

# More About Cargo and Crates.io

So far we've used only the most basic features of Cargo to build, run, and test our code, but it can do a lot more. In this chapter, we'll discuss some of its other, more advanced features to show you how to do the following:

- Customize your build through release profiles
- Publish libraries on [crates.io](https://crates.io)
- Organize large projects with workspaces
- Install binaries from [crates.io](https://crates.io)
- Extend Cargo using custom commands

Cargo can do even more than the functionality we cover in this chapter, so for a full explanation of all its features, see [its documentation](https://doc.rust-lang.org/cargo/).

## Customizing Builds with Release Profiles

In Rust, *release profiles* are predefined and customizable profiles with different configurations that allow a programmer to have more control over various options for compiling code. Each profile is configured independently of the others.

Cargo has two main profiles: the `dev` profile Cargo uses when you run `cargo build` and the `release` profile Cargo uses when you run `cargo build --release`. The `dev` profile is defined with good defaults for development, and the `release` profile has good defaults for release builds.

These profile names might be familiar from the output of your builds:

```
$ cargo build
  Finished dev [unoptimized + debuginfo] target(s) in 0.0s
$ cargo build --release
  Finished release [optimized] target(s) in 0.0s
```

The `dev` and `release` are these different profiles used by the compiler.

Cargo has default settings for each of the profiles that apply when you haven't explicitly added any `[profile.*]` sections in the project's *Cargo.toml* file. By adding `[profile.*]` sections for any profile you want to customize, you override any subset of the default settings. For example, here are the default values for the `opt-level` setting for the `dev` and `release` profiles:

Filename: Cargo.toml

```
[profile.dev]
opt-level = 0

[profile.release]
opt-level = 3
```

The `opt-level` setting controls the number of optimizations Rust will apply to your code, with a range of 0 to 3. Applying more optimizations extends compiling time, so if you're in development and compiling your code often, you'll want fewer optimizations to compile faster even if the resulting code runs slower. The default `opt-level` for `dev` is therefore 0. When you're ready to release your code, it's best to spend more time compiling. You'll only compile in release mode once, but you'll run the compiled program many times, so release mode trades longer compile time for code that runs faster. That is why the default `opt-level` for the `release` profile is 3.

You can override a default setting by adding a different value for it in *Cargo.toml*. For example, if we want to use optimization level 1 in the development profile, we can add these two lines to our project's *Cargo.toml* file:

Filename: Cargo.toml

```
[profile.dev]
opt-level = 1
```

This code overrides the default setting of `0`. Now when we run `cargo build`, Cargo will use the defaults for the `dev` profile plus our customization to `opt-level`. Because we set `opt-level` to `1`, Cargo will apply more optimizations than the default, but not as many as in a release build.

For the full list of configuration options and defaults for each profile, see [Cargo's documentation](#).

## Publishing a Crate to Crates.io

We've used packages from [crates.io](https://crates.io) as dependencies of our project, but you can also share your code with other people by publishing your own packages. The crate registry at [crates.io](https://crates.io) distributes the source code of your packages, so it primarily hosts code that is open source.

Rust and Cargo have features that make your published package easier for people to find and use. We'll talk about some of these features next and then explain how to publish a package.

## Making Useful Documentation Comments

Accurately documenting your packages will help other users know how and when to use them, so it's worth investing the time to write documentation. In Chapter 3, we discussed how to comment Rust code using two slashes, `//`. Rust also has a particular kind of comment for documentation, known conveniently as a *documentation comment*, that will generate HTML documentation. The HTML displays the contents of documentation comments for public API items intended for programmers interested in knowing how to *use* your crate as opposed to how your crate is *implemented*.

Documentation comments use three slashes, `///`, instead of two and support Markdown notation for formatting the text. Place documentation comments just before the item they're documenting. Listing 14-1 shows documentation comments for an `add_one` function in a crate named `my_crate`.

Filename: `src/lib.rs`

```
/// Adds one to the number given.
///
/// # Examples
///
/// ```
/// let arg = 5;
/// let answer = my_crate::add_one(arg);
///
/// assert_eq!(6, answer);
/// ```
pub fn add_one(x: i32) -> i32 {
    x + 1
}
```

Listing 14-1: A documentation comment for a function

Here, we give a description of what the `add_one` function does, start a section with the heading `Examples`, and then provide code that demonstrates how to use the `add_one` function. We can generate the HTML documentation from this documentation comment by running `cargo doc`. This command runs the `rustdoc` tool distributed with Rust and puts the generated HTML documentation in the `target/doc` directory.

For convenience, running `cargo doc --open` will build the HTML for your current crate's documentation (as well as the documentation for all of your crate's dependencies) and open the result in a web browser. Navigate to the `add_one` function and you'll see how the text in the documentation comments is rendered, as shown in Figure 14-1:

