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(54) **REDUCING THE SIZE OF IMAGE FILES USABLE FOR DEPLOYING SOFTWARE IN COMPUTING ENVIRONMENTS**

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G06F 8/65	(2018.01)
G06F 21/57	(2013.01)

(52) **U.S. Cl.**
CPC ***G06F 8/63*** (2013.01); ***G06F 8/65*** (2013.01); ***G06F 21/577*** (2013.01); *G06F 2221/033* (2013.01)

(58) **Field of Classification Search**
CPC . G06F 8/63; G06F 8/65; G06F 21/577; G06F 2221/033
See application file for complete search history.

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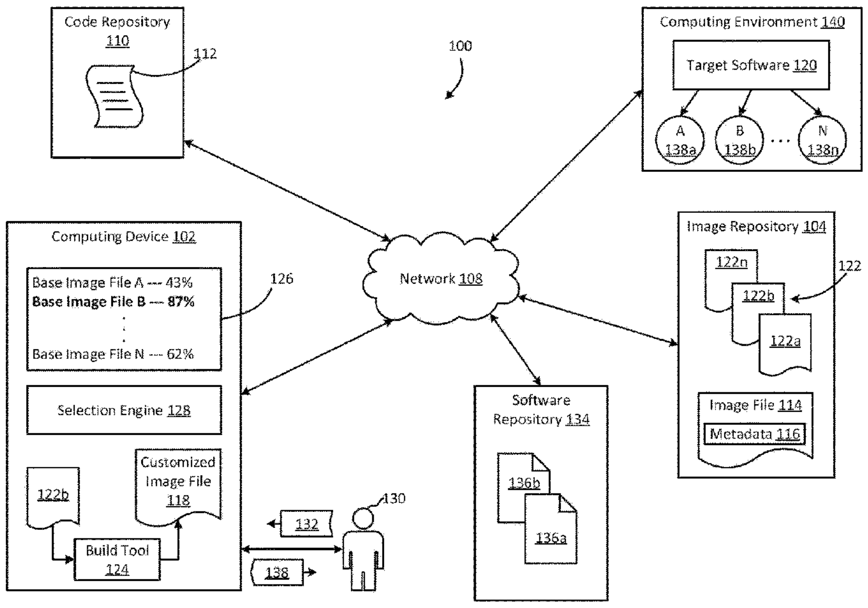
(57) **ABSTRACT**

The sizes of image files for deploying software in a computing environment can be reduced according to some examples described herein. In one example, a system can identify base image files that each include at least a predefined amount of dependencies relied upon by target software. The system can then select a particular base image file, from the base image files, having a smallest size as compared to a remainder of the base image files. The system can then build a customized image file from the base image file, where the customized image file is configured for deploying the target software to a computing environment.

20 Claims, 8 Drawing Sheets



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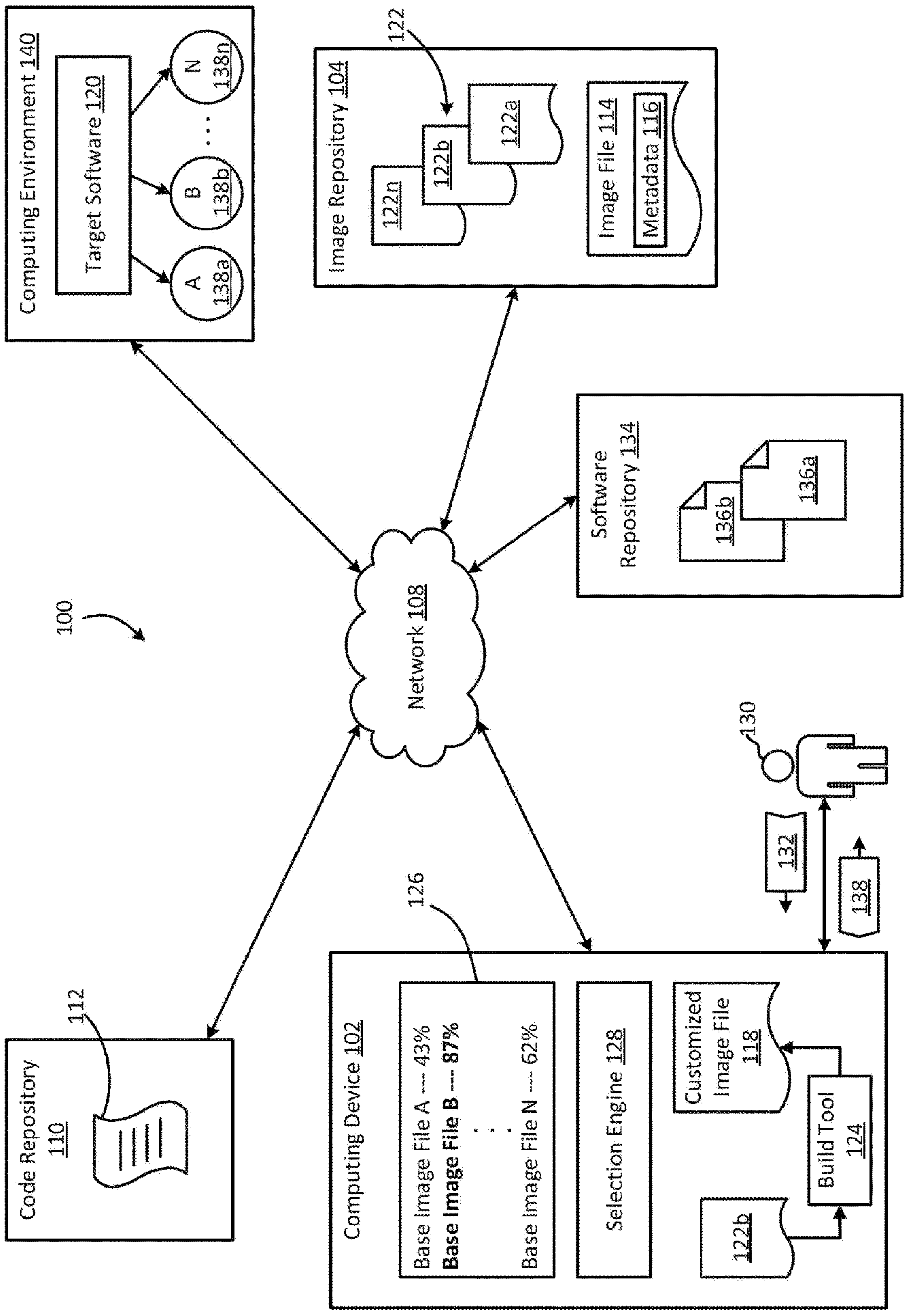
100
Computing Environment 140
Target Software 120
A 138a
B 138b
N 138n
Image Repository 104
122
122a
122b
122n
Image File 114
Metadata 116
Software Repository 134
136a
136b
Network 108
Code Repository 110
112
Computing Device 102
126
Base Image File A --- 43%
Base Image File B --- 87%
Base Image File N --- 62%
Selection Engine 128
Customized Image File 118
Build Tool 124
122b
130
132
138

FIG. 1

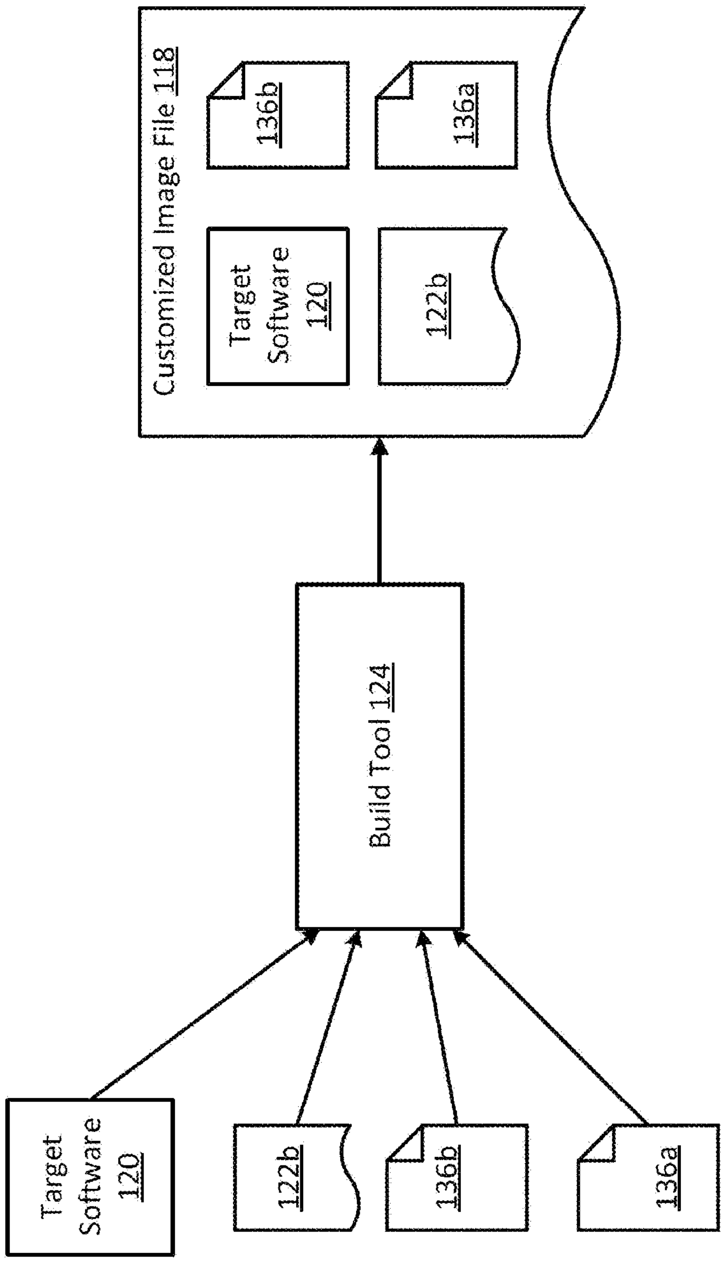
Target Software 120
122b
136b
136a
Build Tool 124
Customized Image File 118
Target Software 120
122b
136b
136a

