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(54) **SYSTEM AND PROCESS FOR DEBUGGING  
OBJECT-ORIENTED PROGRAMMING CODE  
LEVERAGING PREPROCESSORS**

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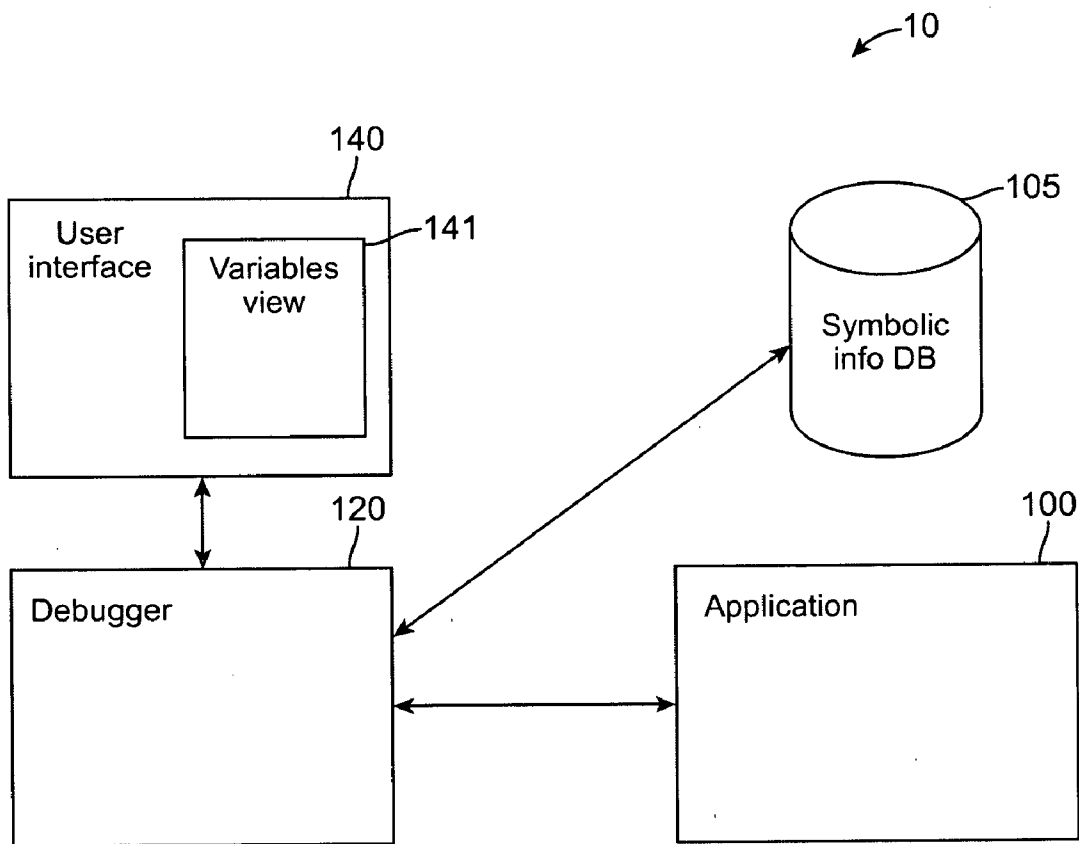
(57) **ABSTRACT**

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A process and system for debugging of a computer program, is provided. One implementation involves including mark-up information into source code of the application program, generating a debug-enabled version of the computer program including debugging methods based on the mark-up information, and providing the debug-enabled version of the program computer to a debugger for debugging purposes using the debugging methods.

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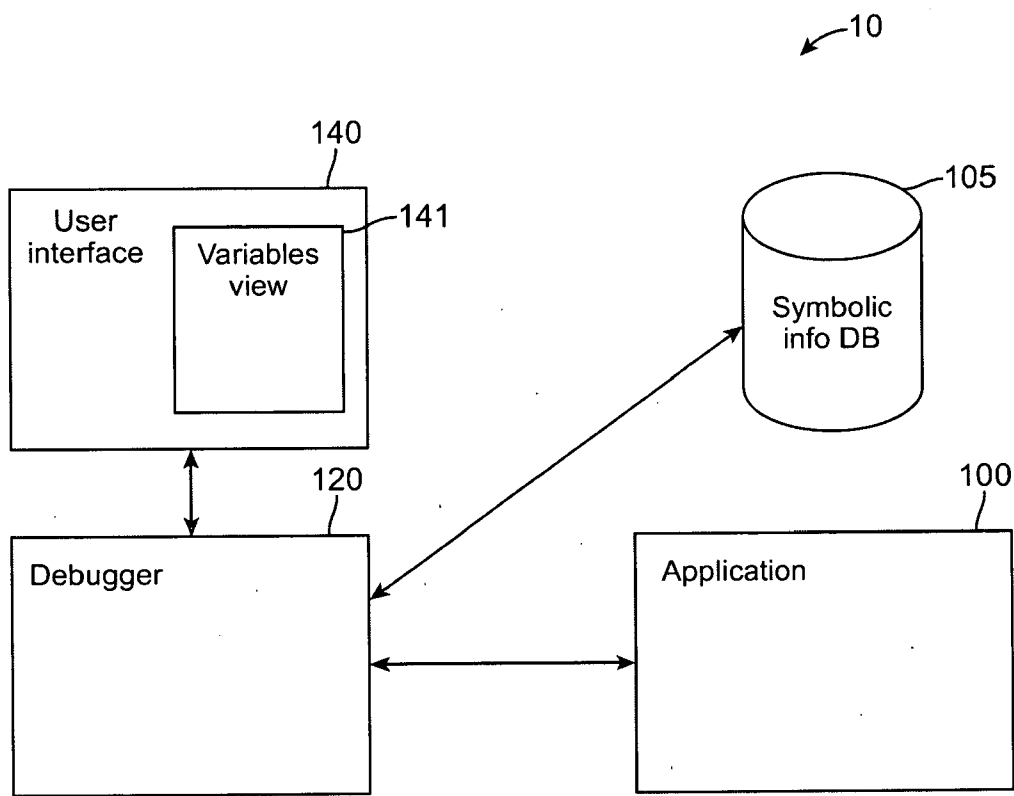


