as an inline equation above:

$$\lim_{n\rightarrow \infty}x = 0 \tag{4}$$

Notice how it is formatted somewhat differently in the **displaymath** environment. Now, we'll enter an unnumbered equation:

$$\sum_{i=0}^{\infty} x + 1$$

and follow it with another numbered equation:

$$\sum_{i=0}^{\infty}x_i=\int_{0}^{\pi+2} f \tag{5}$$

just to demonstrate LaTeX's able handling of numbering.

2.3 Citations

Citations to articles [? ? ? ?], conference proceedings [?] or maybe books [? ?] listed in the Bibliography section of your article will occur throughout the text of your article. You should use BibTeX to automatically produce this bibliography; you simply need to insert one of several citation commands with a key of the item cited in the proper location in the `.tex` file [?]. The key is a short reference you invent to uniquely identify each work; in this sample document, the key is the first author's surname and a word from the title. This identifying key is included with each item in the `.bib` file for your article.

The details of the construction of the `.bib` file are beyond the scope of this sample document, but more information can be found in the *Author's Guide*, and exhaustive details in the *LaTeX User's Guide* [?].

This article shows only the plainest form of the citation command, using `\cite`.

2.4 Tables

Because tables cannot be split across pages, the best placement for them is typically the top of the page nearest their initial cite. To ensure this proper "floating" placement of tables, use the environment **table** to enclose the table's contents and the table caption. The contents of the table itself must go in the **tabular** environment, to be aligned properly in rows and columns, with the desired horizontal and vertical rules. Again, detailed instructions on **tabular** material are found in the *LaTeX User's Guide*.

Table 1: Frequency of Special Characters

Non-English or Math	Frequency	Comments
Ø	1 in 1,000	For Swedish names
π	1 in 5	Common in math
\$	4 in 5	Used in business
Ψ^2_1	1 in 40,000	Unexplained usage

Figure 1: A sample black and white graphic.

Immediately following this sentence is the point at which Table 1 is included in the input file; compare the placement of the table here with the table in the printed output of this document.

To set a wider table, which takes up the whole width of the page's live area, use the environment **table*** to enclose the table's contents and the table caption. As with a single-column table, this wide table will "float" to a location deemed more desirable. Immediately following this sentence is the point at which Table 2 is included in the input file; again, it is instructive to compare the placement of the table here with the table in the printed output of this document.

It is strongly recommended to use the package booktabs [?] and follow its main principles of typography with respect to tables:

(1) Never, ever use vertical rules.
(2) Never use double rules.

It is also a good idea not to overuse horizontal rules.

2.5 Figures

Like tables, figures cannot be split across pages; the best placement for them is typically the top or the bottom of the page nearest their initial cite. To ensure this proper "floating" placement of figures, use the environment **figure** to enclose the figure and its caption.

This sample document contains examples of `.eps` files to be displayable with LaTeX. If you work with pdfLaTeX, use files in the `.pdf` format. Note that most modern TeX systems will convert `.eps` to `.pdf` for you on the fly. More details on each of these are found in the *Author's Guide*.

As was the case with tables, you may want a figure that spans two columns. To do this, and still to ensure proper "floating" placement of tables, use the environment **figure*** to enclose the figure and its caption. And don't forget to end the environment with **figure***, not **figure**!

Table 2: Some Typical Commands

Command	A Number	Comments
`\author`	100	Author
`\table`	300	For tables
`\table*`	400	For wider tables

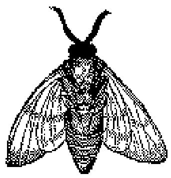

Figure 2: A sample black and white graphic that has been resized with the `includegraphics` command.

2.6 Theorem-like Constructs

Other common constructs that may occur in your article are the forms for logical constructs like theorems, axioms, corollaries and proofs. ACM uses two types of these constructs: theorem-like and definition-like.

Here is a theorem:

Theorem 2.1. *Let f be continuous on $[a, b]$. If G is an antiderivative for f on $[a, b]$, then*

$$\int_a^b f(t)\,dt = G(b) - G(a).$$

Here is a definition:

Definition 2.2. If z is irrational, then by e^z we mean the unique number that has logarithm z:

$$\log e^z = z.$$

The pre-defined theorem-like constructs are **theorem**, **conjecture**, **proposition**, **lemma** and **corollary**. The pre-defined definition-like constructs are **example** and **definition**. You can add your own constructs using the *amsthm* interface [?]. The styles used in the `\theoremstyle` command are **acmplain** and **acmdefinition**.

Another construct is **proof**, for example,

Proof. Suppose on the contrary there exists a real number L such that

$$\lim_{x\to\infty} \frac{f(x)}{g(x)} = L.$$

Then

$$l = \lim_{x\to c} f(x) = \lim_{x\to c} \left[gx \cdot \frac{f(x)}{g(x)} \right] = \lim_{x\to c} g(x) \cdot \lim_{x\to c} \frac{f(x)}{g(x)} = 0 \cdot L = 0,$$

which contradicts our assumption that $l \neq 0$. □

3 CONCLUSIONS

This paragraph will end the body of this sample document. Remember that you might still have Acknowledgments or Appendices; brief samples of these follow. There is still the Bibliography to deal with; and we will make a disclaimer about that here: with the exception of the reference to the LaTeX book, the citations in this paper are to articles which have nothing to do with the present subject and are used as examples only.

A HEADINGS IN APPENDICES

The rules about hierarchical headings discussed above for the body of the article are different in the appendices. In the **appendix** environment, the command **section** is used to indicate the start of each Appendix, with alphabetic order designation (i.e., the first is A, the second B, etc.) and a title (if you include one). So, if you need hierarchical structure *within* an Appendix, start with **subsection** as the highest level. Here is an outline of the body of this document in Appendix-appropriate form:

A.1 Introduction

A.2 The Body of the Paper

A.2.1 Type Changes and Special Characters.

A.2.2 Math Equations.

Inline (In-text) Equations.

Display Equations.

A.2.3 Citations.

A.2.4 Tables.

A.2.5 Figures.

A.2.6 Theorem-like Constructs.

A Caveat for the TeX Expert.

A.3 Conclusions

A.4 References

Generated by bibtex from your `.bib` file. Run latex, then bibtex, then latex twice (to resolve references) to create the `.bbl` file. Insert that `.bbl` file into the `.tex` source file and comment out the command `\thebibliography`.

B MORE HELP FOR THE HARDY

Of course, reading the source code is always useful. The file `acmart.pdf` contains both the user guide and the commented code.

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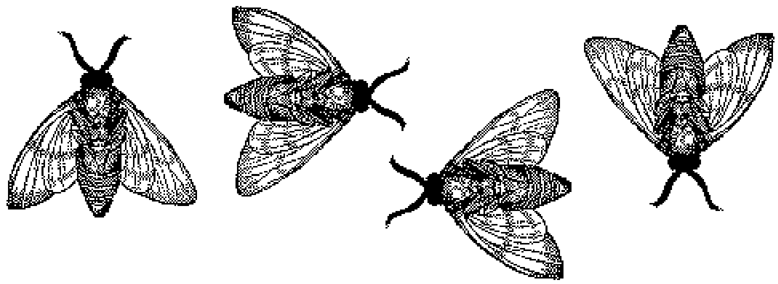

Figure 3: A sample black and white graphic that needs to span two columns of text.

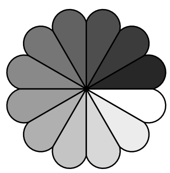

Figure 4: A sample black and white graphic that has been resized with the `includegraphics` command.

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