FIG. 2

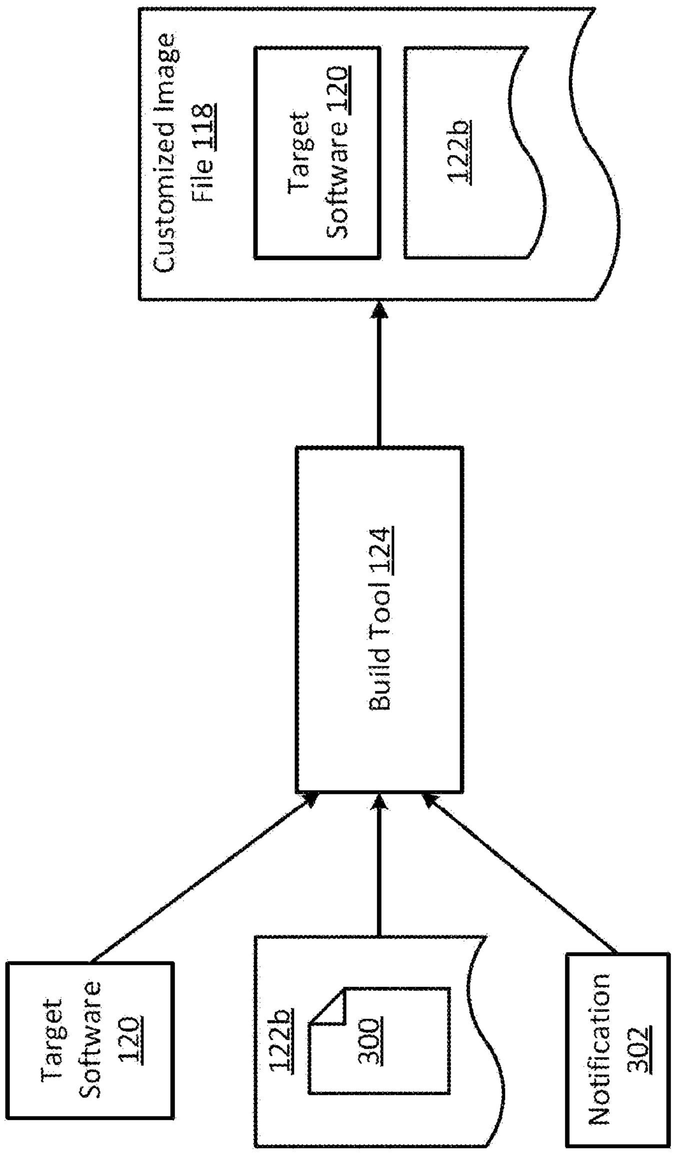
Target Software 120
122b
300
Notification 302
Build Tool 124
Customized Image File 118
Target Software 120
122b

FIG. 3

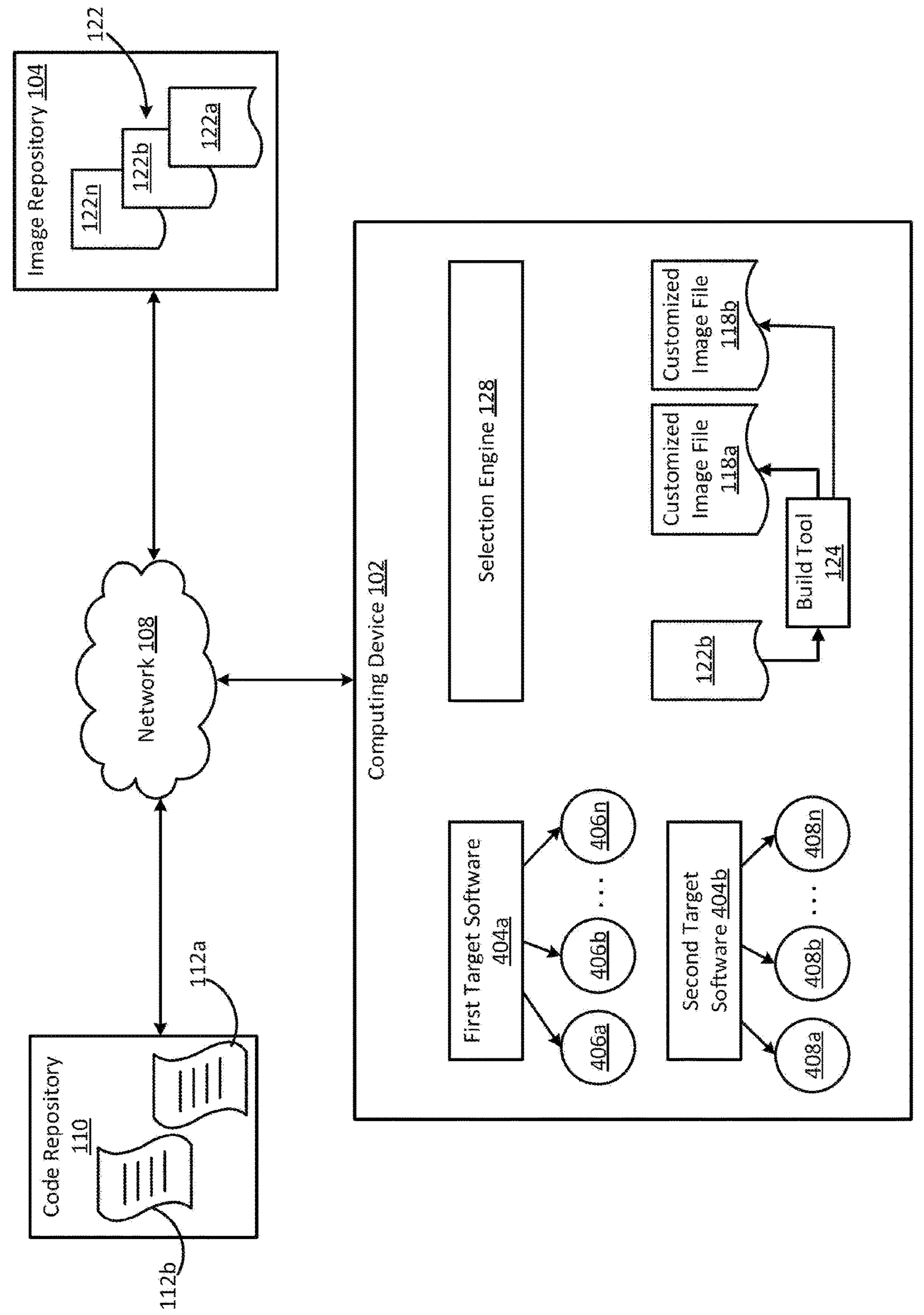
Image Repository 104
122
122n
122b
122a
Network 108
Code Repository 110
112a
112b
Computing Device 102
Selection Engine 128
Customized Image File 118a
Customized Image File 118b
122b
Build Tool 124
First Target Software 404a
406a
406b
. . .
406n
Second Target Software 404b
408a
408b
. . .
408n

FIG. 4

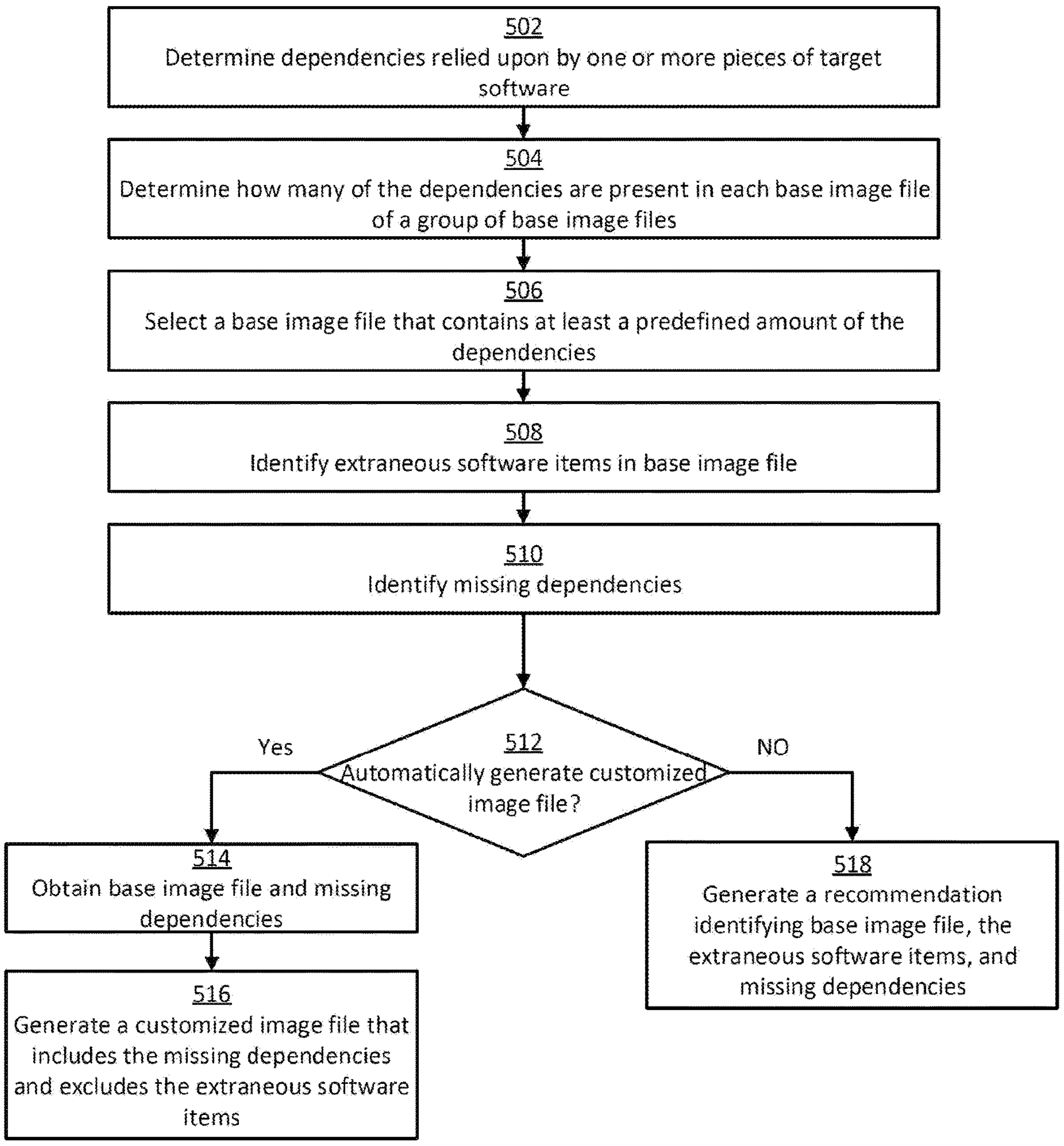
502
Determine dependencies relied upon by one or more pieces of target software
504
Determine how many of the dependencies are present in each base image file of a group of base image files
506
Select a base image file that contains at least a predefined amount of the dependencies
508
Identify extraneous software items in base image file
510
Identify missing dependencies
512
Automatically generate customized image file?
Yes
NO
514
Obtain base image file and missing dependencies
516
Generate a customized image file that includes the missing dependencies and excludes the extraneous software items
518
Generate a recommendation identifying base image file, the extraneous software items, and missing dependencies

