

# Oracle® Database Appliance

## Licensing Information User Manual



Release 19.25

G14673-03

January 2025

ORACLE®

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# Preface

This document, which is part of the Program Documentation under the terms of your Oracle licensing agreement, is intended to help you understand the features, functionality, and options available for Oracle Programs.

If you have a question about your licensing needs, then contact your Oracle sales representative or the License Management Services representative at <http://www.oracle.com/us/corporate/license-management-services/index.html>. You can also refer to the resources listed in “Related Documents” for more information.

- [Audience](#)
- [Documentation Accessibility](#)
- [Related Documents](#)
- [Conventions](#)

## Audience

This book is intended for all purchasers of Oracle Database Appliance.

## Documentation Accessibility

For information about Oracle's commitment to accessibility, visit the Oracle Accessibility Program website at <http://www.oracle.com/pls/topic/lookup?ctx=acc&id=docacc>.

### Access to Oracle Support

Oracle customers that have purchased support have access to electronic support through My Oracle Support. For information, visit <http://www.oracle.com/pls/topic/lookup?ctx=acc&id=info> or visit <http://www.oracle.com/pls/topic/lookup?ctx=acc&id=trs> if you are hearing impaired.

## Related Documents

For more information about Oracle Database Appliance, go to <http://www.oracle.com/goto/oda/docs> and click the appropriate release.

For more information about using Oracle Database, go to <http://docs.oracle.com/database/> and select the database release from the menu.

For more information about Oracle Integrated Lights Out Manager 3.2, see [https://docs.oracle.com/cd/E37444\\_01/](https://docs.oracle.com/cd/E37444_01/).

For more details about other Oracle products that are mentioned in Oracle Database Appliance documentation, see the Oracle Documentation home page at <http://docs.oracle.com>.

## Conventions

The following text conventions are used in this document:

Convention	Meaning
<b>boldface</b>	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
<i>italic</i>	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
<code>monospace</code>	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

# 1

## Introduction

This Licensing Information document is a part of the product or program documentation under the terms of your Oracle license agreement and is intended to help you understand the program editions, entitlements, restrictions, prerequisites, special license rights, and/or separately licensed third party technology terms associated with the Oracle software program(s) covered by this document (the "Program(s)").

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# 2

## Oracle Database Appliance Licensing Overview

This chapter provides an overview of the licensing process for each hardware platform.

Topics:

- [About Licensing](#)  
Oracle Database Appliance provides capacity-on-demand licensing.
- [CPUs and Core Count](#)  
Review this section for information about core license options for your Oracle Database Appliance hardware.
- [Oracle Database Appliance KVM Hard Partitioning Compliance](#)  
Review this section for information about Oracle Database Appliance KVM Hard Partitioning compliance.

### About Licensing

Oracle Database Appliance provides capacity-on-demand licensing.

Capacity-on-demand (CoD) refers to an Oracle Database Appliance server that has a subset of its cores turned off so that the Oracle Database Enterprise Edition or Oracle Database Standard Edition 2 software license cost can be reduced. The number of cores can be reduced before or after the deployment. The number of active cores can be increased at a later time, when more capacity is needed. Oracle Database is licensed separately. Refer to *Database Licensing Information User Manual* for additional information.

When you add your hardware Support Identifier (SI) for Oracle Database Appliance to your My Oracle Support account, you establish a license for all the cores on your system. Oracle Database Appliance models can be deployed as bare metal systems or KVM-based virtualized systems. Both platform types offer capacity-on-demand licensing.

With bare-metal installations, you disable cores that you do not intend Oracle Database to use:

- For Oracle Database Appliance X11, X10, X9-2S, X9-2L, X9-2-HA, X8-2S, X8-2M, X8-2-HA, X7-2S, X7-2M, X7-2-HA: Issue the command `odacli modify-cpucore` to set the low water mark and to increase the cores.

Chapter three explains how to obtain a licensing key and record your initial license requirements with My Oracle Support. It also explains how to change the licensed core count, if necessary, later. Chapter three is appropriate for bare metal installations where your license covers the cores that you are using for Oracle Database.

Chapter four contains information about the third-party products that are included with Oracle Database Appliance.



**Note:**

If you use the Integrated Oracle Data Guard feature only, then you **do not** require a separate Oracle Active Data Guard license.

**About License Options for Oracle Database Standard Edition 2 on Oracle Database Appliance**

For the purposes of licensing Oracle Database Standard Edition 2 on Oracle Database Appliance running multi-chip modules, where each chip in a multi-chip module is counted as an occupied socket for licensing purposes, you may exceed the 2 sockets per server limit. Oracle Database Standard Edition 2 requires one processor license for every 8 enabled cores on Oracle Database Appliance running multi-chip modules. If the number of enabled cores is not divisible by 8, the quotient must be rounded up to the nearest whole number to determine the number of Oracle Database Standard Edition 2 processor licenses required.

**Note:**

The minimum licenses when licensing by SE2 Named User Plus (NUP) metric are 10 NUP licenses per server.

## CPUs and Core Count

Review this section for information about core license options for your Oracle Database Appliance hardware.

- Oracle Database Appliance X11-HA has 2 servers, each with 2 CPUs of 32 cores each. When you deploy Oracle Database Appliance X11-HA, all 128 cores (64 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X11-L contains 2 CPUs with 32 cores for a total of 64 cores. When you deploy Oracle Database Appliance X11-L, all 64 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X11-S contains 1 CPU with 32 cores. When you deploy Oracle Database Appliance X11-S, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X10-HA has 2 servers, each with 2 CPUs of 32 cores each. When you deploy Oracle Database Appliance X10-HA, all 128 cores (64 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X10-L contains 2 CPUs with 32 cores for a total of 64 cores. When you deploy Oracle Database Appliance X10-L, all 64 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X10-S contains 1 CPU with 32 cores. When you deploy Oracle Database Appliance X10-S, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X9-2-HA has 2 servers, each with 2 CPUs of 16 cores each. When you deploy Oracle Database Appliance X9-2-HA, all 64 cores (32 cores in each server) are active with hyper-threading enabled by default.

- Oracle Database Appliance X9-2L contains 2 CPUs with 16 cores for a total of 32 cores. When you deploy Oracle Database Appliance X9-2L, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X9-2S contains 1 CPU with 16 cores. When you deploy Oracle Database Appliance X9-2S, all 16 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X8-2-HA has 2 servers, each with 2 CPUs of 16 cores each. When you deploy Oracle Database Appliance X8-2-HA, all 64 cores (32 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X8-2M contains 2 CPUs with 16 cores for a total of 32 cores. When you deploy Oracle Database Appliance X8-2M, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X8-2S contains 1 CPU with 16 cores. When you deploy Oracle Database Appliance X8-2S, all 16 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X7-2-HA has 2 servers, each with 2 CPUs of 18 cores each. When you deploy Oracle Database Appliance X7-2-HA, all 72 cores (36 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X7-2M contains 2 CPUs with 18 cores for a total of 36 cores. When you deploy Oracle Database Appliance X7-2M, all 36 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X7-2S contains 1 CPU with 10 cores. When you deploy Oracle Database Appliance X7-2S, all 10 cores are active with hyper-threading enabled by default.

Oracle Database Appliance bare metal licensing is determined by the number of enabled cores that you have on your system. The capacity-on-demand licensing feature enables you to change the enabled core count as your system resource needs change.

Initialize the number of licensed cores to the level currently required by your applications. Each server node has the same number of active cores. Later, increase the licensed core count as your applications require more capacity. Change the number of licensed cores by obtaining and applying a core key to configure your appliance, using the tables for your Oracle Database Appliance platform.