FIG. 1

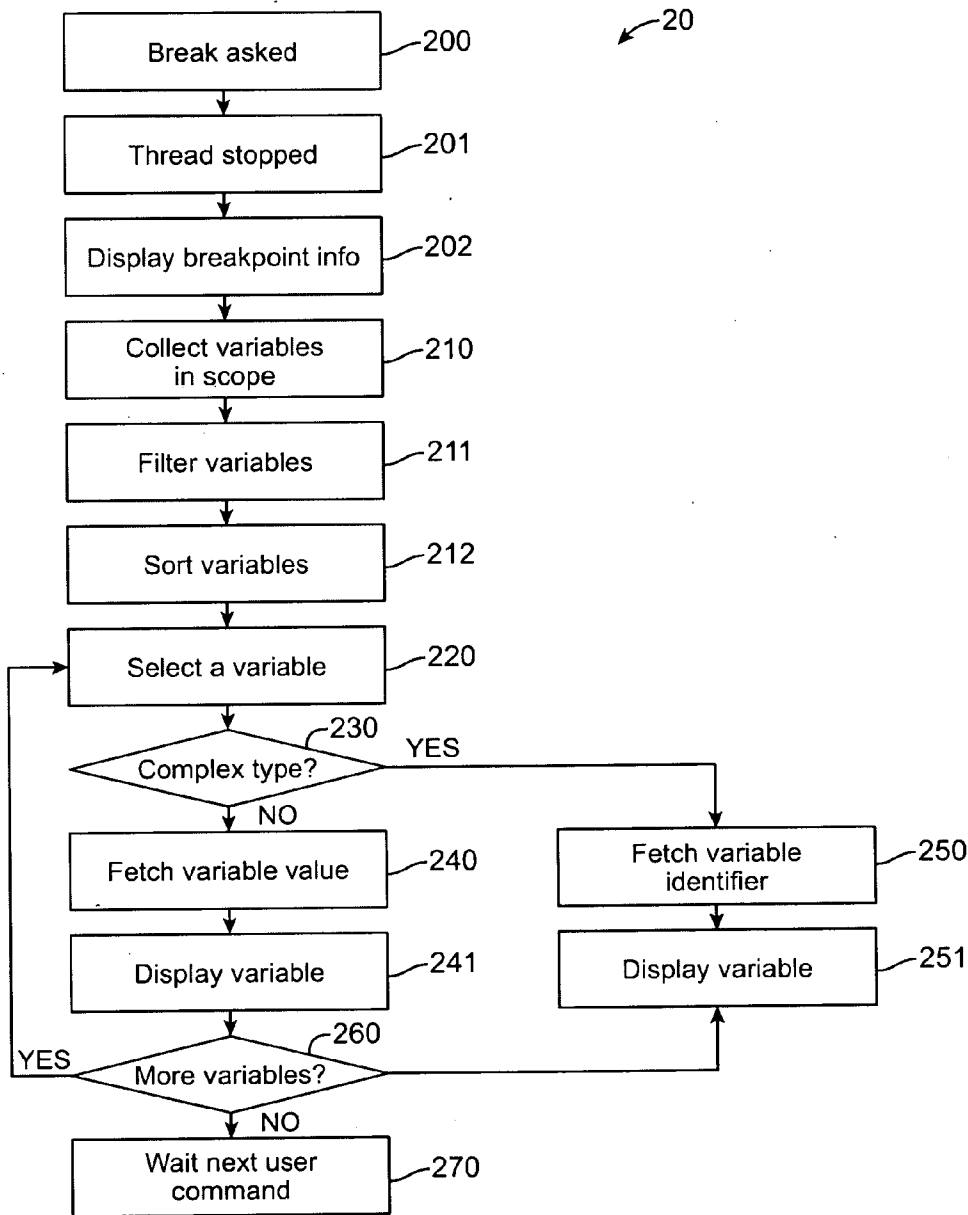


FIG. 2

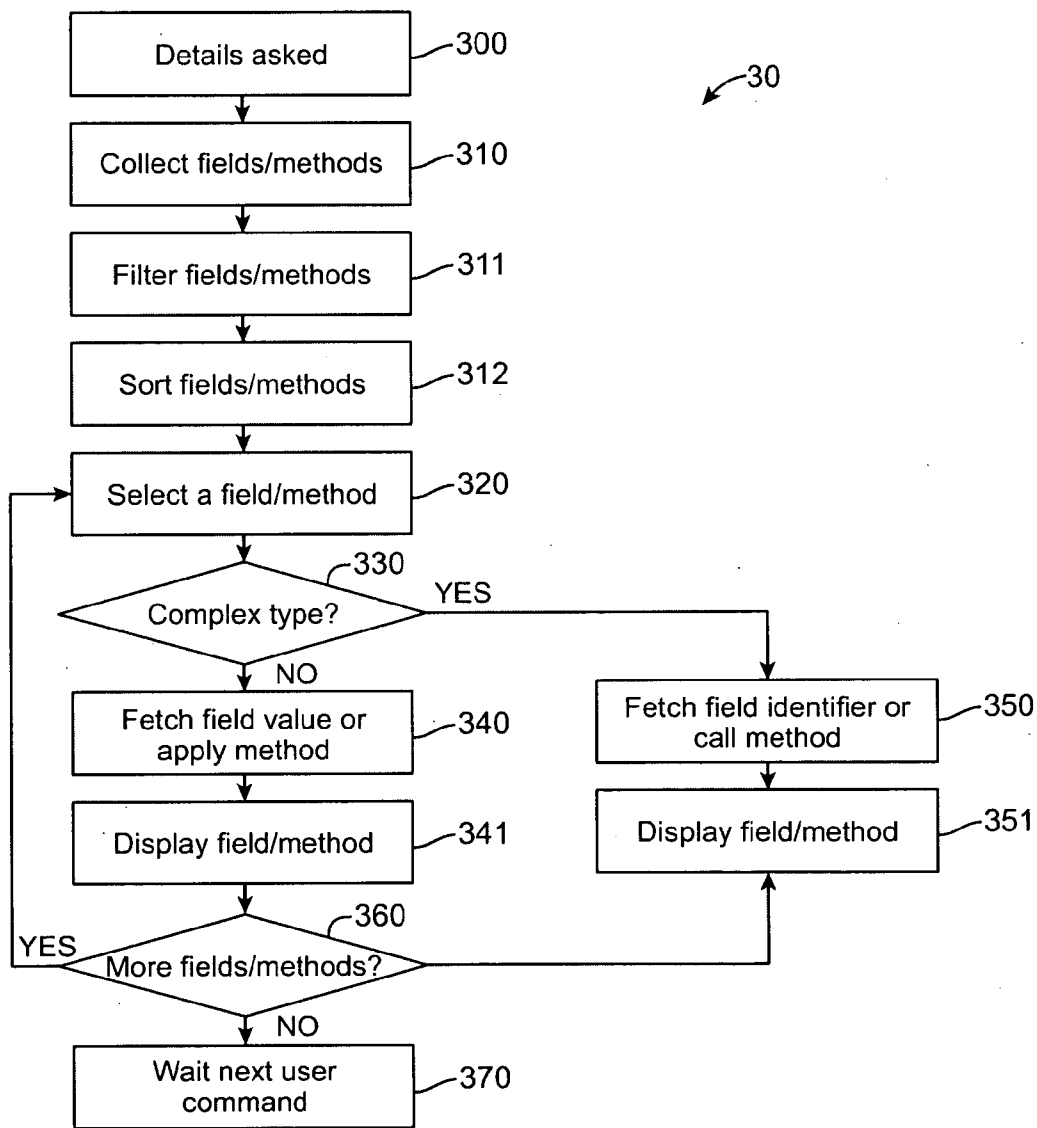


FIG. 3

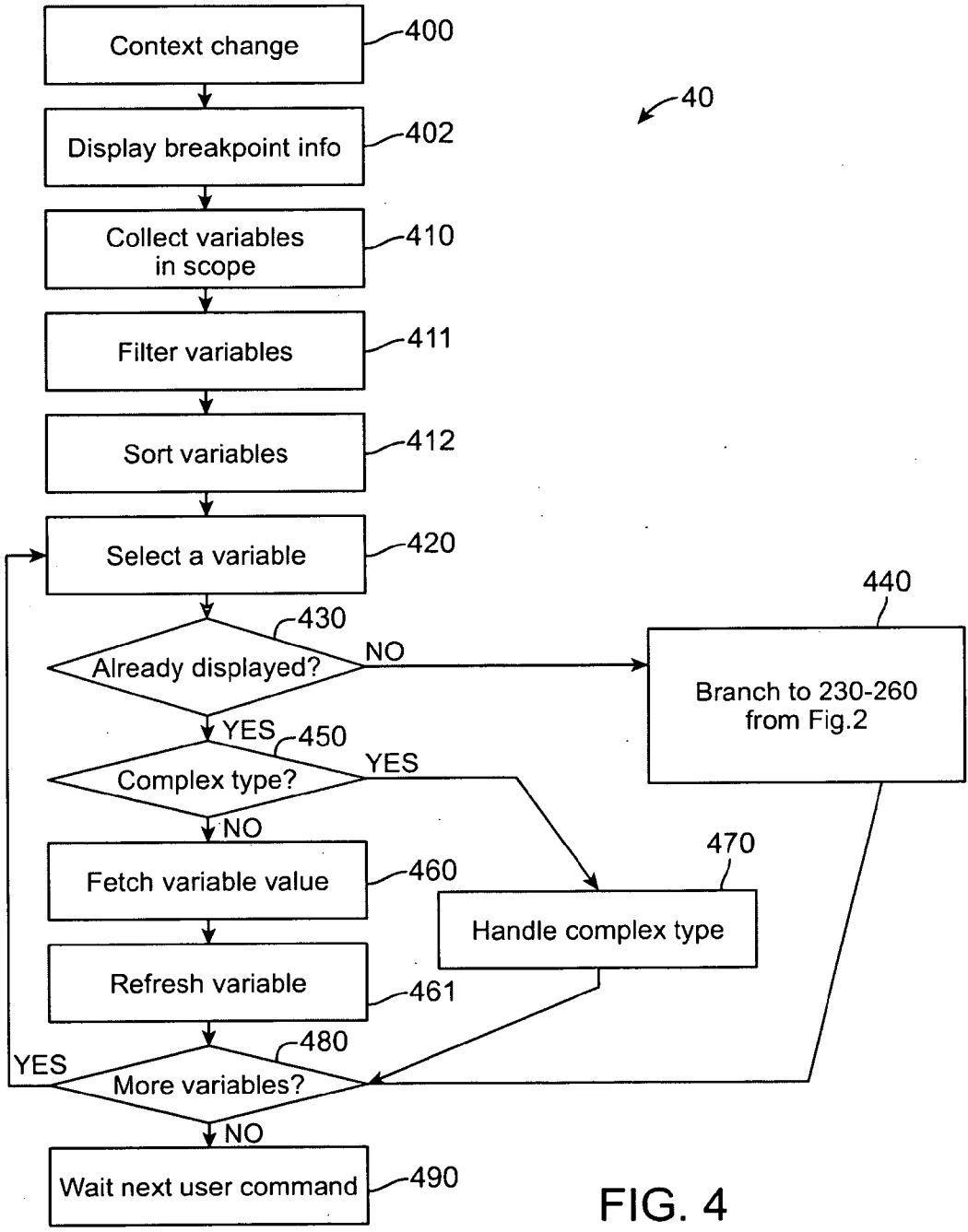


FIG. 4

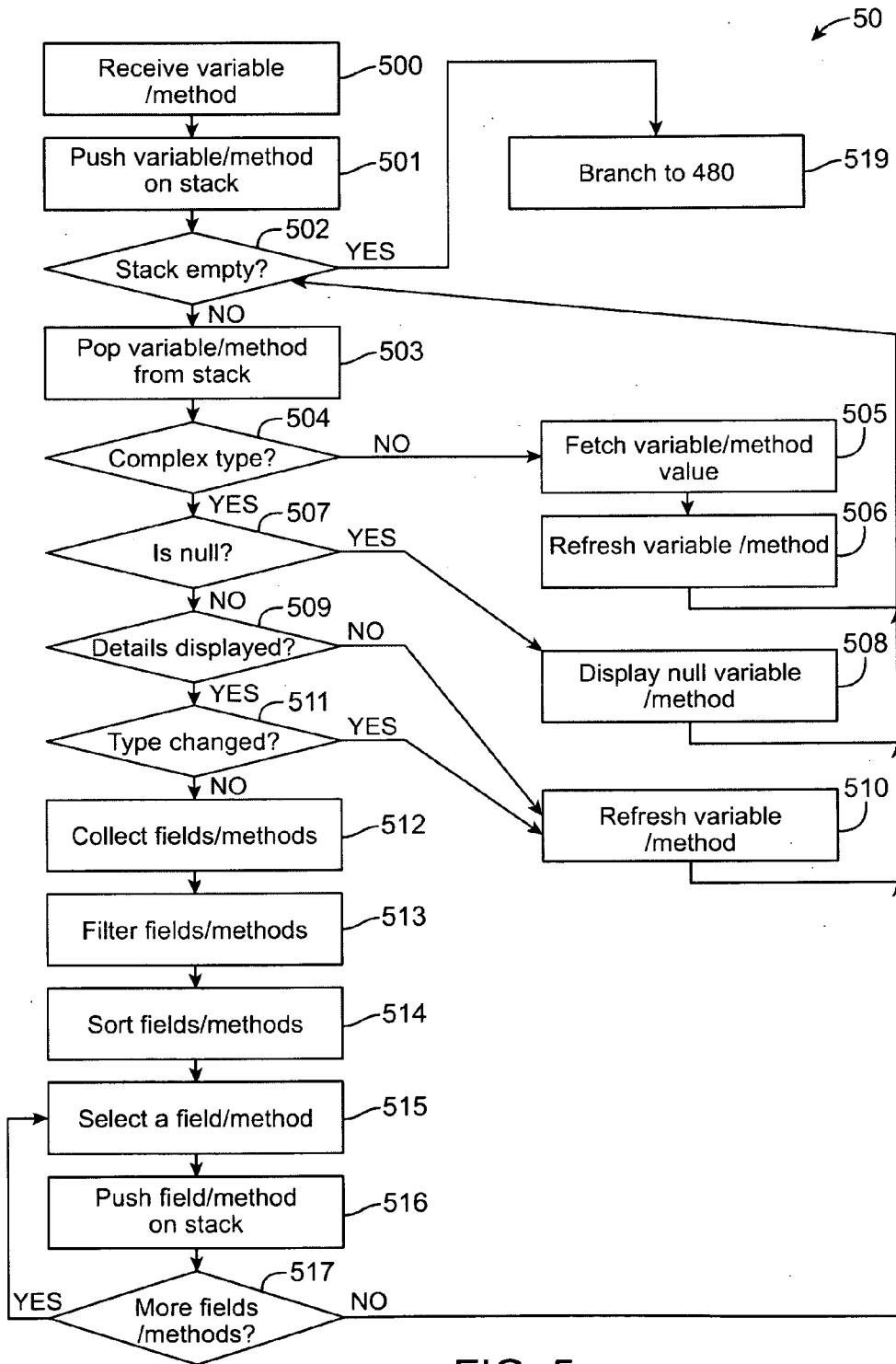


FIG. 5

60

Name	Declared Type	Value
<input type="radio"/> args	String []	String [0] (id=35)
<input type="checkbox"/> <input type="radio"/> employee	Employee	Employee (id=16)
<input type="radio"/> birthYear	int	111
<input type="radio"/> encodedValue	int	59247
<input checked="" type="checkbox"/> <input type="radio"/> gender	String	"male" (id=43)
<input checked="" type="checkbox"/> <input type="radio"/> hexaView	String	"e76f" (id=44)

