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[Continued on next page]

(54) Title: SYSTEMS AND METHODS FOR PERFORMING BAYESIAN OPTIMIZATION

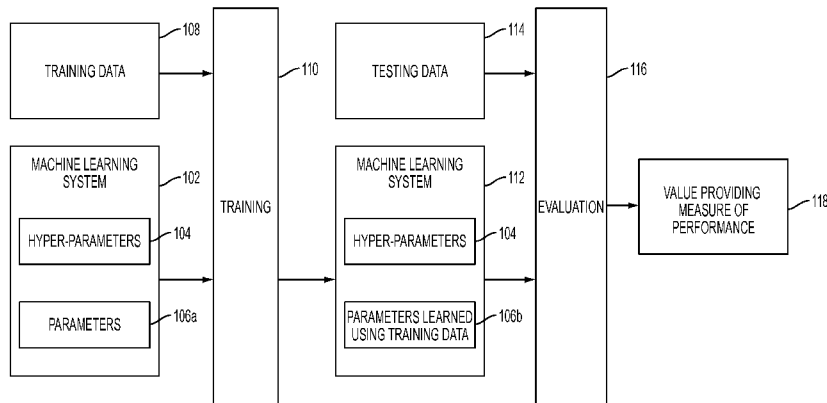


FIG. 1

(57) Abstract: Techniques for use in connection with performing optimization using a plurality of objective functions associated with a respective plurality of tasks. The techniques include using at least one computer hardware processor to perform: identifying, based at least in part on a joint probabilistic model of the plurality of objective functions, a first point at which to evaluate an objective function in the plurality of objective functions; selecting, based at least in part on the joint probabilistic model, a first objective function in the plurality of objective functions to evaluate at the identified first point; evaluating the first objective function at the identified first point; and updating the joint probabilistic model based on results of the evaluation to obtain an updated joint probabilistic model.

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TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/40141

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - G06F 15/18 (2014.01)
 CPC - G06N 99/005, G06N 7/005
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 CPC: G06N 99/005, 7/005

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 USPC: 706/12, 19, 704/243, 256.2; CPC: G06K9/6277, G06K9/6278, G06K9/6296, G06N7/005, G06N99/005, G10L15/144 (keyword limited; terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 Patbase; ProQuest Dialog; Google Scholar; Google Patents
 Keywords: optimize, objective function, fitness function, joint probabilistic, bayesian, multi-objective optimization, parallel processing, markov chain monte carlo, kriging, co-kriging, hyper-parameters, sampling, converging

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0312895 A1 (Sastry et al.) 18 December 2008 (18.12.2008), entire document, esp. Fig. 1-2 and corresponding portions of disclosure	1, 10, 16
Y	Li et al. "Multi-objective uniform design as a SVM model selection tool for face recognition." Expert Systems with Applications, Vol. 38, Issue 6, June 2011, pp 6689-6695	1-3, 10, 16
Y	US 2012/0308124 A1 (Belhumeur et al.) 06 December 2012 (06.12.2012), entire document, esp. para [0040]	1-3, 10, 16, 21, 29, 36, 41, 50, 56, 61, 69 and 75
Y	US 2006/0200333 A1 (Dalal et al.) 07 September 2006 (07.09.2006), entire document, esp. para [0026]-[0032], [0048]-[0077]	21, 29, 36, 41, 50, 56, 61, 69 and 75
Y	Zuluaga et al. "Active Learning for Multi-Objective Optimization." Proceedings of the 30th International Conference on Machine Learning, Volume 28, Cycle 1, 15 February 2013. [See http://jmlr.csail.mit.edu/proceedings/papers/v28 and http://jmlr.csail.mit.edu/proceedings/]	1-3, 10, 16, 21, 29, 36, 41, 50, 56, 61, 69 and 75
Y	Lagaros et al. "Multi-objective design optimization using cascade evolutionary computations." Comput. Methods Appl. Mech. Engrg. 194 (2005), pp. 3496-3515.	1-3, 10, 16, 21, 29, 36, 41, 50, 56, 61, 69 and 75

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 20 November 2014 (20.11.2014)	Date of mailing of the international search report 09 DEC 2014
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Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 14/40141

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.: 4-9, 11-15, 17-20, 22-28, 30-35, 37-40, 42-49, 51-55, 57-60, 62-68, 70-74, 76-80
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

--- See extra sheet ---

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 14/40141

Continuation of Box No. III, Observations where unity of invention is lacking:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

Group I: Claims 1-3, 10 and 16, directed to a system, method and computer-readable storage medium for performing optimization using a plurality of objective functions associated with a respective plurality of tasks.

Group II: Claims 21, 29, 36, 41, 50 and 56, directed to systems, methods and computer-readable storage media for performing optimization using an objective function that maps elements in a first domain to values in a range by using an acquisition utility function.

Group III: Claims 61, 69 and 75, directed to a system, method and computer-readable storage medium for performing optimization using an objective function by evaluating the objective function at multiple points in parallel.

The groups of inventions listed above do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I includes the special technical features of a plurality of objective functions associated with a respective plurality of tasks; a joint probabilistic model of the plurality of objective functions; and updating the joint probabilistic model based on results of evaluation of a first object function in the plurality of objective functions at a first point of evaluation, not required in any other group.

Group II includes the special technical features of identifying the first point at which to evaluate the objective function by using an acquisition utility function and a probabilistic model depending on a non-linear one-to-one mapping of elements in a first domain to elements in a second domain, not required in any other group.

Group III includes the special technical features of beginning evaluation of the objective function at a first point, before evaluating the objective function at the first point is completed, identifying, based on likelihoods of potential outcomes of evaluating the objective function at the first point, a second point different from the first point and beginning evaluation of the objective function at the second point, not required in any other group.

Groups I - III share the technical features of a system and method for use in connection with performing optimization using an objective function, the system comprising at least one computer hardware processor and at least one non-transitory computer-readable storage medium storing processor-executable instructions that, when executed by the at least one computer hardware processor, cause the at least one computer hardware processor to perform: identifying a first point at which to evaluate the objective function at least in part by using a probabilistic model of the objective function, evaluating the objective function at the identified first point, and updating the probabilistic model of the objective function based on results of the evaluation to obtain an updated probabilistic model. However, these shared technical features fail to provide a contribution over the prior art of US 2006/0136205 A1 (Song).

Song discloses a system (Fig. 6-8) and method for use in connection with performing optimization using an objective function (Abstract), the system comprising at least one computer hardware processor (808) and at least one non-transitory computer-readable storage medium (804) storing processor-executable instructions that, when executed by the at least one computer hardware processor, cause the at least one computer hardware processor to perform: identifying a first point at which to evaluate the objective function at least in part by using a probabilistic model of the objective function (Abstract, para [0022], [0042], [0050]-[0051], Claim 2), evaluating the objective function at the identified first point (Abstract, para [0022], [0042], [0050]-[0051], Claim 2), and updating the probabilistic model of the objective function based on results of the evaluation to obtain an updated probabilistic model (para [0050], [0064]-[0065], Claim 3).

Thus, Groups I - III lack unity of invention under PCT Rule 13 because they do not share a same or corresponding special technical feature providing a contribution over prior art.