### Oracle Database Appliance X11-HA Licensed Core Licensing Options

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X11-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

**Table 2-1 Example of Bare Metal License Options for Oracle Database Appliance X11-HA Systems**

Licensed Cores for Each Node (X11-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X11-HA Only)	Active Cores for Oracle RAC One Node (X11-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8

**Table 2-1 (Cont.) Example of Bare Metal License Options for Oracle Database Appliance X11-HA Systems**

Licensed Cores for Each Node (X11-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X11-HA Only)	Active Cores for Oracle RAC One Node (X11-HA Only)
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

**Oracle Database Appliance X11-L and X11-S Licensed Core Licensing Options****Table 2-2 Bare Metal License Options for all Oracle Database Appliance X11-L and X11-S Systems**

Licensed Cores for Single Node (X11-S)	Licensed Cores for Single Node (X11-L)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

**Oracle Database Appliance X10-HA Licensed Core Licensing Options**

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X10-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

**Table 2-3 Example of Bare Metal License Options for Oracle Database Appliance X10-HA Systems**

Licensed Cores for Each Node (X10-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X10-HA Only)	Active Cores for Oracle RAC One Node (X10-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

**Oracle Database Appliance X10-L and X10-S Licensed Core Licensing Options****Table 2-4 Bare Metal License Options for all Oracle Database Appliance X10-L and X10-S Systems**

Licensed Cores for Single Node (X10-S)	Licensed Cores for Single Node (X10-L)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20

**Table 2-4 (Cont.) Bare Metal License Options for all Oracle Database Appliance X10-L and X10-S Systems**

Licensed Cores for Single Node (X10-S)	Licensed Cores for Single Node (X10-L)
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

**Oracle Database Appliance X9-2-HA Licensed Core Licensing Options**

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X9-2-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

**Table 2-5 Example of Bare Metal License Options for Oracle Database Appliance X9-2-HA Systems**

Licensed Cores for Each Node (X9-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X9-2-HA Only)	Active Cores for Oracle RAC One Node (X9-2-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

**Oracle Database Appliance X9-2L and X9-2S Licensed Core Licensing Options****Table 2-6 Bare Metal License Options for all Oracle Database Appliance X9-2L and X9-2S Systems**

Licensed Cores for Single Node (X9-2S)	Licensed Cores for Single Node (X9-2L)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

**Oracle Database Appliance X8-2-HA Licensed Core Licensing Options**

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X8-2-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

**Table 2-7 Example of Bare Metal License Options for Oracle Database Appliance X8-2-HA Systems**

Licensed Cores for Each Node (X8-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X8-2-HA Only)	Active Cores for Oracle RAC One Node (X8-2-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20

**Table 2-7 (Cont.) Example of Bare Metal License Options for Oracle Database Appliance X8-2-HA Systems**

Licensed Cores for Each Node (X8-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X8-2-HA Only)	Active Cores for Oracle RAC One Node (X8-2-HA Only)
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

**Oracle Database Appliance X8-2M and X8-2S Licensed Core Licensing Options****Table 2-8 Bare Metal License Options for all Oracle Database Appliance X8-2M and X8-2S Systems**

Licensed Cores for Single Node (X8-2S)	Licensed Cores for Single Node (X8-2M)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

**Oracle Database Appliance X7-2-HA Licensed Core Licensing Options**

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X7-2-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

**Table 2-9 Example of Bare Metal License Options for Oracle Database Appliance X7-2-HA Systems**

Licensed Cores for Each Node (X7-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X7-2-HA Only)	Active Cores for Oracle RAC One Node (X7-2-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32
34	68	34
36	72	36

**Oracle Database Appliance X7-2 Licensed Core Licensing Options****Table 2-10 Bare Metal License Options for all Oracle Database Appliance X7-2 Systems**

Licensed Cores for Single Node (X7-2S)	Licensed Cores for Single Node (X7-2M)
2	2
4	4
6	6
8	8
10	10
Not applicable	12
Not applicable	14
Not applicable	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26



**Table 2-10 (Cont.) Bare Metal License Options for all Oracle Database Appliance X7-2 Systems**

Licensed Cores for Single Node (X7-2S)	Licensed Cores for Single Node (X7-2M)
Not applicable	28
Not applicable	30
Not applicable	32
Not applicable	34
Not applicable	36

## Oracle Database Appliance KVM Hard Partitioning Compliance

Review this section for information about Oracle Database Appliance KVM Hard Partitioning compliance.

Oracle Database Appliance DB systems and application KVMs conform to Oracle Linux KVM Hard Partitioning requirements as specified in Hard Partitioning with Oracle Linux KVM:

<https://www.oracle.com/a/ocom/docs/linux/ol-kvm-hard-partitioning.pdf>

### Considerations for CPU Pool Subscription

CPU Pools are used for management of CPU resources only. Database license requirements are determined by KVM Hard Partitioning only.

In a DB system with a shared or internal CPU pool, the cores are pinned based on the database shape selected for the DB system. For example, if you create a DB system with `odb2`, then you must license 2 cores.

In a DB system with a shared CPU pool, consider both undersubscription and oversubscription scenarios.

- **Undersubscription:** Consider a shared CPU pool with 8 cores. If you create a DB system with `odb2` and another with `odb4`, then a total of 6 cores are used. So, although the shared CPU pool is undersubscribed, you must run the `virsh` command in each KVM or DB system to determine the pinned cores that need to be licensed. In this case, it is the same 8 cores visible to both DB systems.
- **Oversubscription:** Consider a shared CPU pool with 8 cores, and you create a DB system with `odb4` and another with `odb6`. Although the shared CPU pool is oversubscribed, you must run the `virsh` command in each KVM or DB System to determine the pinned cores that need to be licensed. In this case, it is the same 8 cores visible to both DB systems.

Note that the same CPU pool subscription policy applies to shared CPU pools for application KVMs too.

### Validating the CPUs for an Oracle Database Appliance DB System and Application KVM

You must run the `virsh` command for every DB system to identify the pinned vCPUs and CPU cores licensing requirements.

To validate that the CPUs for a virtual machine are pinned to a physical thread or core, run the following command:

```
# virsh --readonly vcpuinfo VM_name --pretty
```

The following example illustrates how you can validate the CPUs for an Oracle Database Appliance DB System with the db shape `odb2` that uses 2 cores (4 vCPUs):

1. Determine the VM Name by running this command:

```
# odacli describe-dbsystem -n dbs1 | grep "VM Name"
VM Name: x97f18b518
```

In this example, the DB System name is `dbs1`.

2. Run the `virsh` command to confirm that vCPUs are pinned to physical threads or cores for `x97f18b518`:

```
# virsh --readonly vcpuinfo x97f18b518 --pretty

VCPU:      0
CPU:       19
State:     running
CPU time:  79.3s
CPU Affinity: 19,24,55,60 (out of 72)

VCPU:      1
CPU:       55
State:     running
CPU time:  71.5s
CPU Affinity: 19,24,55,60 (out of 72)

VCPU:      2
CPU:       60
State:     running
CPU time:  71.7s
CPU Affinity: 19,24,55,60 (out of 72)

VCPU:      3
CPU:       24
State:     running
CPU time:  73.1s
CPU Affinity: 19,24,55,60 (out of 72)
-----
```

In this example, the pinned vCPUs are 19, 24, 55, and 60, out of 72.

# 3

## Capacity-On-Demand Licensing Information

This chapter provides capacity-on-demand licensing information for Oracle Database Appliance bare metal installations.