FIG. 6

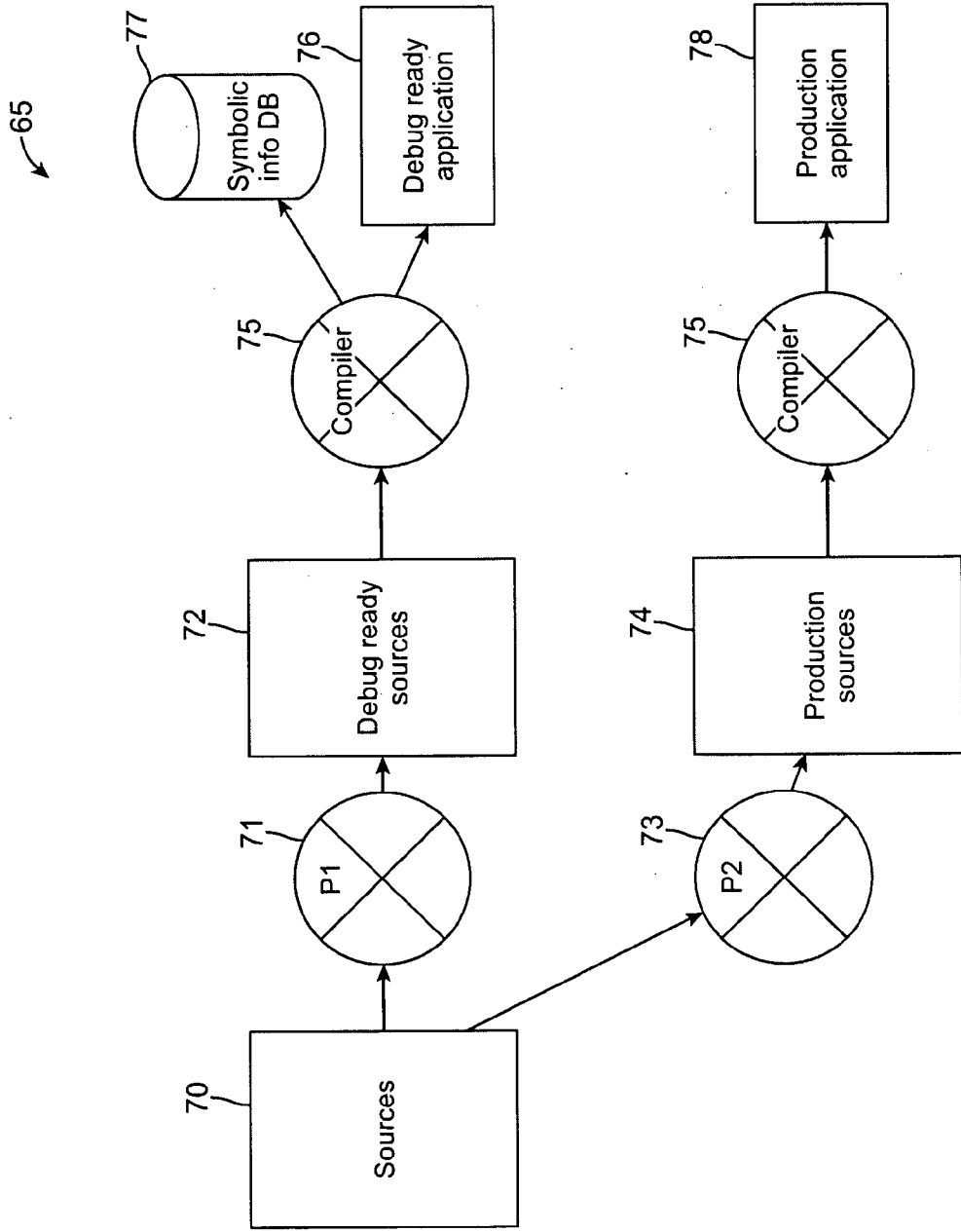


FIG. 7



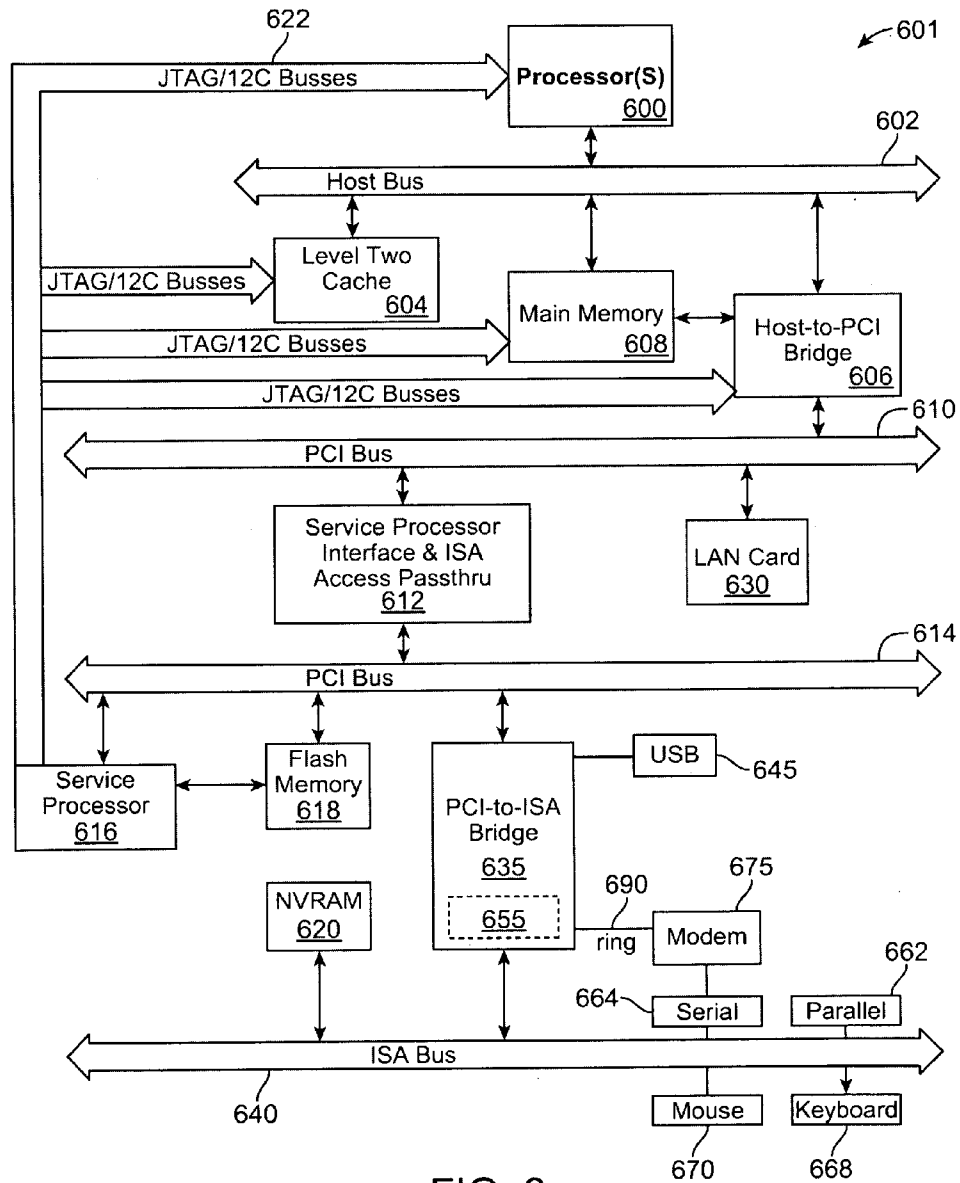


FIG. 8

**SYSTEM AND PROCESS FOR DEBUGGING  
OBJECT-ORIENTED PROGRAMMING CODE  
LEVERAGING PREPROCESSORS**

**DESCRIPTION OF THE PREFERRED  
EMBODIMENTS**

**CROSS-REFERENCE TO RELATED  
APPLICATIONS**

**[0001]** This application claims priority of EP08305492, filed on Aug. 21, 2008.

**BACKGROUND OF THE INVENTION**

**[0002]** 1. Field of the Invention

**[0003]** The present invention relates generally to software program debugging tools and more particularly to software debugging tools for object-oriented software programs.

**[0004]** 2. Background Information

**[0005]** In existing software debugging tools (debuggers), while debugging applications written in object-oriented (OO) programming languages, objects are presented into a debugger according to their structure, that is, the fields that their class define. This requires that the fields cleanly map the semantics of the objects. However, frequently a class defines parts (or whole) of its semantics through methods, while its fields mostly map to implementation details that may or may not help the developer depending on his focus on the class or classes that use it, and his level of knowledge of the class internals. In certain cases the developer intimately knows the class, but the class implementation, for performance reasons or otherwise, encodes its semantics in very difficult to understand fields.

**SUMMARY OF THE INVENTION**

**[0006]** The invention provides a process and system for debugging of an object oriented computer program. One embodiment involves including mark-up information into source code of the application program, the mark-up information associated with eligible debugging methods, then generating a debug-enabled version of the computer program including debugging methods based on the mark-up information, and providing the debug-enabled version of the program computer to a debugger for debugging purposes using the debugging methods.

**[0007]** Other aspects and advantages of the present invention will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the invention.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0008]** For a fuller understanding of the nature and advantages of the invention, as well as a preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings, in which:

**[0009]** FIG. 1 shows a functional block diagram of a computing system implementing an embodiment of the invention.

**[0010]** FIGS. 2-5 show flowcharts of a debugging process, according to an embodiment of the invention.

**[0011]** FIG. 6 shows an example view for debugging, according to an embodiment of the invention.

**[0012]** FIG. 7 shows a functional block diagram of a processing system implementing leveraging preprocessors in debugging application programs, according to an embodiment of the invention.

**[0013]** FIG. 8 shows an example computer system suitable for implementing the present invention.

**[0014]** The following description is made for the purpose of illustrating the general principles of the invention and is not meant to limit the inventive concepts claimed herein. Further, particular features described herein can be used in combination with other described features in each of the various possible combinations and permutations. Unless otherwise specifically defined herein, all terms are to be given their broadest possible interpretation including meanings implied from the specification as well as meanings understood by those skilled in the art and/or as defined in dictionaries, treatises, etc. The invention provides a system and process for debugging object oriented programs (code) by identifying all possible eligible methods that have no parameters and returning a value, and then selecting among these possible eligible methods using pattern-based filtering of methods, wherein the selected eligible methods are leveraged for debugging. In one embodiment of the invention, all methods that take no parameter and return a value are possibly eligible for application of the invention. A developer uses explicit markers to sort those that are elected as semantic fields from those that are not. The former results into additional methods named after a recognizable pattern and a pattern-based filtering of methods is used to determine eligible methods. The debugger may apply further matching and filtering rules to select even fewer methods (e.g., the debugger may be equipped with built-in or user level matching rules such as “all instance methods whose name starts with get”). The recognizable pattern may be unique or multiple, and can be disclosed to and changed by the developer or not depending upon the implementation.

**[0015]** The following description first explains identifying all possible eligible methods that have no parameters and returning a value, and then explains selecting among such methods using a pattern-based filtering of the possible eligible methods. Specifically, all methods that take no parameter and return a value are possible eligible methods for application of the invention. Certain methods of the class under test may include defining semantic fields of the class. Then, a recognizable pattern is used to sort out eligible methods out of the set of possible eligible methods. A debugger according to the invention recognizes and leverages those methods at debug time. As such, the invention provides a process for including mark-up information in the source code of an object oriented application program, and leveraging the mark-up information to generate a debug-enabled version of the application program. Such a debug-enabled version of the application program comprises eligible methods named after a recognizable pattern. Then, a pattern-based filtering of methods is used to select among possible eligible methods.

**[0016]** In object oriented programming, a class is template for creating objects, and defines attributes (e.g., name, value) and methods (e.g., associated subroutines, functions, behaviours) of each object. FIG. 1 shows a functional block diagram of a computer system 10 in which an embodiment of the invention is implemented. Said embodiment of the invention is applicable to debugging (e.g., testing and solving programming issues such as errors) of object oriented programs using a graphical user interface (GUI) debugger. A full-fledged graphical windowing system is not required, and character-based interfaces may be used, provided that information can be presented to the user (e.g., software developer/programmer) in a multi-views and multi-lines format.

[0017] The debugging computer system provides a debugging session, wherein an object oriented software application **100** is running on a computing system. The application **100**, at the moments in time that are of interest to debugging, runs (executes) under the control of a debugger **120** (e.g., a software module). The application **100** may run on a computer-based system that may include a single machine that comprises a single core processor, or a networked system that comprises multiple machines, some of which include a single processor or some of which include multiple processors, etc.