FIG. 5

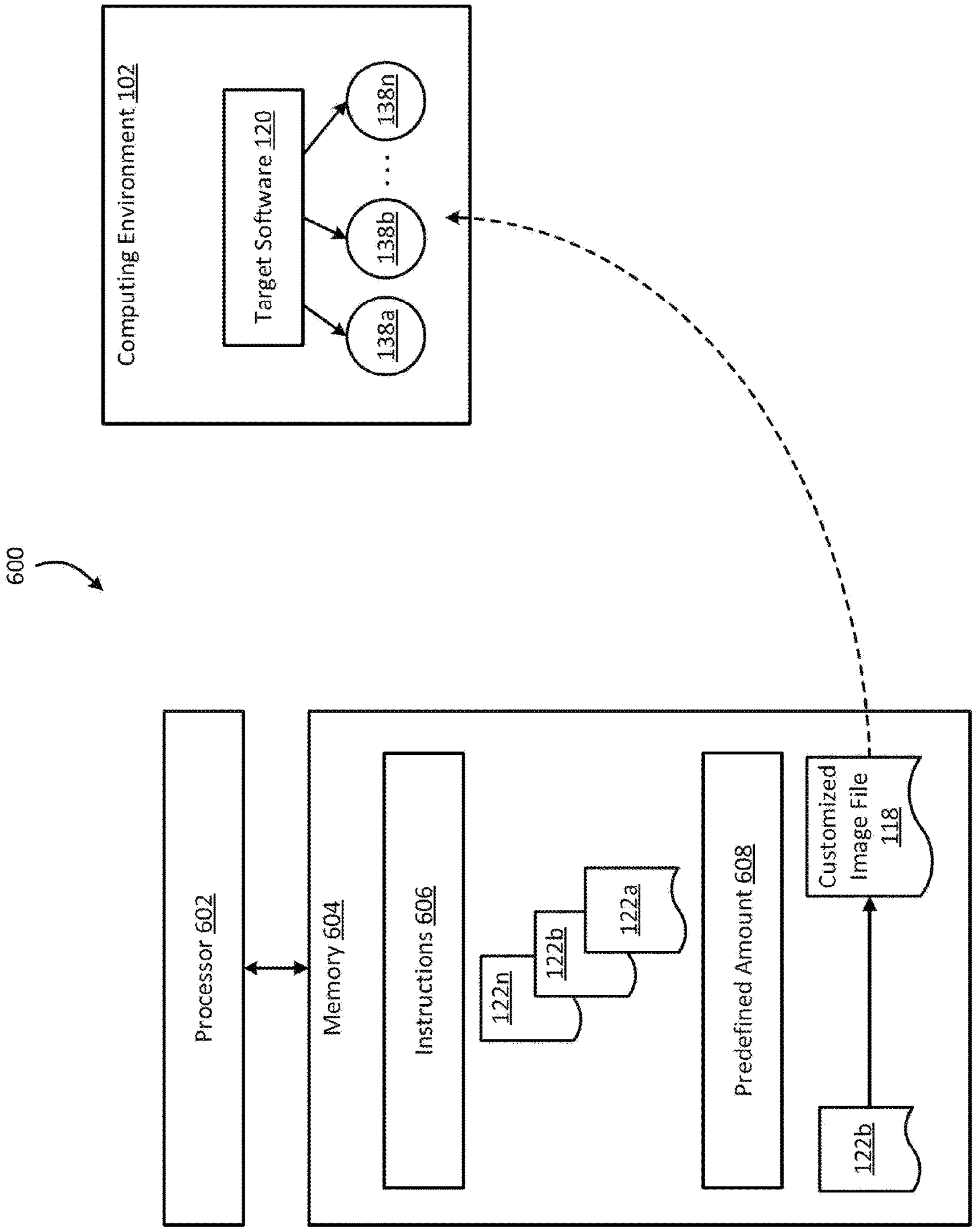
600
Computing Environment 102
Target Software 120
138a
138b
138n
Processor 602
Memory 604
Instructions 606
122a
122b
122n
Predefined Amount 608
Customized Image File 118
122b

FIG. 6

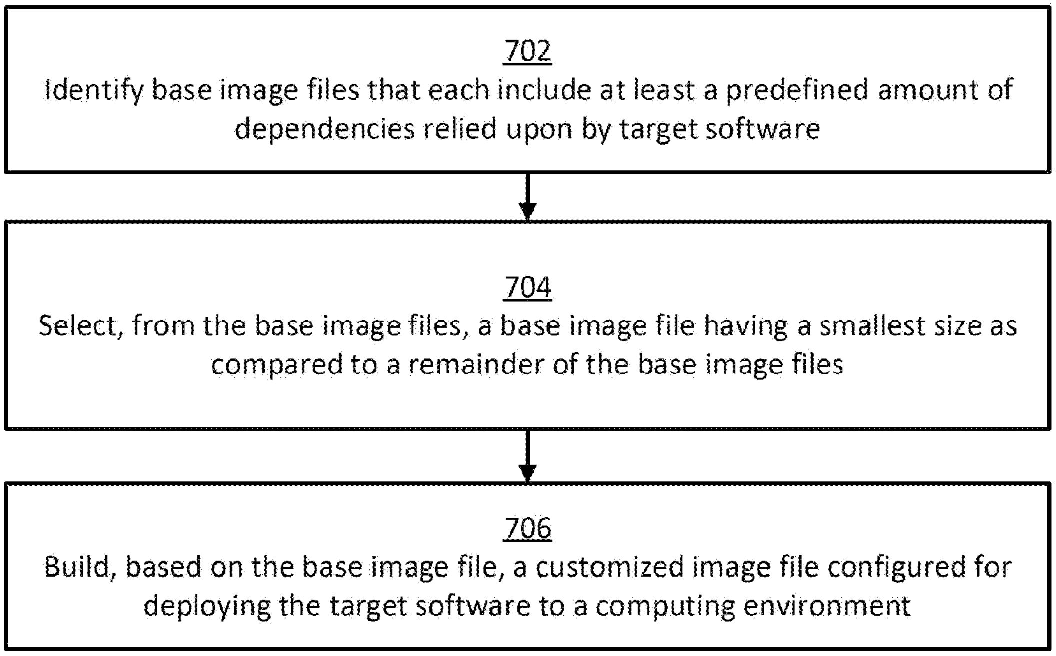
702
Identify base image files that each include at least a predefined amount of dependencies relied upon by target software
704
Select, from the base image files, a base image file having a smallest size as compared to a remainder of the base image files
706
Build, based on the base image file, a customized image file configured for deploying the target software to a computing environment