- [Oracle Database Appliance Capacity-on-Demand Licensing](#)  
Capacity-on-Demand software licensing enables you to deploy as few or as many processors in Oracle Database Appliance as your workload requires.
- [Capacity-On-Demand Licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA](#)  
Review capacity-on-demand licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA.
- [Capacity-On-Demand Licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA](#)  
Review capacity-on-demand licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA.
- [Capacity-On-Demand Licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA](#)  
Review capacity-on-demand licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA.
- [Capacity-On-Demand Licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA](#)  
Review capacity-on-demand licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA.
- [Capacity-On-Demand Licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA](#)  
Review capacity-on-demand licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA.

## Oracle Database Appliance Capacity-on-Demand Licensing

Capacity-on-Demand software licensing enables you to deploy as few or as many processors in Oracle Database Appliance as your workload requires.

Oracle Database Appliance's Capacity-on-Demand feature enables you to add more processor cores to scale up to increased system demands as you need to, without incurring the excessive costs and downtime usually associated with hardware upgrades. Additional cores are increased in 2-core increments.

### Oracle Database Appliance Scaling Capabilities

The following table lists the scaling capacities for Oracle Database Appliance bare metal and virtualized platform deployments. The decision to use bare-metal or Oracle Database Appliance Virtualized Platform depends on your company policies and the benefits that each implementation offers your company.

**Table 3-1 Oracle Database Appliance Scaling Capacities**

Oracle Database Appliance Platform	Minimum Number Processor Cores	Maximum Number Processor Cores
X10-S	2	32
X10-L	2	64
X10-HA	2	128
X9-2S	2	16
X9-2L	2	32
X9-2-HA	2	64
X8-2S	2	16
X8-2M	2	32
X8-2-HA	2	64
X7-2S	2	10
X7-2M	2	36
X7-2-HA	2	72
X6-2S	2	10
X6-2M	2	20
X6-2L	2	20
X6-2-HA	2	40
X5-2	2	72
X4-2	2	48

#### Applications Deployed on Oracle Database Appliance and Capacity-on-Demand

All Oracle products that are deployed on Oracle Database Appliance can take advantage of Capacity-on-Demand licensing.



#### Note:

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

## Capacity-On-Demand Licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA

Review capacity-on-demand licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X11-S model:

- Oracle Database Appliance X11-S is a single server consisting of 32 cores.
- Oracle Database Appliance X11-L is a single server consisting of 64 cores.
- Oracle Database Appliance X11-HA consists of two servers. Each server has 64 cores, for a total of 128 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

#### Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X11-S, X11-L, and X11-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X11-HA, between 2 and 64 cores for each server for a maximum of 128 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.

- If you want the maximum number of cores for each server (32 cores per server for X11-L and X11-HA), then use the default configuration. There is no need to set the CPU core count.



#### Note:

If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

## Capacity-On-Demand Licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA

Review capacity-on-demand licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X10-S model:

- Oracle Database Appliance X10-S is a single server consisting of 32 cores.
- Oracle Database Appliance X10-L is a single server consisting of 64 cores.

- Oracle Database Appliance X10-HA consists of two servers. Each server has 64 cores, for a total of 128 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

#### Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X10-S, X10-L, and X10-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X10-HA, between 2 and 64 cores for each server for a maximum of 128 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.

- If you want the maximum number of cores for each server (32 cores per server for X10-L and X10-HA), then use the default configuration. There is no need to set the CPU core count.



#### Note:

If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

## Capacity-On-Demand Licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA

Review capacity-on-demand licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X9-2 model:

- Oracle Database Appliance X9-2S is a single server consisting of 16 cores.
- Oracle Database Appliance X9-2L is a single server consisting of 32 cores.
- Oracle Database Appliance X9-2-HA consists of two servers. Each server has 32 cores, for a total of 64 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active

cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

### Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X9-2-HA, between 2 and 32 cores for each server for a maximum of 64 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.

- If you want the maximum number of cores for each server (32 cores per server for X9-2L and X9-2-HA), then use the default configuration. There is no need to set the CPU core count.



#### Note:

If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

## Capacity-On-Demand Licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA

Review capacity-on-demand licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X8-2 model:

- Oracle Database Appliance X8-2S is a single server consisting of 16 cores.
- Oracle Database Appliance X8-2M is a single server consisting of 32 cores.
- Oracle Database Appliance X8-2-HA consists of two servers. Each server has 32 cores, for a total of 64 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

### Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X8-2-HA, between 2 and 32 cores for each server for a maximum of 64 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.

- If you want the maximum number of cores for each server (32 cores per server for X8-2M and X8-2-HA), then use the default configuration. There is no need to set the CPU core count.



#### Note:

If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

## Capacity-On-Demand Licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA

Review capacity-on-demand licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X7-2 model:

- Oracle Database Appliance X7-2S is a single server consisting of 10 cores.
- Oracle Database Appliance X7-2M is a single server consisting of 36 cores.
- Oracle Database Appliance X7-2-HA consists of two servers. Each server has 36 cores, for a total of 72 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

### Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:



- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X7-2-HA, between 2 and 36 cores for each server for a maximum of 72 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.

- If you want the maximum number of cores for each server (36 cores per server for X7-2M and X7-2-HA), then use the default configuration. There is no need to set the CPU core count.

**Note:**

If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

# 4

## Third-Party Product Licenses for This Release

This chapter contains the licenses for the third-party products that are included with Oracle Database Appliance for this release.

- [Oracle Database Third-Party Licensing Information](#)  
Understand licensing information about third-party products used by Oracle Database.
- [Other Third-Party Product Licenses](#)  
Review other third-party product licenses for Oracle Database Appliance.
- [Written Offer for Source Code](#)

### Oracle Database Third-Party Licensing Information

Understand licensing information about third-party products used by Oracle Database.

Oracle Database Appliance includes Oracle Database 19c. To view the licenses for these third-party products, refer to the release-specific *Oracle Database Licensing Information User Manual*.

#### Related Topics

- [Licensing Information User Manual Oracle Database 21c](#)
- [Licensing Information User Manual Oracle Database 19c](#)

### Other Third-Party Product Licenses

Review other third-party product licenses for Oracle Database Appliance.

Required notices for open source or other separately licensed software products or components distributed in Oracle Database Appliance release 19.24 are identified in the following table along with the applicable licensing information. Additional notices and/or licenses may be found in the included documentation or readme files of the individual third party software.

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CNRI	yes			
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CNRI	no			
	2.0	1.6	2000	
BeOpen.com	no			
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CNRI	yes (2)			
	2.1	2.0+1.6.1	2001	
PSF	no			
	2.0.1	2.0+1.6.1	2001	
PSF	yes			
	2.1.1	2.1+2.0.1	2001	
PSF	yes			
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		<pre> \usepackage[margin=1in]{geometry} \usepackage{verbatim} \usepackage{amsmath} \usepackage{supertabular} \usepackage{array}  \def\T{{\hbox{\scriptsize{\rm T}}}} \def\epsilon{\varepsilon} \def\bigoh{\mathcal{O}} \def\phi{\varphi} \def\st{{\hbox{\scriptsize{\rm st}}}} \def\th{{\hbox{\scriptsize{\rm th}}}} \def\x{\mathbf{x}}  \title{ID: A software package for low-rank approximation of matrices via interpolative decompositions, Version 0.4} \author{Per-Gunnar Martinsson, Vladimir Rokhlin,\ Yoel Shkolnisky, and Mark Tygert}  \begin{document}  \maketitle  \newpage  {\parindent=0pt  The present document and all of the software in the accompanying distribution (which is contained in the directory {\tt id\_dist} and its subdirectories, or in the file {\tt id\_dist.tar.gz})\, is  \bigskip  Copyright \copyright\ 2014 by P.-G. Martinsson, V. Rokhlin, Y. Shkolnisky, and M. Tygert.  \bigskip  All rights reserved.  \bigskip  Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are </pre>