[0018] The debugging computer system further includes database **105** of symbolic information about the application **100** under test. The database **105** may include various structures, use diverse storage technologies, be packaged with the executable components of the application **100**, etc. The debugger **120** is configured to query information in the database **105** about the application **100**, at the level of detail needed to implement its base debugging functions and implement debugging functions according to the invention.

[0019] In one implementation, the debugger **120** comprises a specialized software module configured to control execution of the application **100** under test, and to provide the user of the debugger **120** with tools to diagnose the execution of the application **100** from multiple points of view. The debugger **120** further interacts with the application **100** to selectively interrupt execution of one or more process threads of the application **100** at precise points in time depending on specific conditions. As such, the debugger **120** controls execution of the application **100** on behalf of the user, leverages the symbolic information **105** to provide debugging functions, and interacts with the user via a user interface module **140**.

[0020] The user interface module **140** is configured to enable the user to interact with the debugger **120** and control execution of the application **100**, and to diagnose the behavior of the application **100**. The user interface **140** provides several views and dialogs, that may leverage a graphical user interface or rely upon character-based multi-line views and dialogs. Said views and dialogs provides controls (e.g., interfaces) to at least present the user with breakpoints which are points at which the execution of one or more threads of the application **100** can be interrupted. Said views may also provide controls to resume the execution of the application **100** in various manners (e.g., step by step, up to the following breakpoint, etc.).

[0021] Preferably, said views further include a view **141** which, for a given moment in time at which a given thread of the application **100** is stopped at a given point in the executable code of the application, presents the user with the variables that are in context. Such variable values are in memory and the application **100** typically uses their addresses to fetch them. The debugger **120** leverages the symbolic information database **105** to fetch types, etc.

[0022] The view **141** provides controls for filtering part of the available information, and, for presenting variables that are not of elementary types via means that makes this practical within a finite view (i.e., types more complex than simple types of a considered programming language such as int and other integral types, chars, strings of chars, booleans, etc.).

[0023] The view **141** also provides controls for the user to choose how much of the internal presentation structure of the view should be displayed. It is important to consider the relationship between the view **141** and structured variables (e.g., objects, and depending on the programming language,

other structures that are supported by dedicated language features, such as arrays, tuples, etc.). A typical object, or class instance, may have many fields. Some of these fields can be objects, or even of the type of the considered object itself. The view **141** provides controls for the user to focus on presenting a subpart of the available information as desired.

[0024] For example, the view **141** may provide controls such as scrolling controls for a windowing system wherein the information is presented into what may be considered as an infinite view, a small part of which is presented to the user on a display and scroll bars are provided to move up or down parts of the available information.

[0025] Another control of the view **141** includes presenting information using a tree (hierarchical) metaphor, wherein only digging deeper into the tree the user can view further information. For example, having a Java class X {int i; X next;} at hand, the tree metaphor would involve presenting the user with only the following view:

[0026] +this=X at 000fff

[0027] where the + is in fact a control that enables the user to instruct the view **141** to expand the tree; doing so could, for a given execution of the application, result into:

[0028] -this=X at 000fff

[0029] i=0

[0030] +next=X at 000fff.

[0031] Another control of the view **141** includes filters that leverage properties that are more related (e.g., field visibility, inherited fields, etc.) or less related (e.g., field name, name matching a regular expression, etc.) to the semantics of the programming language used by the application **100**.

[0032] Other controls for the view **141** provides strategies for rendering information on a display for the user may also be implemented. Such strategies may also be combined. The rendering presented in the above examples are eventually subject to various embodiments of the debugger **120**. The operation of an example debugger **120** may rely upon one or more processes described below, as described in relation to FIGS. 2-6. Only methods that have a suitable signature can be used (i.e., methods defining semantic fields). Such methods present pseudo-field values along with fields of object-typed variables on a user interface for debugging purposes. A recognizable pattern is used to sort out eligible methods out of the set of possible eligible methods. A pattern-based filtering of methods is used to select among the eligible methods.

[0033] FIG. 2 shows an example process **20** according to which the debugger **120** presents a user with the information available at a given breakpoint in execution of the application **100**. At block **200** a break in the execution of the application **100** is requested (e.g., via the user interface **140** or from an internal condition monitored by the debugger **120**). The break can affect one or more threads of the application **100**. At block **201**, one or more of the threads are stopped by the debugger **120**. At block **202**, using the interface **140** the debugger **120** presents the user with information about the current point of execution of the application **100**. At block **210** the debugger collects the variables that are in scope at the current point of execution. At block **211**, optionally the debugger **120** filters out some of the variables based on various criteria, and only retain the remaining for presentation. At block **212**, optionally the debugger **120** sorts the variables according to sorting criteria associated with the view or the debugger itself. At block **220**, the debugger **120** selects the first variable in scope and removes it from the list of variables to handle. At block

**230**, if the variable is of complex type, then the process proceeds to block **250**, otherwise the process proceeds in sequence to block **240**.

**[0034]** At block **240**, since the variable is of simple type, the debugger **120** fetches the value of that variable, which depending on the runtime environment may involve various techniques. For a compiled language such as C++, this would involve computing the memory address and size of the variable, then interpreting the resulting memory chunk according to the variable type. For an interpreted language like Java in which a virtual machine is equipped with dedicated application programming interfaces (APIs) to do so, this would involve communicating with the virtual machine through the appropriate API to obtain the value.

**[0035]** At block **241**, the debugger **120** presents information about said variable into the view **141** and the process proceeds to block **260**. The information displayed may include the type, name and value of the said variable (other information about said variable may also be displayed).

**[0036]** At block **260**, if additional variables remain in scope that have not been presented yet, the process loops back to block **220**, otherwise the process proceeds to block **270** for completion, and the debugger **120** awaits a next command.

**[0037]** At block **250**, referenced above, since said variable is of complex type, the debugger **120** fetches an identifier for the variable (e.g., memory address of the variable, or any other value guaranteed to identify the variable). At block **251**, the debugger presents information about the variable into the view **141**, and the process proceeds to block **260**. The display of information about the variable in view **141** may include the type, name and identifier of the variable. The user is also enabled to request the details of the variable value, which may involve explicit graphics (e.g., when a click-able plus sign is provided) or may not involve explicit graphics (e.g., the user utilizes a contextual menu). The information presented may include (automatically or on demand) the string representation of the variable (e.g., in Java, this would result from the call of the `toString()` method upon the object, since all classes ultimately inherit from `Object`).

**[0038]** According to an embodiment of the invention, the debugger further presents in the view **141** the result of the execution of eligible methods upon object-typed variables, along with the (true) fields of the said variables. Whenever fields of an object type are considered, for all methods that have a return type and do not take parameters, the process involves deriving a pseudo-field name from the method name, running the method to obtain a pseudo-field value, and leveraging those names and values as if they were the names and values of a regular field. For selecting among eligible methods, a recognizable pattern is used to sort out eligible methods out of the set of possible eligible methods. A pattern-based filtering of methods is used to select among the eligible methods.

**[0039]** FIG. 3 shows an example process **30** according to which the debugger **120** presents a user with the details of a complex variable. At block **300** the user interacts with the debugger to request that the details of a complex variable that is in context to be presented. An example interaction would be for the user interacting with the variable as presented in view **141** by clicking the plus sign at its left, using a contextual menu upon it.

**[0040]** At block **310**, the debugger **120** interacts with the symbolic information **105** to determine the names and types of the fields of the variable and to elaborate a list of all

methods that can be called upon the variable, said methods having no parameter and return a value. As above, pattern-based filtering of methods is used to select among the eligible methods. For each of those selected methods, the debugger remembers its name and its return type. Optionally, the debugger associates a short name to each method, deriving that short name from the method name using rules (e.g., method “`getName`” may be associated to name “`name`” by a rule “strip leading get and lowercase leading letter”), and uses the resulting short names for sorting in block **312** further below.

**[0041]** At block **311**, optionally the debugger filters out some of the fields and methods based upon various criteria and only retain the remaining ones for presentation.

**[0042]** At block **312**, optionally, the debugger sorts the collection of fields and methods according to sorting criteria associated with the view or the debugger itself. Depending on the sorting criteria, the fields and methods may be interleaved.

**[0043]** At block **320**, the debugger selects the first field or method of the variable and removes it from the list of fields and variables to be considered.

**[0044]** At block **330**, if the field or the method return value is of complex type, then the process proceeds to block **350**, otherwise the process proceeds in sequence to block **340**.

**[0045]** At block **340**, if a field was obtained at block **320**, the debugger **120** determines the value of the field for the considered variable. Depending on the runtime environment, this may involve various techniques (e.g., for a compiled language such as C++, this would involve computing the memory address and size of the field, then interpreting the resulting memory chunk according to the field type; for an interpreted language such as Java in which a virtual machine is equipped with dedicated APIs to do so, this would involve communicating with the virtual machine through the appropriate API to obtain the value). If at block **320** a method was obtained, then in block **340** herein the debugger calls that method upon the variable at hand to get a value.