FIG. 7

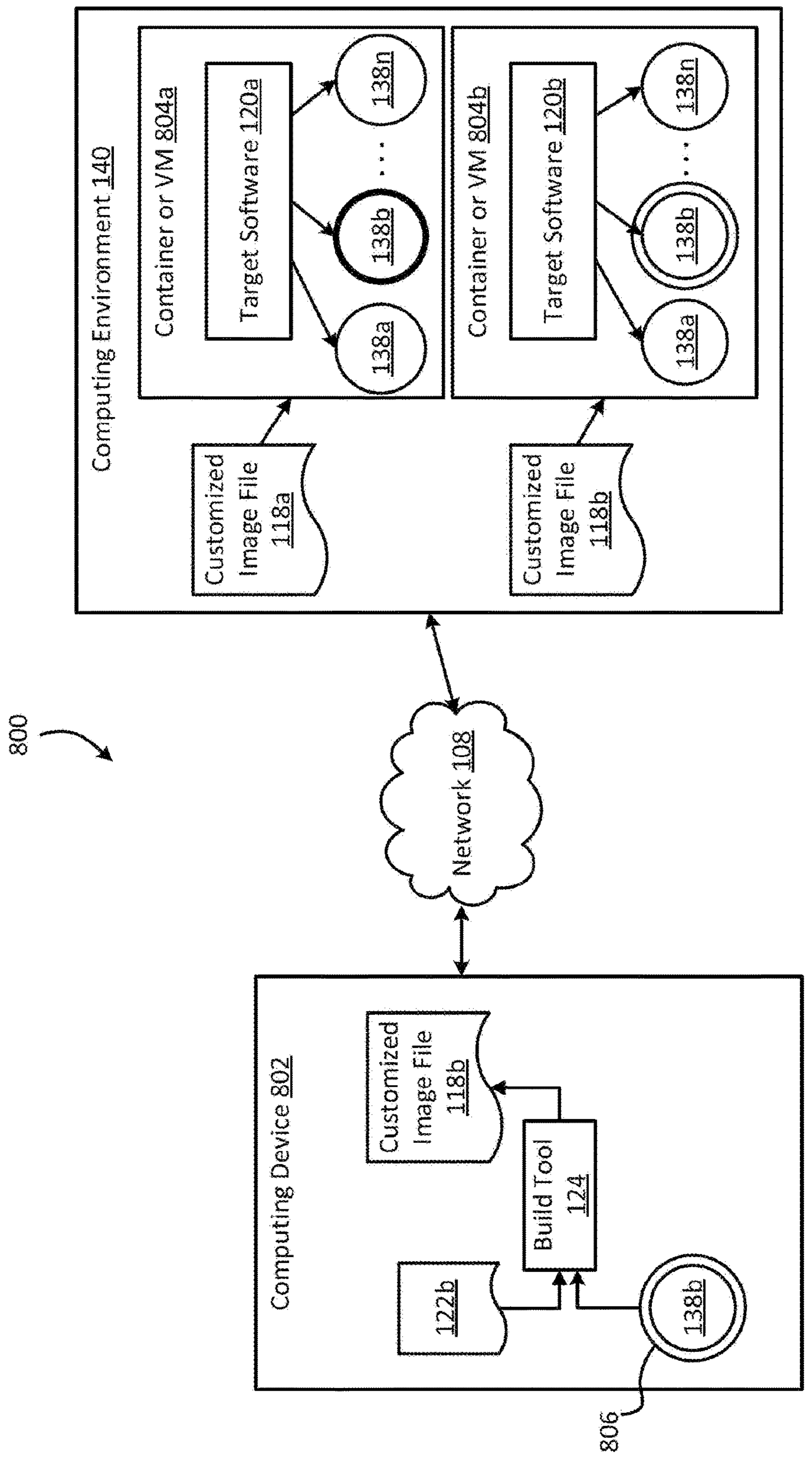
800
Computing Environment 140
Container or VM 804a
Target Software 120a
138a
138b
138n
Container or VM 804b
Target Software 120b
138a
138b
138n
Customized Image File 118a
Customized Image File 118b
Network 108
Computing Device 802
122b
Build Tool 124
Customized Image File 118b
138b
806

FIG. 8

REDUCING THE SIZE OF IMAGE FILES USABLE FOR DEPLOYING SOFTWARE IN COMPUTING ENVIRONMENTS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. application Ser. No. 17/592,140 (now issued as U.S. Pat. No. 11,928,452), titled, "Reducing the Size of Image Files Usable for Deploying Software in Computing Environments," and filed Feb. 3, 2022, the entirety of which is hereby incorporated by reference herein.

TECHNICAL FIELD

The present disclosure relates generally to image files for deploying software in a computing environment. More specifically, but not by way of limitation, this disclosure relates to reducing the size of image files usable for deploying software in a computing environment.

BACKGROUND

Software can be deployed in computing environments using image files. An image file is generally a static file that includes executable code usable to deploy the software in a computing environment. An image file may also include the software's dependencies. Examples of such dependences can include the operating system, configuration files, packages, and libraries used to run the software. Incorporating the software's dependencies into the image files may allow the software to be quickly and easily deployed.

Image files are often configured for deploying their corresponding software inside isolated virtual environments that exist within a larger computing environment. For example, an image file may be configured to deploy software inside a container of a computing environment. A container is a relatively isolated virtual environment that can be generated by leveraging resource isolation features (e.g., cgroups and namespaces) of the Linux kernel. A deployment tool such as Docker® can be used to deploy the software inside the container from the image file. Deployment of software inside of such containers can be referred to as containerization. As another example, the image file may be configured to deploy the software inside a virtual machine of a computing environment. A deployment tool such as a hypervisor can be used to deploy the software inside the virtual machine from the image file.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an example of a system for reducing the size of image files usable for deploying software according to some aspects of the present disclosure.

FIG. **2** is a block diagram of an example of process for building a customized image file from a base image file that is missing dependencies according to some aspects of the present disclosure.

FIG. **3** is a block diagram of an example of a process for building a customized image file from a base image file that has an extraneous software item according to some aspects of the present disclosure.

FIG. **4** is a block diagram of an example of a system for building a customized image file based on dependencies associated with multiple pieces of software according to some aspects of the present disclosure.

FIG. **5** is a flow chart of an example of a process for generating a customized image file or a recommendation according to some aspects of the present disclosure.

FIG. **6** is a block diagram of an example of a system for building a customized image file according to some aspects of the present disclosure.

FIG. **7** is a flow chart of another example of a process building a customized image file according to some aspects of the present disclosure.

FIG. **8** is a block diagram of an example of a system for updating a customized image file according to some aspects of the present disclosure.

DETAILED DESCRIPTION

Software can be deployed in a computing environment using image files. The image files generally include the target software to be deployed along with its dependencies. But such image files can also include extraneous software items (e.g., packages, libraries, binaries, etc.) that are not required to run the target software. This can occur because the image files are often generated from base image files that are generic and over-inclusive. For example, a developer of target software may obtain a base image file from a publisher thereof. The developer may then combine additional software items with the base image file to build a customized image file (e.g., a specialized image file) for the target software. A customized image file can be an image file that has been adapted from a base image file for deploying target software and its dependencies to a computing environment. Because many developers may wish to use the same base image file as the foundation from which to build customized image files for various types of software, the base image file may be designed to be generic. For example, the base image file may contain the relevant dependencies for the target software as well as other extraneous software items, such as dependencies for other software. As a result, the customized image files derived from the base image file may be larger (in terms of storage size) than is necessary to run their target software. When applied to multiple image files, the cumulative effect can be that a significant amount of storage space is unnecessarily consumed due to this over-inclusivity.

Another problem arising from the abovementioned over-inclusivity is that the extraneous software items may be intentionally or accidentally run when the customized image file is deployed. Execution of these extraneous software items can unnecessarily consume computing resources, such as memory, processing power, storage space, and bandwidth. The extraneous software items may also introduce attack vectors that can be exploited by malicious actors, for example if the extraneous software items have vulnerabilities or bugs.

Some examples of the present disclosure can overcome one or more of the abovementioned problems by automatically selecting, from among a group of candidate base image files, the smallest base image file that satisfies one or more predefined criteria for use in constructing a customized image file for target software. One example of the predefined criteria may be that the base image file contains at least a predefined amount of the dependencies of the target software. Such a base image file may be considered the "optimal" base image file for the target software. By selecting the base image file based on these factors, the number of extraneous software items can be reduced and, consequently, the size of the resulting customized image file can be reduced.

For example, a system described herein can determine dependencies relied upon by target software by analyzing the source code for the target software. The system can then analyze each base image file in a group of candidate base image files to determine how many of the dependences are present in each base image file. The system can select whichever of the candidates contains at least a predefined amount of the dependencies. The predefined amount may be user customizable. If multiple base image files contain at least the predefined amount of dependencies, then the smallest base image file (e.g., in terms of storage size) can be selected from among the multiple base image files. The selected base image file can be considered the optimal base image file for the target software. The system can use the selected base image file as a foundation from which to build a customized image file configured for deploying the target software to a computing environment.

As one specific example, the system may determine that the target software is a microservice that requires 13 total dependencies to properly execute. The system can then automatically evaluate each base image file in a group of 135 candidate base image files to determine which of them contains at least a predefined amount of the required dependencies. The predefined amount may be 100% of the required dependencies or less than 100% of the required dependencies. In an example in which the predefined amount is 80%, the system may select one or more base image files that each contain at least 11 of the dependencies (since it is not possible to have a fraction of a dependency). If multiple base image files are selected that contain at least 11 of the dependencies, then the system can select whichever of those base image file is the smallest in size. The system can then build a customized image file based on the selected base image file, where the customized image file is configured for deploying the microservice to a computing environment. The customized image file may be generated based on the base image file and include any missing dependencies, so that the customized image file includes all required dependencies. Using these techniques, a base image file can be selected that strikes a desired balance between size and dependency coverage in relation to the target software, subject to the user's preferences. This, in turn, can reduce the number of attack vectors and resource consumption associated with the customized image file.

These illustrative examples are given to introduce the reader to the general subject matter discussed here and are not intended to limit the scope of the disclosed concepts. The following sections describe various additional features and examples with reference to the drawings in which like numerals indicate like elements but, like the illustrative examples, should not be used to limit the present disclosure.

FIG. **1** is a block diagram of an example of a system **100** for optimizing images for deploying software according to some aspects of the present disclosure. The system **100** includes a computing device **102**, such as a desktop computer, laptop computer, server, mobile phone, or tablet. The computing device **102** can include a selection engine **128** that is executable to automatically identify a base image file (e.g., an optimal base image file) for use in constructing a customized image file **118** for target software **120**.

To identify the base image file, the selection engine **128** can begin by determining dependencies **138***a-n* of the target software **120**. The target software **120** may be any type of software, such as a service, microservice, serverless function, or application. The target software **120** can rely on any number and combination of dependencies **138***a-n*. The selection engine **128** may determine the dependencies

138*a-n* of the target software **120** in any of the following ways, though other ways are also possible and contemplated within the scope of this disclosure.