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		<pre> \medskip  \centerline{\Large \bf IMPORTANT}  \medskip  \hrule  \medskip  \noindent At the minimum, please read Subsection~\ref{warning} and Section~\ref{naming} below, and beware that the {\it N.B.}'s in the source code comments highlight key information about the routines; {\it N.B.} stands for {\it nota bene} (Latin for ``note well'' ).  \medskip  \hrule  \bigskip  \section{Introduction}  This software distribution provides Fortran routines for computing low-rank approximations to matrices, in the forms of interpolative decompositions (IDs) and singular value decompositions (SVDs). The routines use algorithms based on the ID. The ID is also commonly known as the approximation obtained via skeletonization, the approximation obtained via subsampling, and the approximation obtained via subset selection. The ID provides many advantages in many applications, and we suspect that it will become increasingly popular once tools for its computation become more widely available. This software distribution includes some such tools, as well as tools for computing low-rank approximations in the form of SVDs. Section~\ref{defs} below defines IDs and SVDs, </pre>

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		<p>and provides references to detailed discussions of the algorithms used in this software package.</p> <p>Please beware that normalized power iterations are better suited than the software in this distribution for computing principal component analyses in the typical case when the square of the signal-to-noise ratio is not orders of magnitude greater than both dimensions of the data matrix; see~\cite{halko-martinsson-tropp}.</p> <p>The algorithms used in this distribution have been optimized for accuracy, efficiency, and reliability; as a somewhat counterintuitive consequence, many must be randomized. All randomized codes in this software package succeed with overwhelmingly high probability (see, for example, \cite{halko-martinsson-tropp}). The truly paranoid are welcome to use the routines {\tt idd\_diffsnorm} and {\tt idz\_diffsnorm} to evaluate rapidly the quality of the approximations produced by the randomized algorithms (as done, for example, in the files {\tt idd\_a\_test.f}, {\tt idd\_r\_test.f}, {\tt idz\_a\_test.f}, and {\tt idz\_r\_test.f} in the {\tt test} subdirectory of the main directory {\tt id\_dist}). In most circumstances, evaluating the quality of an approximation via routines {\tt idd\_diffsnorm} or {\tt idz\_diffsnorm} is much faster than forming the approximation to be evaluated. Still, we are unaware of any instance in which a properly-compiled routine failed to produce an accurate approximation. To facilitate successful compilation, we encourage the user to read the instructions in the next section, and to read Section~\ref{naming}, too.</p> <p>\section{Compilation instructions}</p>

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		<p>Followed in numerical order, the subsections of this section provide step-by-step instructions for compiling the software under a Unix-compatible operating system.</p> <p>\subsection{Beware that default command-line flags may not be sufficient for compiling the source codes!} \label{warning}</p> <p>The Fortran source codes in this distribution pass {\tt real*8} variables as integer variables, integers as {\tt real*8}'s, {\tt real*8}'s as {\tt complex*16}'s, and so on. This is common practice in numerical codes, and is not an error; be sure to provide the relevant command-line flags to the compiler (for example, run {\tt fort77} and {\tt f2c} with the flag {\tt -!P}). When following the compilation instructions in Subsection~\ref{makefile_edit} below, be sure to set {\tt FFLAGS} appropriately.</p> <p>\subsection{Install LAPACK}</p> <p>The SVD routines in this distribution depend on LAPACK. Before compiling the present distribution, create the LAPACK and BLAS archive (library) {\tt .a} files; information about installing LAPACK is available at {\tt http://www.netlib.org/lapack/} (and several other web sites).</p> <p>\subsection{Decompress and untar the file {\tt id\_dist.tar.gz}}</p> <p>At the command line, decompress and untar the file {\tt id\_dist.tar.gz} by issuing a command such as {\tt tar -xvzf id\_dist.tar.gz}. This will create a directory named {\tt id\_dist}.</p> <p>\subsection{Edit the Makefile}</p>

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		<pre> \label{makefile_edit}  The directory {\tt id\_dist} contains a file named {\tt Makefile}. In {\tt Makefile}, set the following: % \begin{itemize} \item {\tt FC} is the Fortran compiler. \item {\tt FFLAGS} is the set of command-line flags     (specifying optimization settings, for     example)     for the Fortran compiler specified by {\tt     FC};     please heed the warning in     Subsection~\ref{warning} above! \item {\tt BLAS\_LIB} is the file-system path to the BLAS archive     (library) {\tt .a} file. \item {\tt LAPACK\_LIB} is the file-system path to the LAPACK archive     (library) {\tt .a} file. \item {\tt ARCH} is the archiver utility (usually {\tt ar}). \item {\tt ARCHFLAGS} is the set of command-line flags     for the archiver specified by {\tt ARCH} needed     to create an archive (usually {\tt cr}). \item {\tt RANLIB} is to be set to {\tt ranlib}     when {\tt ranlib} is available, and is to be set to {\tt echo}     when {\tt ranlib} is not available. \end{itemize}  \subsection{Make and test the libraries}  At the command line in a shell that adheres to the Bourne shell conventions for redirection, issue the command ``{\tt make clean; make}'' to both create the archive (library) {\tt id\_lib.a} and test it. (In most modern Unix distributions, {\tt sh} is the Bourne shell, or else is fully compatible with the Bourne shell; the Korn shell {\tt ksh} and the Bourne-again shell {\tt bash} also use the Bourne shell conventions for redirection.) {\tt make} places the file {\tt id\_lib.a} in the directory {\tt id\_dist}; the archive (library) file </pre>

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		<p>{\tt id\_lib.a} contains machine code for all user-callable routines in this distribution.</p> <p>\section{Naming conventions} \label{naming}</p> <p>The names of routines and files in this distribution start with prefixes, followed by an underscore ({\tt \_}). The prefixes are two to four characters in length, and have the following meanings:</p> <p>%</p> <p>\begin{itemize}</p> <p>\item The first two letters are always {\tt id},</p> <p>the name of this distribution.</p> <p>\item The third letter (when present) is either {\tt d} or {\tt z};</p> <p>{\tt d} stands for double precision ({\tt real*8}),</p> <p>and {\tt z} stands for double complex ({\tt complex*16}).</p> <p>\item The fourth letter (when present) is either {\tt r} or {\tt p};</p> <p>{\tt r} stands for specified rank, and {\tt p} stands for specified precision.</p> <p>The specified rank routines require the user to provide</p> <p>the rank of the approximation to be constructed,</p> <p>while the specified precision routines adjust the rank adaptively</p> <p>to attain the desired precision.</p> <p>\end{itemize}</p> <p>For example, {\tt iddr\_aid} is a {\tt real*8} routine which computes an approximation of specified rank. {\tt idz\_snorm} is a {\tt complex*16} routine. {\tt id\_randperm} is yet another routine in this distribution.</p> <p>\section{Example programs}</p> <p>For examples of how to use the user-callable</p>



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		<p>routines in this distribution, see the source codes in subdirectory {\tt test} of the main directory {\tt id\_dist}.</p> <p>\section{Directory structure}</p> <p>The main {\tt id\_dist} directory contains a Makefile, the auxiliary text files {\tt README.txt} and {\tt size.txt}, and the following subdirectories, described in the subsections below:</p> <pre>% \begin{enumerate} \item {\tt bin} \item {\tt development} \item {\tt doc} \item {\tt src} \item {\tt test} \item {\tt tmp} \end{enumerate} %</pre> <p>If a ``{\tt make all}'' command has completed successfully, then the main {\tt id\_dist} directory will also contain an archive (library) file {\tt id\_lib.a} containing machine code for all of the user-callable routines.</p> <p>\subsection{Subdirectory {\tt bin}}</p> <p>Once all of the libraries have been made via the Makefile in the main {\tt id\_dist} directory, the subdirectory {\tt bin} will contain object files (machine code), each compiled from the corresponding file of source code in the subdirectory {\tt src} of {\tt id\_dist}.</p> <p>\subsection{Subdirectory {\tt development}}</p> <p>Each Fortran file in the subdirectory {\tt development} (except for {\tt dfft.f} and {\tt prini.f}) specifies its dependencies at the top, then provides a main program for testing and debugging, and finally provides source code</p>