**[0046]** At block **341**, if a field was obtained at block **320**, then the debugger displays the field related information via the view **141**, then proceeds to block **360**. The information displayed may include the type, name, and value of the said field (other information may be displayed). If at block **320** a method was obtained, the debugger performs the same as for a field, using a subpart of the pattern-based method name (indicating the method is an eligible method) as if it was a field name, and the value computed at block **340** as a field value. For example, assuming that `SEMANTIC_FIELD_be` the marker, then a method named `SEMANTIC_FIELD_gender` would be presented as a semantic field named `gender`.

**[0047]** At block **350**, if a field was obtained at block **320**, then since the field is of complex type, the debugger fetches an identifier for the field (e.g., this can be its memory address, or any other value guaranteed to identify the field). If a method was obtained at **320**, then at **350** the debugger calls that method upon the variable at hand to obtain any missing information (e.g., determine if the value is null or it points to a specific memory location).

**[0048]** At block **351**, if a field was obtained at **320**, then the debugger presents the field into the view **141**, then the process proceeds to **360**. The presentation of the field typically includes the type, name (if its enclosing type) and identifier of the field. The user is also enabled to request for the details of the field value. This may involve explicit graphics (e.g., when a click-able plus sign is provided) or may not involve explicit

graphics (e.g., when a contextual menu is provided). The information that is presented may include (automatically or on demand, the string) representation of the field (e.g., in Java, this would result from the call of the toString() method upon the object, since all classes ultimately inherit from Object). If a method was obtained at 320, then at 351 the debugger performs the same as for a field, using the pattern-based marker for the method (indicating the method is an eligible method) as if it was a field name, and the information computed at 350. The simple name is a subpart of the complete, pattern-based method name, wherein for example, assuming that SEMANTIC\_FIELD\_be the marker, then a method named SEMANTIC\_FIELD\_gender would be presented as a semantic field named gender.

[0049] At block 360, if there are more fields or methods to handle for the considered complex variable, the process loops back to block 320, otherwise, the process proceeds to block 370 for completion and awaiting next commands.

[0050] FIG. 4 shows an example process 40 according to which the debugger 120 refreshes the contents of the view 141. The variables in scope here include parameters (on the stack) and global variables (e.g., the static fields of selected classes in Java). At block 400 the context changes. This may be as a result of stepping through the code of the application 100. Note that the current thread of the application 100 is still stopped, after having been resumed for the execution of one or more instructions. It is expected that if the user requested for the application 100 to resume and a breakpoint is reached, either that breakpoint is close enough from the former point in execution, or the process 20 of FIG. 2 is utilized instead of process 40.

[0051] At block 402, the debugger 120 presents the user in the user interface 140 with information about the current point of execution of the application 100. At block 410, the debugger collects the variables that are in scope at the current point of execution (again). At block 411, optionally the debugger filters out some of the variables, based upon various criteria, and only retains the remaining ones as needing to be presented. At block 412, optionally the debugger sorts the variables according to sorting associated with the view or the debugger itself. At block 420, the debugger 120 selects the first variable in scope and removes it from the list of variables to handle. At block 430 the debugger 120 tests whether the current variable was already displayed in view 141 or not. If not, the process proceeds to block 440, otherwise the process continues to block 450.

[0052] At block 440, the debugger 120 utilizes the process 20 of FIG. 2 starting at block 230 and ending before block 260, then branches to block 480 instead of 260 from block 241 and 251. In effect, the debugger handles the display of a variable that was not in scope at the former breakpoint.

[0053] At block 450, the variable being considered was already displayed in view 141, wherein the debugger 120 considers whether the variable is of complex type or not. If the variable is of complex type, the process branches to block 470, otherwise the process continues to block 460. At block 460, since the variable being considered is of simple type, the debugger fetches the values of the variable. At block 461, the debugger refreshes the variable display into the view 141, then proceeds to block 480. In one implementation, a brute-force approach is used to simply display the variable as if it had not been seen at the previous step. In another implemen-

tion, it is determined which variables may have changed, and which have not changed, and only the ones changed are refreshed.

[0054] At block 470, since the variable being considered is of complex type, it is refreshed accordingly (an example is described in conjunction with FIG. 5 further below). At block 480, if there are more variables in scope that have not been presented yet, the process loops back to block 420, otherwise the process proceeds to block 490 for completion and awaiting a next user command.

[0055] FIG. 5 shows an example process 50 according to which the debugger 120 refreshes display of a variable of complex type. The process 50 is inherently recursive, and generally involves matching the tree that represented the previous value of the variable with its current value, pruning dead branches as needed. The process 50 makes explicit use of a stack. At block 500, the process receives a variable of complex type from block 450 (FIG. 4). At block 501, the variable is pushed on the stack. At block 502, if the stack is empty, the process proceeds to block 519, otherwise the process proceeds to block 503. At block 503, a variable or method is popped from the stack. At block 504, if a popped variable is of complex type, the process proceeds to block 507, otherwise the process proceeds to block 505. At block 504, for a popped method, a short name is computed for the method as in block 310 (FIG. 3), and the debugger then calls the method on the variable at hand, as in block 340, to obtain a value, and passes the obtained name and value to subsequent process block(s). Blocks 505-519 are now described first in relation with variables and methods.

#### For Variables

[0056] At block 505, since the variable is of simple type, the value of the variable is fetched. At block 506 the value of the variable is refreshed in the view 141, and the process proceeds to block 502. At block 507, since the variable is of complex type, it is checked against void (e.g. null in Java, or 0 in C programming language). If the variable is void, the process proceeds to block 508, else the process proceeds to block 509.

[0057] At block 508, since the variable of complex type is void, it is displayed as such in the view 141 (this includes pruning the subtree that previously showed detailed values for the same variable at the previous breakpoint, if any). The process then proceeds to block 502.

[0058] At block 509, since a variable of complex type is non-void, it is checked if its details were displayed or not. If not, the process proceeds to block 510, otherwise the process proceeds to block 511.

[0059] At block 510, since a non-void variable of complex type was displayed without its details, or was displayed with details but changed its type, the display of its value is refreshed (e.g., display the same information as that in block 351 in FIG. 3). The process then proceeds to step 502.

[0060] At block 511, since a non-void variable of complex type was displayed with its details, it is checked if its type has changed or not. If yes, the process proceeds to block 510, else the process proceeds to block 512.

[0061] At block 512, since a non-void variable of complex type was displayed with its details and its type has not changed, its fields and suitable methods are collected. There are both real fields and semantic fields, as for any complex type variable or method result.

**[0062]** At block 513, optionally the debugger filters out some of the fields/methods, based upon various criteria, and only retains the remaining ones as needing to be presented.

**[0063]** At block 514, optionally the debugger sorts the fields/methods according to sorting criteria associated with the view or the debugger itself.

**[0064]** At block 515, the first field/methods that is still to be handled is selected and removed from the list of fields/methods to handle.

**[0065]** At block 516, the field/method is pushed onto the stack.

**[0066]** At block 517, if there are more fields/methods on the stack to handle, the process loops back to block 515, else the process loops back to block 502.

**[0067]** At block 519, the stack is empty and all visible variables have been refreshed, wherein the process proceeds to block 480 (FIG. 4).

#### For Methods

**[0068]** Blocks 505-511 use the pattern-based marker for the method (indicating the method is an eligible method) and return the value computed at block 503 as if they were the name and value of a field. The simple name is a subpart of the complete, pattern-based method name, wherein for example, assuming that SEMANTIC\_FIELD be the marker, then a method named SEMANTIC\_FIELD\_gender would be presented as a semantic field named gender.

**[0069]** Block 512, collect fields and suitable methods.

**[0070]** Block 513 is applied to fields and methods.

**[0071]** Block 514 is applied to fields and methods.

**[0072]** Block 515 selects a field or a method.

**[0073]** Block 516 pushes a field or a method upon the stack.

**[0074]** Another example involves calling methods more sparingly. The debugger presents methods as special fields, and provides the user with controls to call them, either individually or batches at a time. There is a continuum of possible implementations ranging from systematic execution (described hereinabove) to the display of a “refresh” indicator close to each special field, which the user would have to click to obtain the corresponding value.

**[0075]** Embodiments of the present invention are applicable to all object programming languages that are equipped with debug-time runtime introspection, at least to the point of enabling the execution of methods which are selected at runtime. This includes at least most interpreted programming languages, certain semi-interpreted programming languages (e.g., Java), and certain compiled programming languages. In the case of compiled programs, it is common practice to pass compiler specific options to produce a debug-enabled version of the executable application; that version carries sufficient information for the debugger to interpret memory and registers contents, and to modify the memory and registers contents with the effect of assigning new values to attributes or running methods of objects; this is not using introspection per se, but points to the same needed basic abilities, i.e., access to an object instance, access to its type description, read its attributes, execute its methods.