One way in which the selection engine **128** can determine the dependencies **138***a-n* involves obtaining the source code **112** for the target software **120**. For example, the selection engine **128** can retrieve the source code **112** from a code repository **110** or another location. The code repository **110** may include the source code of one or more pieces of software. After retrieving the source code **112**, the selection engine **128** can parse through the source code **112** to locate references to (e.g., "include" statements for) libraries and other dependencies therein. The selection engine **128** can then recursively parse through those libraries and other dependencies to obtain a complete listing of the dependencies associated with the target software **120**.

In some examples, the selection engine **128** may determine the location from which the source code **112** can be retrieved by analyzing the content or metadata **116** of an existing image file **114** for deploying the target software **120**. The existing image file **114** may have previously been built and stored in an image repository **104** that is accessible to one or more users. The existing image file **114** may contain some or all of the dependencies **138***a-n* of the target software **120** along with extraneous software items. The metadata **116** may be included in the existing image file **114** or may be stored separately from the existing image file **114**. The content or metadata **116** may include, for example, a network address from which the source code **112** can be retrieved. Examples of the network address can include an internet protocol (IP) address or a uniform resource locator (URL) address. In some such examples, the selection engine **128** can access the content or metadata **116**, extract the network address therefrom, and obtain the source code **112** from the network address.

Another way in which the selection engine **128** can determine the dependencies **138***a-n* involves analyzing complementary information associated with the existing image file **114**. Examples of the complementary information can include a "read me" file, a configuration file, a website, or the metadata **116** associated with the target software **120**. In some examples, the complementary information may include a list of the dependencies of the target software **120** or otherwise indicate the dependencies. The selection engine **128** can therefore analyze the complementary information to determine the dependencies **138***a-n.*

Having determined the dependencies **138***a-n* of the target software **120**, the selection engine **128** can determine a group of base image files **122** to analyze. For example, the selection engine **128** can access an image repository **104** in which hundreds or thousands of base image files are stored to identify a group of base image files **122** that are relevant to the target software **120**. This may involve filtering through the base image files in the image repository **104** based on one or more filter criteria to identify the group of base image files **122**. Examples of the filter criteria can include the size (e.g., disk size), name, or content of the base image files. For example, the selection engine **128** may filter the base image files by operating system and only select base image files having an operating system with which the target software **120** is compatible. This filtering process can reduce the total number of base image files in the group **122** and thus reduce the total number of base image files that are subsequently analyzed.

The selection engine **128** can next determine how many of the dependencies **138***a-n* are present in each base image file in the group of base image files **122**. These amounts are represented in box **126** of FIG. **1**. For example, the selection engine **128** may determine that base image file **122***a* contains 43% of the dependencies **138***a-n*, base image file **122***b* contains 87% of the dependencies **138***a-n*, and base image file **122***n* contains 62% of the dependencies **138***a-n*. The selection engine **128** may determine how many of the dependencies **138***a-n* are present in each base image file by analyzing the content of the base image file or complementary information associated with the base image file. Analyzing the content of a base image file may involve downloading the base image files (e.g., via a network **108** such as the Internet), opening it, and inspecting its contents.

Once the selection engine **128** has determined how many of the dependencies **138***a-n* are present in each of the base image files **122***a-n* in the group **122**, the selection engine **128** can select a base image file from the group **122**. In particular, the selection engine **128** can identify and select whichever base image file in the group **122** has at least a predefined amount of the dependencies **138***a-n*. The predefined amount may be user customizable. For example, a user **130** may provide user input **132** specifying the predefined amount. The predefined amount may be 100% or less than 100%.

As one particular example, the predefined amount can be 80%. So, the selection engine **128** may select base image file **122***b*, as represented in FIG. **1** by bolded text, because it is the only base image file that contains 80% or more of the dependencies **138***a-n*. As another example, the predefined amount may be 60%. Since base image file **122***b* and base image file **122***n* both contain at least 60% of the dependencies **138***a-n*, the selection engine **128** may select whichever of those two base image files is smaller in size. In this way, the selection engine **128** may filter the base image files **122***a-n* first by their dependency coverage and then by size. As yet another example, the predefined amount may be 100%. So, the selection engine **128** may not select any of the base image files in the group **122**, because none of them contain all of the dependencies **138***a-n*.

If a base image file **122***b* is selected from the group **122**, the selection engine **128** can next build a customized image file **118** based on the selected base image file **122***b*. To build the customized image file **118**, the selection engine **128** can interact with a build tool **124**. The build tool **124** can be software configured for building image files. The selection engine **128** can provide the base image file **122***b*, along with any other necessary or desired inputs, to the build tool **124** for causing the build tool **124** to construct the customized image file **118**. In some cases the base image file **122***b* may exclude the target software **120**, so the target software **120** may need to be supplied to the build tool **124** as a separate input. Once built, the customized image file **118** can be usable to deploy the target software **120** to a computing environment **140**. In some examples, the computing environment **140** may be a distributed computing environment, such as a cloud computing system, a data grid, or a computing cluster. Alternatively, the computing environment **140** may be another type of computing environment.

In some examples, the selected base image file **122***b* may lack one or more of the dependencies **138***a-n* associated with the target software **120**. So, the selection engine **128** can resolve this gap. For example, the selection engine **128** can identify missing dependencies. Missing dependencies are dependencies of the target software **120** that are absent from the base image file **122***b*. The selection engine **128** may identify the missing dependencies by comparing the required dependencies **138***a-n* to a list of dependencies present in the base image file **122***b*. After identifying the missing dependencies, the selection engine **128** can obtain the missing dependencies and provide them to the build tool **124** for inclusion in the customized image file **118**. Obtaining the missing dependencies can involve downloading program code (e.g., binaries or source code) for the missing dependencies from one or more locations, such as a software repository **134**.

One example of the above process is shown in FIG. **2**. In this example, the selection engine **128** can determine that the base image file **122***b* is missing dependencies **138***a-b*. So, the selection engine **128** can obtain the missing dependencies **138***a-b*. This may involve downloading the program code **136***a-b* for the missing dependencies **138***a-b* from the software repository **134**. The selection engine **129** can then provide the base image file **122***b*, the target software **120**, and the missing dependencies **138***a-b* (e.g., the program code **136***a-b*) as input to the build tool **124**, which can generate a customized image file **118** based on those inputs. Since the base image file **122***b* may be immutable in some situations, it may not be possible to directly edit the base image file **122***b* to add in the target software **120** and dependencies **138***a-b*. So, the build tool **124** can create the customized image file **118** as a new image file that is distinct from the base image file **122***b* and includes the target software **120**, the dependencies **138***a-b*, and the base image file's content. In this way, the customized image file **118** may be built without modifying the base image file **122***b*.

In some examples, the selected base image file **122***b* may include one or more extraneous software items that are not required by the target software **120**. So, the selection engine **128** can resolve this over-inclusiveness. For example, the selection engine **128** can identify extraneous software items in the base image file **122***b*. The selection engine **128** may identify the extraneous software items by comparing the dependencies **138***a-n* of the target software **120** to a list of software items present in the base image file **122***b*. The selection engine **128** can then notify the build tool **124** of the extraneous software items so that they can be excluded from the customized image file **118** during the build process. This can reduce the overall size of the customized image file **118**, avoid the unnecessary consumption of computing resources by the extraneous software items, and eliminate attack vectors associated with the extraneous software items.

One example of the above process is shown in FIG. **3**. As shown, the base image file **122***b* can include an extraneous software item **300**. The build tool **124** can be notified of this extraneous software item **300** and, in response to this notification **302**, generate a customized image file **118** that excludes the extraneous software item **300**. Since the base image file **122***b* may be immutable in some situations, it may not be possible to directly edit the base image file **122***b* to remove the extraneous software item **300**. So, the build tool **124** can create the customized image file **118** as a new image file that is distinct from the base image file **122***b* and excludes the extraneous software item **300**. In this way, the customized image file **118** may be built without modifying the base image file **122***b*.

Although the above examples involve the selection engine **128** working with the build tool **124** to automatically build the customized image file **118**, in other examples the selection engine **128** may instead output a recommendation **138** to the user **130** of how to construct the customized image file **118**. This is further shown in FIG. **1**. The recommendation **138** can notify the user **130** of the selected base image file **122***b*, any missing dependencies, and any extraneous software items. In some examples, the recommendation **138** can also include an option to download the base image file **122***b*. Additionally or alternatively, the recommendation **138** can include options to download the missing dependencies. The options may take the form of hyperlinks, in some examples. Providing the recommendation **138** to the user **130** may allow the user **130** to manually construct the customized image file **118**.

Once the customized image file **118** has been built for the target software **120**, the customized image file **118** can be used to deploy the target software **120** in a computing environment **140**. For example, the customized image file **118** can be transmitted to the computing environment **140**, which can contain a deployment tool that is executable for deploying the target software **120** based on the customized image file **118**. In some examples, the deployment tool can deploy the target software **120** inside a relatively isolated virtual environment, such as a container or a virtual machine, within the greater computing environment **140**.

FIG. **4** shows a block diagram of an example in which the selection engine **128** may select a base image file based on dependencies associated with multiple pieces of target software. This may be useful in situations in which the base image file will be used to generate one or more customized image files for deploying two or more pieces of target software.

As shown in FIG. **4**, the selection engine **128** can determine first target software **404*a*** and second target software **404*b*** for which one or more customized image files **118*a*-*b*** are to be built. The selection engine **128** can next determine a first set of dependencies **406*a*-*n*** for the first target software **404*a*** and a second set of dependencies **408*a*-*n*** for the second target software **404*b***. The selection engine **128** can determine these dependencies using any of the techniques described above. The selection engine **128** can then select a base image file **122*b*** from among a group of base image files **122** based on the first set of dependencies **406*a*-*n*** and the second set of dependencies **408*a*-*n***.