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		<p>for a library of user-callable subroutines.  The Fortran file {\tt dfft.f} is a copy of P. N. Swarztrauber's FFTPACK library  for computing fast Fourier transforms.  The Fortran file {\tt prini.f} is a copy of V. Rokhlin's library  of formatted printing routines.  Both {\tt dfft.f} (version 4) and {\tt prini.f} are in the public domain.  The shell script {\tt RUNME.sh} runs shell scripts {\tt make\_src.sh} and {\tt make\_test.sh}, which fill the subdirectories {\tt src} and {\tt test} of the main directory {\tt id\_dist} with source codes for user-callable routines and with the main program testing codes.</p> <p>\subsection{Subdirectory {\tt doc}}</p> <p>Subdirectory {\tt doc} contains this documentation, supplementing comments in the source codes.</p> <p>\subsection{Subdirectory {\tt src}}</p> <p>The files in the subdirectory {\tt src} provide source code for software libraries. Each file in the subdirectory {\tt src} (except for {\tt dfft.f} and {\tt prini.f}) is the bottom part of the corresponding file in the subdirectory {\tt development} of {\tt id\_dist}.  The file {\tt dfft.f} is just a copy of P. N. Swarztrauber's FFTPACK library for computing fast Fourier transforms.  The file {\tt prini.f} is a copy of V. Rokhlin's library of formatted printing routines.  Both {\tt dfft.f} (version 4) and {\tt prini.f} are in the public domain.</p> <p>\subsection{Subdirectory {\tt test}}</p> <p>The files in subdirectory {\tt test} provide source code for testing and debugging. Each file in subdirectory {\tt test} is the top part of the corresponding file in subdirectory {\tt development} of {\tt id\_dist},</p>

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		<p>and provides a main program and a list of its dependencies. These codes provide examples of how to call the user-callable routines.</p> <pre> \section{Catalog of the routines}  The main routines for decomposing {\tt real*8} matrices are: % \begin{enumerate} % \item IDs of arbitrary (generally dense) matrices: {\tt iddp\_id}, {\tt iddr\_id}, {\tt iddp\_aid}, {\tt iddr\_aid} % \item IDs of matrices that may be rapidly applied to arbitrary vectors (as may the matrices' transposes): {\tt iddp\_rid}, {\tt iddr\_rid} % \item SVDs of arbitrary (generally dense) matrices: {\tt iddp\_svd}, {\tt iddr\_svd}, {\tt iddp\_asvd}, {\tt iddr\_asvd} % \item SVDs of matrices that may be rapidly applied to arbitrary vectors (as may the matrices' transposes): {\tt iddp\_rsvd}, {\tt iddr\_rsvd} % \end{enumerate}  Similarly, the main routines for decomposing {\tt complex*16} matrices are: % \begin{enumerate} % \item IDs of arbitrary (generally dense) matrices: {\tt idzp\_id}, {\tt idzr\_id}, {\tt idzp\_aid}, {\tt idzr\_aid} % \item IDs of matrices that may be rapidly applied to arbitrary vectors (as may the matrices' adjoints): {\tt idzp\_rid}, {\tt idzr\_rid} % \item SVDs of arbitrary (generally dense) matrices: {\tt idzp\_svd}, {\tt idzr\_svd}, {\tt </pre>