**[0076]** All methods that take no parameter and return a value are possibly eligible for application of the invention. A developer uses explicit markers to sort those that are elected as semantic fields from those that are not. The former results into additional methods named after a recognizable pattern and a pattern-based filtering of methods is used to determine eligible methods.

**[0077]** The debugger may apply further matching and filtering rules to select even fewer methods (e.g., the debugger may be equipped with built-in or user level matching rules

such as “all instance methods whose name starts with get”). The recognizable pattern may be unique or multiple, and can be disclosed to and changed by the developer or not depending upon the implementation.

**[0078]** The invention only leverages the user code as it is written and can be readily adopted by diverse debuggers, without requiring sharing of knowledge about the debugger implementations. The invention can be reused with logging frameworks since the invention enables writing of rendering methods that are available with the code under test, wherein said methods can be reused for other debugging purposes, and especially logging. The invention further provides efficient encapsulation, wherein the effort of bridging the internals towards semantics is left with the class under test author, which is the most capable of doing so.

**[0079]** As noted, according to an embodiment of the invention, mark-up information is included in the source code of an application program. The mark-up information is then processed to generate a debug-enabled version of the application program. Such a debug-enabled version of the application program may comprise eligible debugging methods named after a recognizable pattern. An example debugger includes a built-in filtering rule (naming rule) that keeps eligible methods named after said recognizable pattern, and a short name derivation rule that leverages said recognizable pattern.

**[0080]** In one implementation, the mark-up information comprises specific keywords that are included into comments of the source code of the considered programming language for the application program. A preprocessor P1 then processes the application program source code (including the mark-up information) and generates a debug-enabled version of the application program. The debug-enabled version of the application program may be compiled depending upon the language (for all languages except purely interpreted ones). Then the result is provided to a debugger described further above, and may be further parameterized to filter methods and derive their short names (details further below).

**[0081]** Eligible methods naming rules must enable the filtering of the eligible methods. One example involves a recognizable pattern that is both compatible with the considered programming language, and very unlikely to appear in typical method names (e.g., a name starting with \_DEBUG\_, or a name such as 7ZEG6534). Different patterns may be used, with or without offering the user the choice of using some or all of them at any given time.

**[0082]** Said naming rules must also carry the desired short name of a method (if specified). One example involves using the recognizable pattern (e.g., \_DEBUG\_\*, wherein \* denotes the short name).

**[0083]** Said naming rules may also carry other parameters (if needed), wherein in one example a developer associates a debug level to each eligible method, or associates one or more debug channels to each eligible method. The user can decide at which level or upon which channel the debugger focuses.

**[0084]** After P1 preprocessing, then, optionally, a production version of the application program is generated which is more compact than the debug-enabled version, and potentially more compact than the original application program. The production version of the application program may comprise a copy of the original application program without methods marked by the developer as needed for debugging purposes only.

**[0085]** For example, a preprocessor P2 processes the source code of the application program and generates source code for a production version of the application program, which is provided to a production system (i.e., sent to a production

environment, after having been transformed from sources to whatever the production system consumes, using the normal, existing means to do so).

**[0086]** For each mark-up that signifies to P1 that an eligible method is needed, P1 generates a wrapper method with the appropriate name. A developer would have the choice to develop methods that have the appropriate name beforehand, and to mark such method as e.g., “use for debug”. Certain mark-up information may be dedicated to P2 as needed.

**[0087]** An example source code including mark-up information and result of processing by P1, P2 are provided in Tables 1-3 below, respectively (comments start with //). Further, FIG. 6 shows an example view 60 resulting from the code in Tables 1-3.

TABLE 1

Original application source code with mark-up (e.g., comments that contain DEBUG)
<pre> public class Employee { // WITH A BUG     public int encodedValue;     private static final int BIRTH_YEAR_MASK = 0xFF;     private static final int GENDER_MASK = 0xE000;     public static final String         FEMALE = "female",         MALE = "male";     public Employee(int birthYear, boolean female) {         if (birthYear &gt; 2100) {             throw new IllegalArgumentException("year of birth must be             &lt;= 2100");         }         if (birthYear &lt; 1900) {             throw new IllegalArgumentException("year of birth must be             &gt;= 1900");         }         this.encodedValue = birthYear;         if (!female) {             this.encodedValue  = GENDER_MASK;         }     }     // DEBUG String getBirthYear birthYear     public int getBirthYear() {         return this.encodedValue &amp; BIRTH_YEAR_MASK;     }     // DEBUG String getGender gender     public String getGender() {         return (this.encodedValue &amp; GENDER_MASK) == 0 ?         FEMALE : MALE;     }     // DEBUG {     private String DEBUG hexaView() {         return Integer.toHexString(this.encodedValue);     }     // DEBUG }     public static void main(String[] args) {         Employee employee = new Employee(1903, false);         System.out.println(employee.getBirthYear());     } } </pre>

TABLE 2

Result of P1 - debug-enabled application
<pre> public class Employee { // WITH A BUG     public int encodedValue;     private static final int BIRTH_YEAR_MASK = 0xFF;     private static final int GENDER_MASK = 0xE000;     public static final String         FEMALE = "female",         MALE = "male";     public Employee(int birthYear, boolean female) {         if (birthYear &gt; 2100) { </pre>

TABLE 2-continued

Result of P1 - debug-enabled application
<pre>             throw new IllegalArgumentException("year of birth must be &lt;=             2100");         }         if (birthYear &lt; 1900) {             throw new IllegalArgumentException("year of birth must be &gt;=             1900");         }         this.encodedValue = birthYear;         if (!female) {             this.encodedValue  = GENDER_MASK;         }     }     private int DEBUG birthYear() {         return getBirthYear();     }     public int getBirthYear() {         return this.encodedValue &amp; BIRTH_YEAR_MASK;     }     private String DEBUG gender() {         return getGender();     }     public String getGender() {         return (this.encodedValue &amp; GENDER_MASK) == 0 ?         FEMALE : MALE;     }     private String DEBUG hexaView() {         return Integer.toHexString(this.encodedValue);     }     public static void main(String[] args) {         Employee employee = new Employee(1903, false);         System.out.println(employee.getBirthYear());     } } </pre>

TABLE 3

Result of P2 - production-ready application
<pre> public class Employee { // WITH A BUG     public int encodedValue;     private static final int BIRTH_YEAR_MASK = 0xFF;     private static final int GENDER_MASK = 0xE000;     public static final String         FEMALE = "female",         MALE = "male";     public Employee(int birthYear, boolean female) {         if (birthYear &gt; 2100) {             throw new IllegalArgumentException("year of birth must be &lt;=             2100");         }         if (birthYear &lt; 1900) {             throw new IllegalArgumentException("year of birth must be &gt;=             1900");         }         this.encodedValue = birthYear;         if (!female) {             this.encodedValue  = GENDER_MASK;         }     }     public int getBirthYear() {         return this.encodedValue &amp; BIRTH_YEAR_MASK;     }     public String getGender() {         return (this.encodedValue &amp; GENDER_MASK) == 0 ?         FEMALE : MALE;     }     public static void main(String[] args) {         Employee employee = new Employee(1903, false);         System.out.println(employee.getBirthYear());     } } </pre>

[0088] FIG. 7 shows an example functional block diagram of a system 65, according to an embodiment of the invention.

[0089] Source files 70 of the application program to be debugged are processed by a processor 71 (i.e., P1) to generate debug-ready sources 72. A processor 73 (i.e., P2) processes the source files 70 and generates production sources 74.

[0090] The processor 71 may comprise a software module configured for processing the mark-up information in the source files 70 as described herein. The processor 71 is configured for reading source files 70 of the target language including mark-up information (e.g., embedded into comments), and generating debug-ready source files 72. The debug-ready sources 72 comprises a version of the sources 70 augmented with debug-only methods which take no parameter, return a result, and have a name that encodes a marker and a simple/short name (that the debugger will be able to decode).

[0091] The processor 72 is configured for reading source files 70 of the target language including mark-up information, and generating production source files 74. The processor 72 may comprise a software module from processor 71, or a single software module used with different options can provide functionality of processors 71, 72. Production sources 74 comprise a version of the source files 70 without the debug methods that the author of sources 70 deems desirable for debug purposes only.

[0092] Optionally, depending on the target language of the sources 70, the following can be in the realm of programming-language to machine binary compilers, programming-language to virtual machine binary compilers, or pure interpreted target languages, in which case the sources 72 and 74 are executed and debugged directly on the target system. A compiler 75 transforms source files to binaries suitable for execution in a target computing system, wherein a same program typically produces the applications 76, 78, and the symbolic information leveraged by debuggers 77.