In some examples, the selection engine **128** can select a base image file **122*b*** that contains at least a predefined amount of the total number of dependencies present across both the first set of dependencies **406*a*-*n*** and the second set of dependencies **408*a*-*n***. The predefined amount can be user customizable. For instance, the first set of dependencies **406*a*-*n*** may contain 15 dependencies, the second set of dependencies **408*a*-*n*** may contain 13 dependencies, and the predefined amount may be 90%. So, the selection engine **128** can select a base image file that contains at least 90% of the 28 total dependencies present across the first set of dependencies **406*a*-*n*** and the second set of dependencies **408*a*-*n***.

In other examples, the selection engine **128** can select a base image file that contains at least a predefined amount of overlapping dependencies between the first set of dependencies **406*a*-*n*** and the second set of dependencies **408*a*-*n***. For instance, there can be 10 dependencies that are present in both the first set of dependencies **406*a*-*n*** and the second set of dependencies **408*a*-*n***. So, the selection engine **128** can select a base image file **122*b*** that has at least 90% of the 10 overlapping dependencies. If multiple base image files in the group **122** contain at least the predefined amount of dependencies, the base image file **122*b*** with the smallest size can be selected from the group **122**. This may reduce the amount of extraneous software items present in the selected base image file.

Using these techniques, a single base image file **122*b*** can be selected for use in generating one or more customized image files **118*a*-*b*** usable to deploy multiple pieces of target software **404*a*-*b***. The selected base image file **122*b*** can be

have a desired balance of dependency coverage and size, as compared to the other base image files in the group **122**.

It will be appreciated that the specific number and arrangement of components shown in FIGS. **1**-**4** are intended to be illustrative and non-limiting. Other examples may involve more components, different components, or a different arrangement of the components than is shown in FIGS. **1**-**4**. For example, the selection engine **128** may be located on a different computing device than the build tool **124**. In one such example, the selection engine **128** may be located on a server (e.g., a cloud server) that is accessible to a client device of a user **130** via a network **108**. The user **130** may operate the client device to interact with the selection engine **128** in order to determine which base image file to use in building a customized image file **118**. The user **130** may then build the customized image file **118** using a build tool **124** that is located on their client device or in another location that is different from the server.

FIG. **5** is a flow chart of an example of a process for generating a customized image file or a recommendation according to some aspects of the present disclosure. Other examples may involve more operations, fewer operations, different operations, or a different order of the operations shown in FIG. **5**. The operations of FIG. **5** are described below with reference to the components of FIG. **1** described above.

In block **502**, a computing device **102** (e.g., executing selection engine **128**) determines dependencies **138*a*-*n*** relied upon one or more pieces of target software, such as target software **120**. This may involve analyzing source code, such as source code **112**, of the one or more pieces of target software or complementary information associated with the one or more pieces of target software.

In block **504**, the computing device **102** determines how many of the dependencies are present in each base image file **122*a*-*n*** of a group of base image files **122**. For example, the computing device **102** can analyze the contents of a base image file, or metadata associated with the base image file, to determine the base image file's contents. The computing device **102** can then compare the base image file's contents to a list of the dependencies to identify the number of overlaps between the two. The computing device **102** can iterate this process for each base image file in the group **122**.

In block **506**, the computing device **102** selects a base image file **122*b*** that contains at least a predefined amount of the dependencies. The predefined amount may be considered a criterion that is chosen by the user based on their objectives. The base image file **122*b*** may be further selected based on its size, for example if multiple base image files contain at least the predefined amount of the dependencies, so that that the smallest base image file satisfying the user's criterion is selected.

In block **508**, the computing device **102** identifies one or more extraneous software items in the base image file **122*b***. For example, the computing device **102** can compare the base image file's contents to a list of the dependencies to identify the differences between the two. If the differences correspond to software items that are both present in the base image file **122*b*** and absent from the list, then those software items may be considered extraneous software items.

In block **510**, the computing device **102** identifies one or more missing dependencies. For example, the computing device **102** can compare the base image file's contents to a list of the dependencies to identify the differences between the two. If the differences correspond to software items that are both present on the list and absent from the base image file **122***b*, then those software items may be considered missing dependencies.

In block **512**, the computing device **102** determines whether a customized image file **118** for the target software **120** is to be automatically generated. This may be a user selectable option. The user may set the option to one value if the customized image file **118** is to be automatically generated and to another value if the customized image file **118** is not to be automatically generated. The computing device **102** can determine whether the customized image file **118** is to be automatically generated based on the option's value.

If the computing device **102** determines that the customized image file **118** is to be automatically generated at block **512**, the process can proceed to block **514**. In block **514**, the computing device **102** can obtain the base image file **122***b* and any missing dependencies. For example, the computing device **102** can download some or all of these files from one or more repositories via network **108**. In block **516**, the computing device **102** can generate the customized image file **118** using a build tool **124**. The customized image file **118** can be customized to include some or all of the missing dependences and exclude some or all of the extraneous software items.

If the computing device **102** determines that the customized image file **118** is not to be automatically generated at block **512**, the process can proceed to block **518**. In block **518**, the computing device **102** can generate a recommendation **138** for a user **130** relating to how to build the customized image file **118**. The recommendation **138** can specify the base image file **122***b*, some or all of the extraneous software items, and some or all of the missing dependencies. The user **130** may then be able to manually construct the customized image file **118** based on the recommendation **138**.

FIG. **6** is a block diagram of another example of a system **600** for building a customized image file **118** according to some aspects of the present disclosure. The system **600** includes a processor **602** communicatively coupled to a memory **604**. In some examples, the processor **602** and the memory **604** may be parts of the same computing device, such as the computing device **102** of FIG. **1**. In other examples, the processor **602** and the memory **604** may be distributed from (e.g., remote to) one another.

The processor **602** is hardware that can include one processing device or multiple processing devices. Non-limiting examples of the processor **602** include a Field-Programmable Gate Array (FPGA), an application-specific integrated circuit (ASIC), or a microprocessor. The processor **602** can execute instructions **606** stored in the memory **604** to perform computing operations. In some examples, the instructions **606** may correspond to the selection engine **128**, the build tool **124**, or both. The instructions **606** may include processor-specific instructions generated by a compiler or an interpreter from code written in any suitable computer-programming language, such as C, C++, C #, Python, or Java.

The memory **604** is hardware that can include one memory device or multiple memory devices. The memory **604** can be volatile or can be non-volatile, such that it can retain stored information when powered off. Some examples of the memory **604** can include electrically erasable and programmable read-only memory (EEPROM), flash memory, or any other type of non-volatile memory. At least some of the memory **604** includes a non-transitory computer-readable medium from which the processor **602** can read instructions. A computer-readable medium can include electronic, optical, magnetic, or other storage devices capable of providing the processor **602** with computer-readable instructions or other program code. Some examples of a computer-readable medium include magnetic disks, memory chips, ROM, random-access memory (RAM), an ASIC, a configured processor, optical storage, or any other medium from which a computer processor can read the instructions **606**.

In some examples, the processor **602** can execute the instructions **606** to perform some or all of the functionality described herein. For example, the processor **602** can identify base image files **122***a-n* that each include at least a predefined amount **608** of dependencies **138***a-n* relied upon by target software **120**. The processor **602** can then select a base image file **122***b*, from the base image files **122***a-n*, having a smallest size as compared to a remainder of the base image files. After selecting the base image file **122***b*, the processor **602** can build a customized image file **118**. The customized image file **118** can be configured for deploying the target software **120** to a computing environment **140**, as represented by the dashed arrow.

In some examples, the processor **602** can implement the process shown in FIG. **7**. Other examples may involve more operations, fewer operations, different operations, or a different order of the operations shown in FIG. **7**. The operations of FIG. **7** are described below with reference to the components of FIGS. **1** and **6** described above.

In block **702**, the processor **602** identifies base image files **122***b-n* that each include at least a predefined amount **608** of dependencies **138***a-n* relied upon by target software **120**. For example, the processor **602** can determine the dependencies **138***a-n* of the target software **120**. The processor **602** can then determine how many of the dependencies **138***a-n* are present in each base image file **122***a-n* among a group of base image files **122**. For example, the processor **602** can determine that base image file **122***a* includes 7 of the dependencies **138***a-n*, that base image file **122***b* includes 11 of the dependencies **138***a-n*, and that base image file **122***n* includes 9 of the dependencies **138***a-n*. The processor **602** can store those numeric values in memory in relation to their corresponding base image files **122***a-n*. The processor **602** can compare the stored values to the predefined amount **608** to determine that a subset of the group **122**, for example base image file **122***b* and base image file **122***n* (but not base image file **122***a*), include at least the predefined amount **608** of the dependencies **138***a-n*.

In block **704**, the processor **602** selects a base image file **122***b*, from the base image files **122***b-n*, having a smallest size as compared to a remainder of the base image files. For example, the processor **602** can determine a first size of base image file **122***b* and a second size of base image file **122***n*. One example of the first size and the second size may be 1.1 GB and 1.25 GB, respectively. The processor **602** can compare the first size to the second size to determine which of the two is smallest. Based on this comparison, the processor **602** can determine that the base image file **122***b* has the smallest size and consequently select the base image file **122***b* for further use.

In block **706**, the processor **602** builds a customized image file **118** based on the selected base image file **122***b*. For example, the processor **602** can provide the base image file **122***b* as input to a build tool **124** for use in constructing the customized image file **118**. The customized image file **118** can be configured for deploying the target software **120** to a computing environment **140**.