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Provider	Component	Licensing Information
		<pre> idzp\_asvd),\\{\tt idzr\_asvd} % \item SVDs of matrices that may be rapidly applied to arbitrary vectors (as may the matrices' adjoints): {\tt idzp\_rsvd}, {\tt idzr\_rsvd} % \end{enumerate}  This distribution also includes routines for constructing pivoted \$QR\$ decompositions (in {\tt idd\_qrpiv.f} and {\tt idz\_qrpiv.f}), for estimating the spectral norms of matrices that may be applied rapidly to arbitrary vectors as may their adjoints (in {\tt idd\_snorm.f} and {\tt idz\_snorm.f}), for converting IDs to SVDs (in {\tt idd\_id2svd.f} and {\tt idz\_id2svd.f}), and for computing rapidly arbitrary subsets of the entries of the discrete Fourier transforms of vectors (in {\tt idd\_sfft.f} and {\tt idz\_sfft.f}).  \subsection{List of the routines}  The following is an alphabetical list of the routines in this distribution, together with brief descriptions of their functionality and the names of the files containing the routines' source code:  \begin{center} % \tablehead{\bf Routine &amp; \bf Description &amp; \bf Source file \\\} \tabletail{\hline} % \begin{supertabular}{&gt;{\raggedright}p{1.2in} p{.53\textwidth} l} % \hline {\tt id\_frand} &amp; generates pseudorandom numbers drawn uniformly from the interval \$[0,1]\$; this routine is more efficient than routine {\tt id\_srand}, but cannot generate fewer than 55 pseudorandom numbers per call &amp; {\tt id\_rand.f} \\\hline %</pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> {\tt id\_frandi} &amp; initializes the seed values for routine {\tt id\_frand} to specified values &amp; {\tt id\_rand.f} \\hline % {\tt id\_frando} &amp; initializes the seed values for routine {\tt id\_frand} to their original, default values &amp; {\tt id\_rand.f} \\hline % {\tt id\_randperm} &amp; generates a uniformly random permutation &amp; {\tt id\_rand.f} \\hline % {\tt id\_srand} &amp; generates pseudorandom numbers drawn uniformly from the interval <math>[0,1]</math>; this routine is less efficient than routine {\tt id\_frand}, but can generate fewer than 55 pseudorandom numbers per call &amp; {\tt id\_rand.f} \\hline % {\tt id\_srandi} &amp; initializes the seed values for routine {\tt id\_srand} to specified values &amp; {\tt id\_rand.f} \\hline % {\tt id\_srando} &amp; initializes the seed values for routine {\tt id\_srand} to their original, default values &amp; {\tt id\_rand.f} \\hline % {\tt idd\_copycols} &amp; collects together selected columns of a matrix &amp; {\tt idd\_id.f} \\hline % {\tt idd\_diffsnorm} &amp; estimates the spectral norm of the difference between two matrices specified by routines for applying the matrices and their transposes to arbitrary vectors; this routine uses the power method with a random starting vector &amp; {\tt idd\_snorm.f} \\hline % {\tt idd\_enorm} &amp; calculates the Euclidean norm of a vector &amp; {\tt idd\_snorm.f} \\hline % {\tt idd\_estrank} &amp; estimates the numerical rank of an arbitrary (generally dense) matrix to a specified precision; this routine is </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> randomized, and must be initialized with routine {\tt idd\_frmi} &amp; {\tt iddp\_aid.f} \\hline % {\tt idd\_frm} &amp; transforms a vector into a vector which is sufficiently scrambled to be subsampled, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform &amp; {\tt idd\_frm.f} \\hline % {\tt idd\_frmi} &amp; initializes routine {\tt idd\_frm} &amp; {\tt idd\_frm.f} \\hline % {\tt idd\_getcols} &amp; collects together selected columns of a matrix specified by a routine for applying the matrix to arbitrary vectors &amp; {\tt idd\_id.f} \\hline % {\tt idd\_house} &amp; calculates the vector and scalar needed to apply the Householder transformation reflecting a given vector into its first entry &amp; {\tt idd\_house.f} \\hline % {\tt idd\_houseapp} &amp; applies a Householder matrix to a vector &amp; {\tt idd\_house.f} \\hline % {\tt idd\_id2svd} &amp; converts an approximation to a matrix in the form of an ID into an approximation in the form of an SVD &amp; {\tt idd\_id2svd.f} \\hline % {\tt idd\_ldiv} &amp; finds the greatest integer less than or equal to a specified integer, that is divisible by another (larger) specified integer &amp; {\tt idd\_sfft.f} \\hline % {\tt idd\_pairsamps} &amp; calculates the indices of the pairs of integers that the individual integers in a specified set belong to &amp; {\tt idd\_frm.f} \\hline % {\tt idd\_permmult} &amp; multiplies together a bunch of permutations &amp; {\tt idd\_qrpiv.f} \\hline % {\tt idd\_qinqr} &amp; reconstructs the \$\$\$ matrix </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> in a \$QR\$ decomposition from the output of routines {\tt iddp\_qr piv} or {\tt iddr\_qr piv} &amp; {\tt idd\_qr piv.f} \\hline % {\tt idd\_qrmatmat} &amp; applies to multiple vectors collected together as a matrix the \$Q\$ matrix (or its transpose) in the \$QR\$ decomposition of a matrix, as described by the output of routines {\tt iddp\_qr piv} or {\tt iddr\_qr piv}; to apply \$Q\$ (or its transpose) to a single vector without having to provide a work array, use routine {\tt idd\_qrmatvec} instead &amp; {\tt idd\_qr piv.f} \\hline % {\tt idd\_qrmatvec} &amp; applies to a single vector the \$Q\$ matrix (or its transpose) in the \$QR\$ decomposition of a matrix, as described by the output of routines {\tt iddp\_qr piv} or {\tt iddr\_qr piv}; to apply \$Q\$ (or its transpose) to several vectors efficiently, use routine {\tt idd\_qrmatmat} instead &amp; {\tt idd\_qr piv.f} \\hline % {\tt idd\_random\_} {\tt transf} &amp; applies rapidly a random orthogonal matrix to a user-supplied vector &amp; {\tt id\_rtrans.f} \\hline % {\tt idd\_random\_transf\_init} &amp; \raggedright initializes routines {\tt idd\_random\_transf} and {\tt idd\_random\_transf\_inverse} &amp; {\tt id\_rtrans.f} \\hline % {\tt idd\_random\_} {\tt transf\_inverse} &amp; applies rapidly the inverse of the operator applied by routine {\tt idd\_random\_transf} &amp; {\tt id\_rtrans.f} \\ \\hline % {\tt idd\_reconid} &amp; reconstructs a matrix from its ID &amp; {\tt idd\_id.f} \\hline % {\tt idd\_reconint} &amp; constructs \$P\$ in the ID \$A = B \setminus P\$, where the columns of \$B\$ are a subset of the columns of \$A\$, and \$P\$ is the </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> projection coefficient matrix, given {\tt list}, {\tt krank}, and {\tt proj} output by routines {\tt iddr\_id}, {\tt iddp\_id}, {\tt iddr\_aid}, {\tt iddp\_aid}, {\tt iddr\_rid}, or {\tt iddp\_rid} &amp; {\tt idd\_id.f} \\hline % {\tt idd\_sfft} &amp; rapidly computes a subset of the entries of the discrete Fourier transform of a vector, composed with permutation matrices both on input and on output &amp; {\tt idd\_sfft.f} \\hline % {\tt idd\_sffti} &amp; initializes routine {\tt idd\_sfft} &amp; {\tt idd\_sfft.f} \\hline % {\tt idd\_sfrm} &amp; transforms a vector into a scrambled vector of specified length, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform &amp; {\tt idd\_frm.f} \\hline % {\tt idd\_sfrmi} &amp; initializes routine {\tt idd\_sfrm} &amp; {\tt idd\_frm.f} \\hline % {\tt idd\_snorm} &amp; estimates the spectral norm of a matrix specified by routines for applying the matrix and its transpose to arbitrary vectors; this routine uses the power method with a random starting vector &amp; {\tt idd\_snorm.f} \\hline % {\tt iddp\_aid} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idd\_sfrmi} &amp; {\tt iddp\_aid.f} \\hline % {\tt iddp\_asvd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idd\_sfrmi} &amp; {\tt iddp\_asvd.f} \\hline % </pre>