[0093] The application 76 comprises a binary, debug-ready application that has all the methods generated by the processor P1. The database 77 includes symbolic information associated to the debug-ready application 76; note that in this embodiment the present invention is implemented in P1 and affects processing by P2, leveraging the normal operation of the compiler 75. The application 78 comprises a binary, production application that includes no debug-only methods.

[0094] The developer of the class under test selects which methods will be used as special fields. As the writer of the code of the application under test, the developer is uniquely positioned to decide whether a given method has side effects or not, and may not select methods that have side effects, thereby eliminating the risk of modifying the behaviour of the application program under test. The developer is provided an opportunity to decide the short name of each special field, which may potentially vary from the method name. The developer is also provided with an opportunity to introduce as many special fields deemed necessary, without impacting the production version of the application.

[0095] The invention promotes programming of as many special fields as needed, and provides appropriate mechanisms to release production-grade systems that are unencumbered with debug-only code. The invention further provides more efficient encapsulation, wherein the effort of bridging the internals towards semantics is left with the author/developer of the class under test.

[0096] The invention further provides lightweight runtime by use of markers to exclude renderers that are not necessary. The invention provides versatility (e.g., levels, channels, parameters). A preferred embodiment leverages the full Java programming language, making certain desirable patterns simple to implement.

[0097] In one example, Java annotations (available since Java 5) are, at the conceptual level, a preferable manner of marking methods for the purpose of the present invention. Such annotations are more flexible than comments and better linked to the methods they decorate. However, they have the drawback that they are not available in most languages, and that a processor that understands them is needed. While such processors exist, understanding how they work and leveraging them can be more complex than a very simple comments grammar. An implementation targeting the Java language would then prefer annotations, while other implementations would use the simpler and more generally available techniques described above.

[0098] FIG. 8 illustrates an information handling system 601 which is a simplified example of a computer system capable of performing the computing operations described herein. Computer system 601 includes processor 600 which is coupled to host bus 602. A level two (L2) cache memory 604 is also coupled to host bus 602. Host-to-PCI bridge 606 is coupled to main memory 608, includes cache memory and main memory control functions, and provides bus control to handle transfers among PCI bus 610, processor 600, L2 cache 604, main memory 608, and host bus 602. Main memory 608 is coupled to Host-to-PCI bridge 606 as well as host bus 602. Devices used solely by host processor(s) 600, such as LAN card 630, are coupled to PCI bus 610. Service Processor Interface and ISA Access Pass-through 612 provides an interface between PCI bus 610 and PCI bus 614. In this manner, PCI bus 614 is insulated from PCI bus 610. Devices, such as flash memory 618, are coupled to PCI bus 614. In one implementation, flash memory 618 includes BIOS code that incorporates the necessary processor executable code for a variety of low-level system functions and system boot functions.

[0099] PCI bus 614 provides an interface for a variety of devices that are shared by host processor(s) 600 and Service Processor 616 including, for example, flash memory 618. PCI-to-ISA bridge 635 provides bus control to handle transfers between PCI bus 614 and ISA bus 640, universal serial bus (USB) functionality 645, power management functionality 655, and can include other functional elements not shown, such as a real-time clock (RTC), DMA control, interrupt support, and system management bus support. Nonvolatile RAM 620 is attached to ISA Bus 640. Service Processor 616 includes JTAG and I2C busses 622 for communication with processor(s) 600 during initialization steps. JTAG/I2C busses 622 are also coupled to L2 cache 604, Host-to-PCI bridge 606, and main memory 608 providing a communications path between the processor, the Service Processor, the L2 cache, the Host-to-PCI bridge, and the main memory. Service Processor 616 also has access to system power resources for powering down information handling device 601.

[0100] Peripheral devices and input/output (I/O) devices can be attached to various interfaces (e.g., parallel interface 662, serial interface 664, keyboard interface 668, and mouse interface 670 coupled to ISA bus 640). Alternatively, many I/O devices can be accommodated by a super I/O controller (not shown) attached to ISA bus 640.



[0101] In order to attach the computer system 601 to another computer system to copy files over a network, LAN card 630 is coupled to PCI bus 610. Similarly, to connect computer system 601 to an ISP to connect to the Internet using a telephone line connection, modem 675 is connected to serial port 664 and PCI-to-ISA Bridge 635.

[0102] While the computer system described in FIG. 8 is capable of executing the processes described herein, this computer system is simply one example of a computer system. Those skilled in the art will appreciate that many other computer system designs having one or more processors are capable of performing the processes described herein.

[0103] As is known to those skilled in the art, the aforementioned example embodiments described above, according to the present invention, can be implemented in many ways, such as program instructions for execution by a processor, as software modules, as computer program product on computer readable media, as logic circuits, as silicon wafers, as integrated circuits, as application specific integrated circuits, as firmware, etc. Though the present invention has been described with reference to certain versions thereof, however, other versions are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

[0104] Those skilled in the art will appreciate that various adaptations and modifications of the just-described preferred embodiments can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

What is claimed is:

1. A method of interactive debugging of an object-oriented computer program, comprising:
  - including mark-up information into source code of the application program, the mark-up information associated with eligible debugging methods;
  - generating a debug-enabled version of the computer program including debugging methods based on the mark-up information;
  - providing the debug-enabled version of the program computer to a debugger for debugging purposes using the debugging methods.
2. The method of claim 1 wherein debugging methods further include eligible debugging methods named after a recognizable pattern.
3. The method of claim 2 wherein the debugger comprises a debugger configured for filtering based on naming rules for maintaining eligible methods named after said recognizable pattern, and a short name derivation rule that leverages said recognizable pattern.
4. The method of claim 3 wherein the mark-up information comprises specific keywords that are included into comments of the source code for the computer program.
5. The method of claim 3 wherein the naming rules include:
  - a recognizable pattern for debugging methods that is both compatible with the considered programming language for the computer program, and unlikely to appear in typical method names; and
  - rules for deriving a short name of a debugging method from the method name.

6. The method of claim 2 wherein the debugging methods comprise debug-only methods which take no parameter, return a result, and have a name that encodes a marker and a short name.

7. The method of claim 6 wherein generating a debug-enabled version of the computer program further includes generating wrapper debugging methods with the appropriate names.

8. The method of claim 1 further including generating a production version of the computer program.

9. A system for interactive debugging of a computer program, comprising:

- a preprocessing module configured for receiving source code of the computer program including mark-up information, the mark-up information associated with eligible debugging methods, and generating a debug-enabled version of the computer program including debugging methods based on the mark-up information; and

- a debugger configured for executing the debug-enabled version of the program computer for debugging purposes using the debugging methods.

10. The system of claim 9 wherein debugging methods further include eligible debugging methods named after a recognizable pattern.

11. The system of claim 10 wherein the debugger is configured for filtering based on naming rules for maintaining eligible methods named after said recognizable pattern, and a short name derivation rule that leverages said recognizable pattern.

12. The system of claim 11 wherein the mark-up information comprises specific keywords that are included into comments of the source code for the computer program.

13. The system of claim 11 wherein the naming rules include:

- a recognizable pattern for debugging methods that is both compatible with the considered programming language for the computer program, and unlikely to appear in typical method names; and

- rules for deriving a short name of a debugging method from the method name.

14. The system of claim 10 wherein the debugging methods comprise debug-only methods which take no parameter, return a result, and have a name that encodes a marker and a short name.

15. The system of claim 14 wherein the preprocessing module is further configured for generating a debug-enabled version of the computer program by generating wrapper debugging methods with the appropriate names.

16. A computer program product for interactive debugging of an application program, comprising a computer usable medium including a computer readable program, wherein the computer readable program when executed on a computer causes the computer to:

- receive source code of the application program including mark-up information, the mark-up information associated with eligible debugging methods, and generate a debug-enabled version of the application program including debugging methods based on the mark-up information; and

- executing the debug-enabled version of the application program for debugging purposes using the debugging methods.

**17.** The computer program product of claim **16** wherein debugging methods further include eligible debugging methods named after a recognizable pattern, and instructions for executing the debug-enabled version further include instructions for filtering based on naming rules for maintaining eligible methods named after said recognizable pattern, and a short name derivation rule that leverages said recognizable pattern.

**18.** The computer program product of claim **17** wherein the naming rules include: a recognizable pattern for debugging methods that is both compatible with the considered programming language for the application program, and unlikely

to appear in typical method names; and rules for a desired short name of a debugging method.

**19.** The computer program product of claim **17** wherein the debugging methods comprise debug-only methods which take no parameter, return a result, and have a name that encodes a marker and a short name.

**20.** The computer program product of claim **19** wherein the instructions to generate a debug-enabled version of the application program further includes instructions to generate a debug-enabled version of the computer program by generating wrapper debugging methods with the appropriate names.

\* \* \* \* \*