FIG. **8** is a block diagram of an example of a system **800** for updating a customized image file according to some aspects of the present disclosure. The system **800** includes an instance of target software **120***a* deployed in a computing environment **140** from a customized image file **118***a*.

After deploying the target software **120***a*, the system **800** (e.g., computing device **802**) can monitor one or more security databases to detect a vulnerability associated with the target software **120***a*, such as a vulnerability in the target software **120***a* itself or one of its dependencies. One example of such a database can include a common vulnerabilities and exposures database. The system **800** may perform this monitoring automatically by interacting with various application programming interfaces (APIs) associated with the security databases.

Upon determining that such a vulnerability exists, the system **800** can obtain a new version of the vulnerable software and use it to generate a new version of the customized image file **118***b* that lacks the vulnerability. The system **800** can automatically generate the new version of the customized image file **118***b* using any of the techniques described above. Using the new version of the customized image file **118***b*, the system **800** may then deploy a new instance of the target software **120***b* that lacks the vulnerability in the computing environment **140**. Additionally, or alternatively, the system **800** can upload the new version of the customized image file **118***b* to a repository for use by other users. In this way, the system **800** can automatically detect and resolve security vulnerabilities.

In one specific example shown in FIG. **8**, the system **800** (e.g., the computing device **802**) has determined that a vulnerability exists in dependency **138***b*, as indicated by its thick border in FIG. **1**. So, the system **800** can obtain a new version **806** of dependency **138***b* and provide it to a build tool **124**, along with a base image file **122***b* selected using any of the techniques described above, to generate the new version of the customized image file **118***b* that excludes the vulnerability. The customized image file **118***b* may then be used to deploy a new instance of the target software **120***b* that lacks the vulnerability in the computing environment **140**.

In some examples, either or both of the instances of the target software **120***a-b* may be deployed inside containers or virtual machines **804***a-b*. For example, the first instance of the target software **120***a* can be deployed inside container or virtual machine **804***a*, and the second instance of the target software **120***b* can be deployed inside container or virtual machine **804***b*. The customized image files **118***a-b* can be configured to facilitate such deployments.

Although FIG. **8** shows a certain number and arrangement of components, this is intended to be illustrative and non-limiting. Other examples may include more components, fewer components, different components, or a different arrangement of the components than is shown in FIG. **8**. For instance, in other examples the instances of the target software **120***a-b* may be deployed in separate computing environments, rather than the same computing environment **140**. Additionally, the computing device **802** may be part of the computing environment **140**, rather than external to it, in other examples.

In some aspects, the size of image files usable for deploying software in computing environments can be reduced according to one or more of the following examples. As used below, any reference to a series of examples is to be understood as a reference to each of those examples disjunctively (e.g., "Examples 1-4" is to be understood as "Examples 1, 2, 3, or 4").

Example #1: A non-transitory computer-readable medium comprising program code that is executable by a processor for causing the processor to: identify base image files that each include at least a predefined amount of dependencies relied upon by target software; select a base image file, from the base image files, having a smallest size as compared to a remainder of the base image files; and build, based on the base image file, a customized image file configured for deploying the target software to a computing environment.

Example #2: The non-transitory computer-readable medium of Example #1, further comprising program code that is executable by the processor for causing the processor to: receive an existing image file configured for deploying the target software to the computing environment, the existing image file being different from the customized image file and the base image file; extract a network address from metadata of the existing image file; obtain source code for the target software from the network address; and determine the dependencies of the target software by analyzing the source code.

Example #3: The non-transitory computer-readable medium of any of Examples #1-2, further comprising program code that is executable by the processor for causing the processor to: determine how many of the dependencies are present in each base image file of a group of base image files; and select the base image files from the group of base image files in response to determining that the base image files each include at least the predefined amount of the dependencies relied upon by the target software.

Example #4: The non-transitory computer-readable medium of any of Examples #1-3, wherein the predefined amount is less than 100% of the dependencies.

Example #5: The non-transitory computer-readable medium of any of Examples #1-3, wherein the predefined amount is 100% of the dependencies.

Example #6: The non-transitory computer-readable medium of any of Examples #1-5, further comprising program code that is executable by the processor for causing the processor to: based on selecting the base image file, obtain the base image file from a repository that includes the base image files; and build the customized image file to include the base image file and one or more missing dependencies that are absent from the base image file.

Example #7: The non-transitory computer-readable medium of any of Examples #1-6, wherein the dependencies relied upon by the target software are a first plurality of dependencies, and further comprising program code that is executable by the processor for causing the processor to: determine a second plurality of dependencies relied upon by other target software; determine overlapping dependencies between the first plurality of dependencies and the second plurality of dependencies; and select the base image file from the base image files in response to determining that the base image file includes at least the predefined amount of the overlapping dependencies.

Example #8: The non-transitory computer-readable medium of any of Examples #1-7, wherein the base image file excludes the target software and the customized image file includes the target software.

Example #9: The non-transitory computer-readable medium of any of Examples #1-8, further comprising program code that is executable by the processor for causing the processor to: determine one or more extraneous software items that are included in the base image file and extraneous to execution of the target software; and generate the customized image file to exclude the extraneous software items.

Example #10. The non-transitory computer-readable medium of any of Examples #1-9, further comprising program code that is executable by the processor for causing the processor to: deploy a first instance of the target software to the computing environment; and subsequent to deploying the first instance to the computing environment: determine that a dependency, among the dependencies relied upon by the target software, has a vulnerability; in response to determining that the dependency has the vulnerability, build an updated version of the customized image file in which a first version of the dependency that includes the vulnerability is replaced by a second version of the dependency that lacks the vulnerability; deploy a second instance of the target software using the updated version of the customized image file, the second instance lacking the vulnerability; and subsequent to deploying the second instance, shut down the first instance of the target software.

Example #11: A method comprising: identifying, by a processor, base image files that each include at least a predefined amount of dependencies relied upon by target software; selecting, by the processor and from the base image files, a base image file having a smallest size as compared to a remainder of the base image files; and building, by the processor and based on the base image file, a customized image file configured for deploying the target software to a computing environment.

Example #12: The method of Example #11, further comprising: receiving an existing image file configured for deploying the target software to the computing environment, the existing image file being different from the customized image file and the base image file; extracting metadata of the existing image file; obtaining source code for the target software using information in the metadata; and determining the dependencies based on the source code.

Example #13: The method of any of Examples #11-12, further comprising: determining how many of the dependencies are present in each base image file of a group of base image files; and selecting the base image files from the group of base image files in response to determining that the base image files each include at least the predefined amount of dependencies relied upon by the target software.

Example #14: The method of any of Examples #11-13, wherein the predefined amount is less than 100% of the dependencies.

Example #15: The method of any of Examples #11-14, further comprising: based on selecting the base image file, obtaining the base image file from a repository that includes the base image files; and building the customized image file to include the base image file and one or more missing dependencies that are absent from the base image file.

Example #16: The method of any of Examples #11-13 and 15, wherein the predefined amount is 100% of the dependencies.

Example #17: The method of any of Examples #11-16, wherein the dependencies relied upon by the target software are a first plurality of dependencies, and further comprising: determining a second plurality of dependencies relied upon by other target software; determining overlapping dependencies between the first plurality of dependencies and the second plurality of dependencies; and selecting the base image file from the base image files in response to determining that the base image file includes at least the predefined amount of the overlapping dependencies.

Example #18: The method of any of Examples #11-17, wherein the base image file includes the target software.

Example #19: The method of any of Examples #11-18, further comprising: determining one or more extraneous software items that are included in the base image file and extraneous to execution of the target software; and generating the customized image file to exclude the extraneous software items.

Example #20: A system comprising: a processor; and a memory including instructions that are executable by the processor for causing the processor to: identify base image files that each include at least a predefined amount of dependencies relied upon by target software; select a base image file, from the base image files, having a smallest size as compared to a remainder of the base image files; and build, based on the base image file, a customized image file configured for deploying the target software to a computing environment.

Example #21: A non-transitory computer-readable medium comprising program code that is executable by a processor for causing the processor to: determine dependencies relied upon by target software; and based on determining the dependencies: identify base image files that each include at least a predefined amount of the dependencies relied upon by target software; select a base image file, from the base image files, having a smallest size as compared to a remainder of the base image files; determining one or more dependencies of the target software that are absent from the base image file; and generate and output a recommendation for how to build a customized image file configured for deploying the target software to a computing environment, the recommendation identifying the base image file as a starting point and indicating that the one or more dependencies are absent from the base image file for enabling a user to build the customized image file.

Example #22: The non-transitory computer-readable medium of Example #21, wherein the recommendation further includes an option to download the base image file from a repository of base image files.

Example #23: The non-transitory computer-readable medium of any of Examples #21-22, wherein the recommendation further includes options to download the one or more dependencies from one or more locations.

Example #24: The non-transitory computer-readable medium of any of Examples #21-23, further comprising program code that is executable by the processor for causing the processor to: receive an existing image file configured for deploying the target software to the computing environment, the existing image file being different from the customized image file and the base image file; extract a network address from metadata of the existing image file; obtain source code for the target software from the network address; and determine the dependencies by analyzing the source code.

Example #25: The non-transitory computer-readable medium of any of Examples #21-24, wherein the predefined amount is less than 100% of the dependencies.

Example #26: The non-transitory computer-readable medium of any of Examples #21-25, wherein the predefined amount is 100% of the dependencies.

Example #27: The non-transitory computer-readable medium of any of Examples #21-26, further comprising program code that is executable by the processor for causing the processor to determine how many of the dependencies are present in each of the base image files.