**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> {\tt iddp\_id} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient than routine {\tt iddp\_aid} &amp; {\tt idd\_id.f} \\ \hline % {\tt iddp\_qrpiv} &amp; computes the pivoted \$QR\$ decomposition of an arbitrary (generally dense) matrix via Householder transformations, stopping at a specified precision of the decomposition &amp; {\tt idd\_qrpiv.f} \\ \hline % {\tt iddp\_rid} &amp; computes the ID, to a specified precision, of a matrix specified by a routine for applying its transpose to arbitrary vectors; this routine is randomized &amp; {\tt iddp\_rid.f} \\ \hline % {\tt iddp\_rsvd} &amp; computes the SVD, to a specified precision, of a matrix specified by routines for applying the matrix and its transpose to arbitrary vectors; this routine is randomized &amp; {\tt iddp\_rsvd.f} \\ \hline % {\tt iddp\_svd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient than routine {\tt iddp\_asvd} &amp; {\tt idd\_svd.f} \\ \hline % {\tt iddr\_aid} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified rank; this routine is randomized, and must be initialized by routine {\tt iddr\_aidi} &amp; {\tt iddr\_aid.f} \\ \hline % {\tt iddr\_aidi} &amp; initializes routine {\tt iddr\_aid} &amp; {\tt iddr\_aid.f} \\ \hline % {\tt iddr\_asvd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified rank; this routine is randomized, and must be initialized with routine {\tt idd\_aidi} &amp; {\tt iddr\_asvd.f} \\ \hline </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> % {\tt iddr\_id} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified rank; this routine is often less efficient than routine {\tt iddr\_aid} &amp; {\tt idd\_id.f} \\ \hline % {\tt iddr\_grpiv} &amp; computes the pivoted \$QR\$ decomposition of an arbitrary (generally dense) matrix via Householder transformations, stopping at a specified rank of the decomposition &amp; {\tt idd\_grpiv.f} \\ \hline % {\tt iddr\_rid} &amp; computes the ID, to a specified rank, of a matrix specified by a routine for applying its transpose to arbitrary vectors; this routine is randomized &amp; {\tt iddr\_rid.f} \\ \hline % {\tt iddr\_rsvd} &amp; computes the SVD, to a specified rank, of a matrix specified by routines for applying the matrix and its transpose to arbitrary vectors; this routine is randomized &amp; {\tt iddr\_rsvd.f} \\ \hline % {\tt iddr\_svd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified rank; this routine is often less efficient than routine {\tt iddr\_asvd} &amp; {\tt idd\_svd.f} \\ \hline % {\tt idz\_copycols} &amp; collects together selected columns of a matrix &amp; {\tt idz\_id.f} \\ \hline % {\tt idz\_diffsnorm} &amp; estimates the spectral norm of the difference between two matrices specified by routines for applying the matrices and their adjoints to arbitrary vectors; this routine uses the power method with a random starting vector &amp; {\tt idz\_snorm.f} \\ \hline % {\tt idz\_enorm} &amp; calculates the Euclidean norm of a vector &amp; {\tt idz\_snorm.f} \\ \hline %</pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> {\tt idz\_estrank} &amp; estimates the numerical rank of an arbitrary (generally dense) matrix to a specified precision; this routine is randomized, and must be initialized with routine {\tt idz\_frmi} &amp; {\tt idzp\_aid.f} \\hline % {\tt idz\_frm} &amp; transforms a vector into a vector which is sufficiently scrambled to be subsampled, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform &amp; {\tt idz\_frm.f} \\hline % {\tt idz\_frmi} &amp; initializes routine {\tt idz\_frm} &amp; {\tt idz\_frm.f} \\hline % {\tt idz\_getcols} &amp; collects together selected columns of a matrix specified by a routine for applying the matrix to arbitrary vectors &amp; {\tt idz\_id.f} \\hline % {\tt idz\_house} &amp; calculates the vector and scalar needed to apply the Householder transformation reflecting a given vector into its first entry &amp; {\tt idz\_house.f} \\hline % {\tt idz\_houseapp} &amp; applies a Householder matrix to a vector &amp; {\tt idz\_house.f} \\hline % {\tt idz\_id2svd} &amp; converts an approximation to a matrix in the form of an ID into an approximation in the form of an SVD &amp; {\tt idz\_id2svd.f} \\hline % {\tt idz\_ldiv} &amp; finds the greatest integer less than or equal to a specified integer, that is divisible by another (larger) specified integer &amp; {\tt idz\_sfft.f} \\hline % {\tt idz\_permmult} &amp; multiplies together a bunch of permutations &amp; {\tt idz\_qrpiv.f} \\hline % {\tt idz\_qinqr} &amp; reconstructs the \$\$\$ matrix in a \$\$\$ decomposition from the output of routines {\tt idzp\_qrpiv} or </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> {\tt idzr\_qr piv} &amp; {\tt idz\_qr piv.f} \\hline % {\tt idz\_qr matmat} &amp; applies to multiple vectors collected together as a matrix the \$Q\$ matrix (or its adjoint) in the \$QR\$ decomposition of a matrix, as described by the output of routines {\tt idzp\_qr piv} or {\tt idzr\_qr piv}; to apply \$Q\$ (or its adjoint) to a single vector without having to provide a work array, use routine {\tt idz\_qr matvec} instead &amp; {\tt idz\_qr piv.f} \\hline % {\tt idz\_qr matvec} &amp; applies to a single vector the \$Q\$ matrix (or its adjoint) in the \$QR\$ decomposition of a matrix, as described by the output of routines {\tt idzp\_qr piv} or {\tt idzr\_qr piv}; to apply \$Q\$ (or its adjoint) to several vectors efficiently, use routine {\tt idz\_qr matmat} instead &amp; {\tt idz\_qr piv.f} \\hline % {\tt idz\_random\_ transf} &amp; applies rapidly a random unitary matrix to a user-supplied vector &amp; {\tt id\_rtrans.f} \\ \\hline % {\tt idz\_random\_ transf\_init} &amp; \raggedright initializes routines {\tt idz\_random\_ transf} and {\tt idz\_random\_ transf\_inverse} &amp; {\tt id\_rtrans.f} \\hline % {\tt idz\_random\_ transf\_inverse} &amp; applies rapidly the inverse of the operator applied by routine {\tt idz\_random\_ transf} &amp; {\tt id\_rtrans.f} \\hline % {\tt idz\_reconid} &amp; reconstructs a matrix from its ID &amp; {\tt idz\_id.f} \\hline % {\tt idz\_reconint} &amp; constructs \$P\$ in the ID \$A = B \setminus P\$, where the columns of \$B\$ are a subset of the columns of \$A\$, and \$P\$ is the projection coefficient matrix, given {\tt list}, {\tt krank}, and {\tt proj} output by routines {\tt idzr\_id}, {\tt idzp\_id}, </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> {\tt idzr\_aid}, {\tt idzp\_aid}, {\tt idzr\_rid}, or {\tt idzp\_rid} &amp; {\tt idz\_id.f} \\hline % {\tt idz\_sfft} &amp; rapidly computes a subset of the entries of the discrete Fourier transform of a vector, composed with permutation matrices both on input and on output &amp; {\tt idz\_sfft.f} \\hline % {\tt idz\_sffti} &amp; initializes routine {\tt idz\_sfft} &amp; {\tt idz\_sfft.f} \\hline % {\tt idz\_sfrm} &amp; transforms a vector into a scrambled vector of specified length, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform &amp; {\tt idz\_frm.f} \\hline % {\tt idz\_sfrmi} &amp; initializes routine {\tt idz\_sfrm} &amp; {\tt idz\_frm.f} \\hline % {\tt idz\_snorm} &amp; estimates the spectral norm of a matrix specified by routines for applying the matrix and its adjoint to arbitrary vectors; this routine uses the power method with a random starting vector &amp; {\tt idz\_snorm.f} \\hline % {\tt idzp\_aid} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idz\_frmi} &amp; {\tt idzp\_aid.f} \\hline % {\tt idzp\_asvd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idz\_frmi} &amp; {\tt idzp\_asvd.f} \\hline % {\tt idzp\_id} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> than routine {\tt idzp\_aid} &amp; {\tt idz\_id.f} \\ \hline % {\tt idzp\_grpiv} &amp; computes the pivoted \$QR\$ decomposition of an arbitrary (generally dense) matrix via Householder transformations, stopping at a specified precision of the decomposition &amp; {\tt idz\_grpiv.f} \\ \hline % {\tt idzp\_rid} &amp; computes the ID, to a specified precision, of a matrix specified by a routine for applying its adjoint to arbitrary vectors; this routine is randomized &amp; {\tt idzp\_rid.f} \\ \hline % {\tt idzp\_rsvd} &amp; computes the SVD, to a specified precision, of a matrix specified by routines for applying the matrix and its adjoint to arbitrary vectors; this routine is randomized &amp; {\tt idzp\_rsvd.f} \\ \hline % {\tt idzp\_svd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient than routine {\tt idzp\_asvd} &amp; {\tt idz\_svd.f} \\ \hline % {\tt idzr\_aid} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified rank; this routine is randomized, and must be initialized by routine {\tt idzr\_aidi} &amp; {\tt idzr\_aid.f} \\ \hline % {\tt idzr\_aidi} &amp; initializes routine {\tt idzr\_aid} &amp; {\tt idzr\_aid.f} \\ \hline % {\tt idzr\_asvd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified rank; this routine is randomized, and must be initialized with routine {\tt idz\_aidi} &amp; {\tt idzr\_asvd.f} \\ \hline % {\tt idzr\_id} &amp; computes the ID of an arbitrary (generally dense) matrix, to a specified rank; this routine is </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> often less efficient than routine {\tt idzr\_aid} &amp; {\tt idz\_id.f} \\ \hline % {\tt idzr\_grpiv} &amp; computes the pivoted \$QR\$ decomposition of an arbitrary (generally dense) matrix via Householder transformations, stopping at a specified rank of the decomposition &amp; {\tt idz\_grpiv.f} \\ \hline % {\tt idzr\_rid} &amp; computes the ID, to a specified rank, of a matrix specified by a routine for applying its adjoint to arbitrary vectors; this routine is randomized &amp; {\tt idzr\_rid.f} \\ \hline % {\tt idzr\_rsvd} &amp; computes the SVD, to a specified rank, of a matrix specified by routines for applying the matrix and its adjoint to arbitrary vectors; this routine is randomized &amp; {\tt idzr\_rsvd.f} \\ \hline % {\tt idzr\_svd} &amp; computes the SVD of an arbitrary (generally dense) matrix, to a specified rank; this routine is often less efficient than routine {\tt idzr\_asvd} &amp; {\tt idz\_svd.f} \\ % \end{supertabular} \end{center}  \section{Documentation in the source codes}  Each routine in the source codes includes documentation in the comments immediately following the declaration of the subroutine's calling sequence. This documentation describes the purpose of the routine, the input and output variables, and the required work arrays (if any). This documentation also cites relevant references. Please pay attention to the {\it N.B.}'s; {\it N.B.} stands for {\it nota bene} (Latin for `note well') and highlights important information about the </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<p>routines.</p> <p><code>\section{Notation and decompositions}</code>  <code>\label{defs}</code></p> <p>This section sets notational conventions employed in this documentation and the associated software, and defines both the singular value decomposition (SVD) and the interpolative decomposition (ID). For information concerning other mathematical objects used in the code (such as Householder transformations, pivoted <math>QR</math> decompositions, and discrete and fast Fourier transforms --- DFTs and FFTs), see, for example, <code>\cite{golub-van_loan}</code>. For detailed descriptions and proofs of the mathematical facts discussed in the present section, see, for example, <code>\cite{golub-van_loan}</code> and the references in <code>\cite{halko-martinsson-tropp}</code>.</p> <p>Throughout this document and the accompanying software distribution,  <math>\ x\ </math> always denotes the Euclidean norm of the vector <math>x</math>,  and <math>\ A\ </math> always denotes the spectral norm of the matrix <math>A</math>.  Subsection~\ref{Euclidean} below defines the Euclidean norm;  Subsection~\ref{spectral} below defines the spectral norm.  We use <math>A^*</math> to denote the adjoint of the matrix <math>A</math>.</p> <p><code>\subsection{Euclidean norm}</code>  <code>\label{Euclidean}</code></p> <p>For any positive integer <math>n</math>, and vector <math>x</math> of length <math>n</math>,  the Euclidean (<math>l^2</math>) norm <math>\ x\ </math> is  <math display="block">\ x\  = \sqrt{\sum_{k=1}^n  x_k ^2},</math> where <math>x_1, x_2, \dots, x_{n-1}, x_n</math> are the entries of <math>x</math>.</p>