Example #28: A method comprising: determining, by a processor, dependencies relied upon by target software; and based on determining the dependencies: identifying, by the processor, base image files that each include at least a predefined amount of the dependencies relied upon by target software; selecting, by the processor and from the base image files, a base image file having a smallest size as compared to a remainder of the base image files; determining, by the processor, one or more dependencies of the target software that are absent from the base image file; and generating, by the processor, a recommendation for how to build a customized image file configured for deploying the target software to a computing environment, the recommendation identifying the base image file as a starting point and indicating that the one or more dependencies are absent from the base image file for enabling a user to build the customized image file.

Example #29: The method of Example #28, wherein the recommendation further includes an option to download the base image file from a repository of base image files.

Example #30: The method of any of Examples #28-29, wherein the recommendation further includes options to download the one or more dependencies from one or more locations.

Example #31: The method of any of Examples #28-30, further comprising: receiving an existing image file configured for deploying the target software in the computing environment, the existing image file being different from the customized image file and the base image file; extracting metadata from the existing image file; and determining the dependencies by using information included in the metadata.

Example #32: The method of any of Examples #28-21, further comprising determining how many of the dependencies are present in each of the base image files.

Example #33: The method of any of Examples #28-32, wherein the dependencies relied upon by the target software are a first plurality of dependencies, and further comprising: determining a second plurality of dependencies relied upon by other target software; determining overlapping dependencies between the first plurality of dependencies and the second plurality of dependencies; and selecting the base image file from the base image files in response to determining that the base image file includes at least the predefined amount of the overlapping dependencies.

Example #34. The method of any of Examples #28-33, wherein the base image file excludes the target software and the customized image file includes the target software.

Example #35: A non-transitory computer-readable medium comprising program code that is executable by a processor for causing the processor to: determine dependencies relied upon by target software; and based on determining the dependencies: identify base image files that each include at least a predefined amount of the dependencies relied upon by target software; select a base image file, from the base image files, having a smallest size as compared to a remainder of the base image files; determine one or more extraneous software items that are included in the base image file and extraneous to execution of the target software; and generate and output a recommendation for how to build a customized image file configured for deploying the target software to a computing environment, the recommendation identifying the base image file and indicating that the one or more extraneous software items are removable from the base image file.

Example #36: A method comprising: determining, by a processor, dependencies relied upon by target software; and based on determining the dependencies: identifying, by the processor, base image files that each include at least a predefined amount of the dependencies relied upon by target software; selecting, by the processor and from the base image files, a base image file having a smallest size as compared to a remainder of the base image files; determining, by the processor, one or more extraneous software items that are included in the base image file and extraneous to execution of the target software; and outputting, by the processor, a recommendation for how to build a customized image file configured for deploying the target software to a computing environment, the recommendation identifying the base image file and indicating that the one or more extraneous software items are removable from the base image file.

Example #37: A system comprising: means for identifying base image files that each include at least a predefined amount of dependencies relied upon by target software; means for selecting a base image file, from the base image files, having a smallest size as compared to a remainder of the base image files; and means for building, based on the base image file, a customized image file configured for deploying the target software to a computing environment.

The foregoing description of certain examples, including illustrated examples, has been presented only for the purpose of illustration and description and is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Numerous modifications, adaptations, and uses thereof will be apparent to those skilled in the art without departing from the scope of the disclosure. For instance, any example described herein can be combined with any other examples to yield further examples.

The invention claimed is:

1. A non-transitory computer-readable medium storing program code that is executable by a processor for causing the processor to:

determine dependencies relied upon by a target software; and

based on determining the dependencies relied upon by the target software:

identify a group of base image files that each base image file includes at least a threshold amount of the dependencies relied upon by the target software, wherein the threshold amount of the dependencies relied upon by the target software is a customizable numerical value, and wherein identifying the group of base image files involves:

for each respective candidate base image file among a plurality of candidate base image files:

determining a respective number of dependencies of the target software that are present in the respective candidate base image file;

determining whether the respective number of dependencies of the target software that are present in the respective candidate base image file is greater than or equal to the threshold amount of the dependencies relied upon by the target software; and

in response to determining that the respective number of dependencies of the target software that are present in the respective candidate base image file is greater than or equal to the threshold amount of the dependencies relied upon by the target software, incorporating the respective candidate base image file into the group of base image files;

select a base image file from the group of base image files, in response to determining that the base image file has a smallest size as compared to a remainder of base image files in the group of base image files;

cause a customized image file to be built based on the selected base image file; and

deploy the target software to a computing environment using the customized image file.

2. The non-transitory computer-readable medium of claim **1**, wherein the program code is further executable by the processor for causing the processor to:

download the selected base image file from a repository of base image files.

3. The non-transitory computer-readable medium of claim **2**, wherein the program code is further executable by the processor for causing the processor to:

download one or more of the dependencies relied upon by the target software from one or more locations.

4. The non-transitory computer-readable medium of claim **1**, further comprising program code that is executable by the processor for causing the processor to:

receive an existing image file configured to deploy the target software to the computing environment, wherein the existing image file is different from the customized image file and the selected base image file;

extract a network address from metadata of the existing image file;

obtain source code for the target software from the network address; and

determine the dependencies relied upon by the target software by analyzing the source code for the target software.

5. The non-transitory computer-readable medium of claim **1**, wherein the threshold amount of the dependencies relied upon by the target software is used as a selection criterion for selecting the group of base image files from among the plurality of candidate base image files.

6. The non-transitory computer-readable medium of claim **1**, further comprising program code that is executable by the processor for causing the processor to:

receive the threshold amount of the dependencies relied upon by the target software as a user input from a user.

7. The non-transitory computer-readable medium of claim **1**, wherein the selected base image file excludes the target software and the customized image file includes the target software.

8. The non-transitory computer-readable medium of claim **1**, further comprising program code that is executable by the processor for causing the processor to:

determine an extraneous software item that is included in the selected base image file and extraneous to execution of the target software; and

generate an output to indicate the extraneous software item.

9. The non-transitory computer-readable medium of claim **1**, further comprising program code that is executable by the processor for causing the processor to:

determine a missing software item that is absent from the selected base image file, wherein the missing software item is one of the dependencies relied upon by the target software; and

generate an output to indicate the missing software item.

10. The non-transitory computer-readable medium of claim **1**, wherein the threshold amount of the dependencies relied upon by the target software is less than 100% of the dependencies relied upon by the target software.

11. A method comprising:

determining, by a processor, dependencies relied upon by a target software; and

based on determining the dependencies relied upon by the target software:

identifying, by the processor, a group of base image files that each base image file includes at least a threshold amount of the dependencies relied upon by the target software, wherein the threshold amount of the dependencies relied upon by the target software is a customizable numerical value, and wherein identifying the group of base image files involves:

for each respective candidate base image file among a plurality of candidate base image files:

determining a respective number of dependencies of the target software that are present in the respective candidate base image file;

determining whether the respective number of dependencies of the target software that are present in the respective candidate base image file is greater than or equal to the threshold amount of the dependencies relied upon by the target software; and

in response to determining that the respective number of dependencies of the target software that are present in the respective candidate base image file is greater than or equal to the threshold amount of the dependencies relied upon by the target software, incorporating the respective candidate base image file into the group of base image files;

selecting, by the processor, a base image file from the group of base image files, in response to determining that the base image file has a smallest size as compared to a remainder of base image files in the group of base image files;

causing, by the processor, a customized image file to be built based on the selected base image file; and

deploying, by the processor, the target software to a computing environment using the customized image file.

12. The method of claim **11**, further comprising:

receiving an existing image file configured to deploy the target software to the computing environment, wherein the existing image file is different from the customized image file and the selected base image file;

extracting a network address from metadata of the existing image file;

obtaining source code for the target software from the network address; and

determining the dependencies relied upon by the target software by analyzing the source code for the target software.

13. The method of claim **11**, wherein the threshold amount of the dependencies relied upon by the target software is used as a selection criterion for selecting the group of base image files from among the plurality of candidate base image files.

14. The method of claim **11**, further comprising receiving the threshold amount of the dependencies relied upon by the target software as a user input from a user.

15. The method of claim **11**, wherein the selected base image file excludes the target software and the customized image file includes the target software.

16. The method of claim **11**, further comprising:

determining an extraneous software item that is included in the selected base image file and extraneous to execution of the target software; and

generating an output to indicate the extraneous software item.

17. The method of claim **11**, further comprising:

determining a missing software item that is absent from the selected base image file, wherein the missing software item is one of the dependencies relied upon by the target software; and

generating an output to indicate the missing software item.

18. The method of claim **11**, wherein the threshold amount of the dependencies relied upon by the target software is less than 100% of the dependencies relied upon by the target software.

19. A system comprising:

a processor; and

a memory storing instructions that are executable by the processor for causing the processor to:

determine dependencies relied upon by a target software; and

based on determining the dependencies relied upon by the target software:

identify a group of base image files that each base image file includes at least a threshold amount of the dependencies relied upon by the target software, wherein the threshold amount of the dependencies relied upon by the target software is a customizable numerical value, and wherein identifying the group of base image files involves:

for each respective candidate base image file among a plurality of candidate base image files:

determining a respective number of dependencies of the target software that are present in the respective candidate base image file;

determining whether the respective number of dependencies of the target software that are present in the respective candidate base image file is greater than or equal to the threshold amount of the dependencies relied upon by the target software; and

in response to determining that the respective number of dependencies of the target software that are present in the respective candidate base image file is greater than or equal to the threshold amount of the dependencies relied upon by the target software, incorporating the respective candidate base image file into the group of base image files;

select a base image file from the group of base image files, in response to determining that the base image file has a smallest size as compared to a remainder of base image files in the group of base image files;

cause a customized image file to be built based on the selected base image file; and

deploy the target software to a computing environment using the customized image file.

20. The system of claim **19**, wherein the threshold amount of the dependencies relied upon by the target software is less than 100% of the dependencies relied upon by the target software.

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