**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<pre> \subsection{Spectral norm} \label{spectral}  For any positive integers <math>m</math> and <math>n</math>, and <math>m \times n</math> matrix <math>A</math>, the spectral (<math>l^2</math> operator) norm <math>\ A\ </math> is % \begin{equation} \ A_{m \times n}\  = \max \frac{\ A_{m \times n} v\ }{\ v\ }, \end{equation} % where the <math>\max</math> is taken over all <math>n \times 1</math> column vectors <math>v</math> such that <math>\ v\  \neq 0</math>. </pre> <pre> \subsection{Singular value decomposition (SVD)}  For any positive real number <math>\epsilon</math>, positive integers <math>k</math>, <math>m</math>, and <math>n</math> with <math>k \leq m</math> and <math>k \leq n</math>, and any <math>m \times n</math> matrix <math>A</math>, a rank-<math>k</math> approximation to <math>A</math> in the form of an SVD (to precision <math>\epsilon</math>) consists of an <math>m \times k</math> matrix <math>U</math> whose columns are orthonormal, an <math>n \times k</math> matrix <math>V</math> whose columns are orthonormal, and a diagonal <math>k \times k</math> matrix <math>\Sigma</math> with diagonal entries <math>\Sigma_{1,1} \geq \Sigma_{2,2} \geq \dots \geq \Sigma_{n-1,n-1} \geq \Sigma_{n,n} \geq 0</math>, such that % \begin{equation} \ A_{m \times n} - U_{m \times k} \Sigma_{k \times k} V_{k \times n}^*\  \leq \epsilon. \end{equation} % The product <math>U \Sigma V^*</math> is known as an SVD. The columns of <math>U</math> are known as left singular vectors; the columns of <math>V</math> are known as right singular vectors. </pre>

**Table 4-1 (Cont.) Open Source or Other Separately Licensed Software**

Provider	Component	Licensing Information
		<p>The diagonal entries of <math>\Sigma</math> are known as singular values.</p> <p>When <math>k = m</math> or <math>k = n</math>, and <math>A = U \Sigma V^T</math>, then <math>U \Sigma V^T</math> is known as the SVD of <math>A</math>; the columns of <math>U</math> are the left singular vectors of <math>A</math>, the columns of <math>V</math> are the right singular vectors of <math>A</math>, and the diagonal entries of <math>\Sigma</math> are the singular values of <math>A</math>.</p> <p>For any positive integer <math>k</math> with <math>k &lt; m</math> and <math>k &lt; n</math>, there exists a rank-<math>k</math> approximation to <math>A</math> in the form of an SVD, to precision <math>\sigma_{k+1}</math>, where <math>\sigma_{k+1}</math> is the <math>(k+1)^{\text{st}}</math> greatest singular value of <math>A</math>.</p> <p><b>Interpolative decomposition (ID)</b></p> <p>For any positive real number <math>\epsilon</math>, positive integers <math>k</math>, <math>m</math>, and <math>n</math> with <math>k \leq m</math> and <math>k \leq n</math>, and any <math>m \times n</math> matrix <math>A</math>, a rank-<math>k</math> approximation to <math>A</math> in the form of an ID (to precision <math>\epsilon</math>) consists of a <math>k \times n</math> matrix <math>P</math>, and an <math>m \times k</math> matrix <math>B</math> whose columns constitute a subset of the columns of <math>A</math>, such that</p> $\ A - BP\  \leq \epsilon$ <p>where <math>\  \cdot \ </math> is the Frobenius norm, and <math>P</math> is a projection matrix, and every entry of <math>P</math> has an absolute value less than or equal to a reasonably small positive real number, say 2.</p> <p>The product <math>BP</math> is known as an ID. The matrix <math>P</math> is known as the projection or interpolation matrix of the ID. Property 1 above approximates each column of <math>A</math> via a linear combination of the columns of <math>B</math> (which are themselves columns of <math>A</math>), with the</p>

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		<p>coefficients in the linear combination given by the entries of <math>P</math>.</p> <p>The interpolative decomposition is ``interpolative'' due to Property~2 above. The ID is numerically stable due to Property~3 above. It follows from Property~2 that the least (<math>k^{\text{th}}</math> greatest) singular value of <math>P</math> is at least 1. Combining Properties~2 and~3 yields that % \begin{equation}    P_{k \times n}    \leq \sqrt{4k(n-k)+1}. \end{equation}</p> <p>When <math>k = m</math> or <math>k = n</math>, and <math>A = B \setminus P</math>, then <math>B \setminus P</math> is known as the ID of <math>A</math>. For any positive integer <math>k</math> with <math>k &lt; m</math> and <math>k &lt; n</math>, there exists a rank-<math>k</math> approximation to <math>A</math> in the form of an ID, to precision <math>\sqrt{k(n-k)+1}</math>; <math>\sum_{k+1}^{\infty} \sigma_k^2</math>, where <math>\sum_{k+1}^{\infty} \sigma_k^2</math> is the <math>(k+1)^{\text{st}}</math> greatest singular value of <math>A</math> (in fact, there exists an ID in which every entry of the projection matrix <math>P</math> has an absolute value less than or equal to 1).</p> <p>\section{Bug reports, feedback, and support}</p> <p>Please let us know about errors in the software or in the documentation via e-mail to {\tt tygert@aya.yale.edu}. We would also appreciate hearing about particular applications of the codes, especially in the form of journal articles e-mailed to {\tt tygert@aya.yale.edu}. Mathematical and technical support may also be available via e-mail. Enjoy!</p> <p>\bibliographystyle{siam} \bibliography{doc}</p> <p>\end{document}</p> <p>*****</p>

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