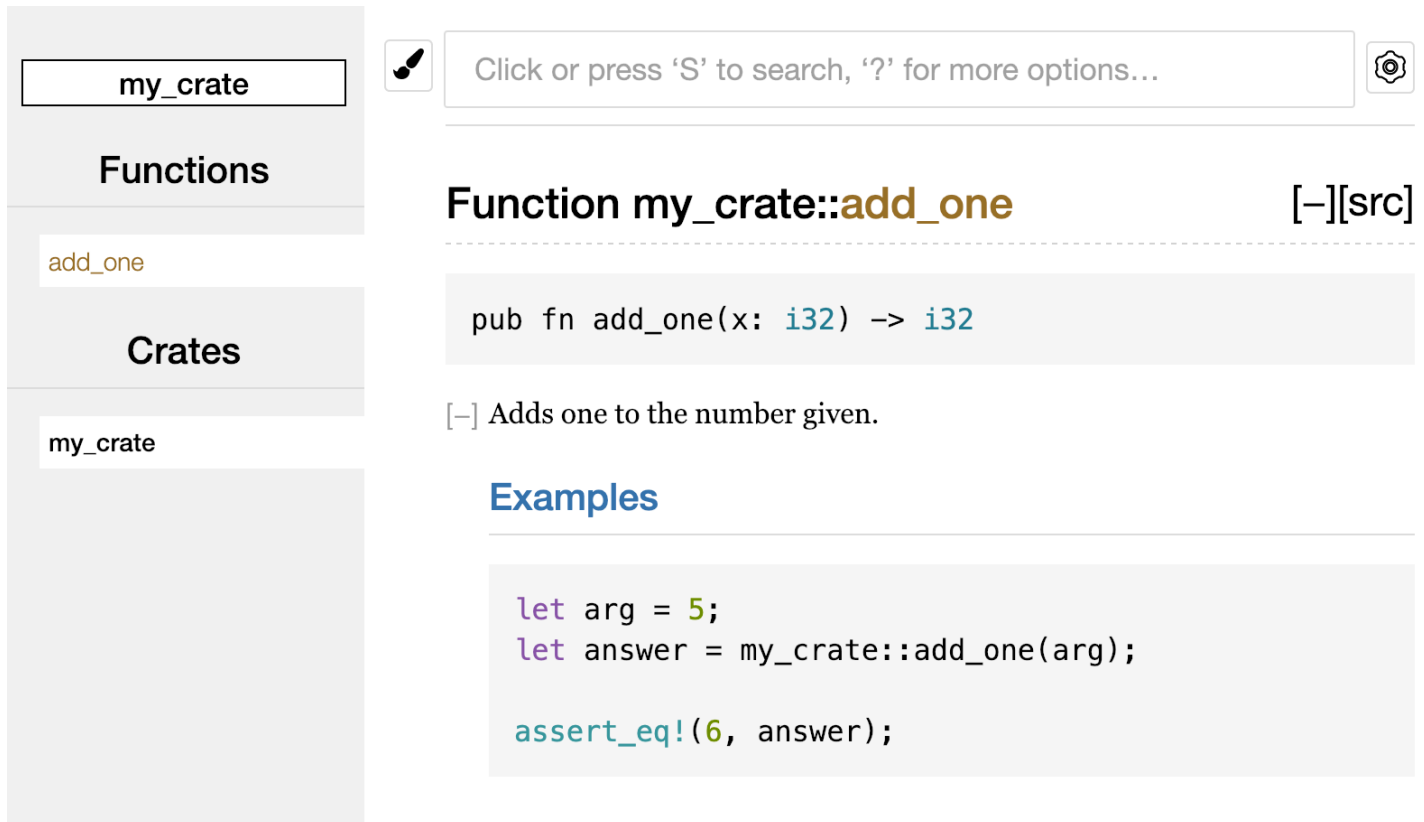


Figure 14-1: HTML documentation for the `add_one` function

## Commonly Used Sections

We used the `# Examples` Markdown heading in Listing 14-1 to create a section in the HTML with the title “Examples.” Here are some other sections that crate authors commonly use in their documentation:

- **Panics:** The scenarios in which the function being documented could panic. Callers of the function who don't want their programs to panic should make sure they don't call the function in these situations.

- **Errors:** If the function returns a `Result`, describing the kinds of errors that might occur and what conditions might cause those errors to be returned can be helpful to callers so they can write code to handle the different kinds of errors in different ways.
- **Safety:** If the function is `unsafe` to call (we discuss unsafety in Chapter 19), there should be a section explaining why the function is unsafe and covering the invariants that the function expects callers to uphold.

Most documentation comments don't need all of these sections, but this is a good checklist to remind you of the aspects of your code users will be interested in knowing about.

## Documentation Comments as Tests

Adding example code blocks in your documentation comments can help demonstrate how to use your library, and doing so has an additional bonus: running `cargo test` will run the code examples in your documentation as tests! Nothing is better than documentation with examples. But nothing is worse than examples that don't work because the code has changed since the documentation was written. If we run `cargo test` with the documentation for the `add_one` function from Listing 14-1, we will see a section in the test results like this:

```
Doc-tests my_crate
```

```
running 1 test
```

```
test src/lib.rs - add_one (line 5) ... ok
```

```
test result: ok. 1 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out;
finished in 0.27s
```

Now if we change either the function or the example so the `assert_eq!` in the example panics and run `cargo test` again, we'll see that the doc tests catch that the example and the code are out of sync with each other!

## Commenting Contained Items

The style of doc comment `//!` adds documentation to the item that contains the comments rather than to the items following the comments. We typically use these doc comments inside the crate root file (`src/lib.rs` by convention) or inside a module to document the crate or the module as a whole.

For example, to add documentation that describes the purpose of the `my_crate` crate that contains the `add_one` function, we add documentation comments that start with `//!` to the beginning of the `src/lib.rs` file, as shown in Listing 14-2:

Filename: `src/lib.rs`

```

//! # My Crate
//!
//! `my_crate` is a collection of utilities to make performing certain
//! calculations more convenient.

/// Adds one to the number given.
// --snip--

```

#### Listing 14-2: Documentation for the `my_crate` crate as a whole

Notice there isn't any code after the last line that begins with `//!`. Because we started the comments with `//!` instead of `///`, we're documenting the item that contains this comment rather than an item that follows this comment. In this case, that item is the `src/lib.rs` file, which is the crate root. These comments describe the entire crate.

When we run `cargo doc --open`, these comments will display on the front page of the documentation for `my_crate` above the list of public items in the crate, as shown in Figure 14-2:

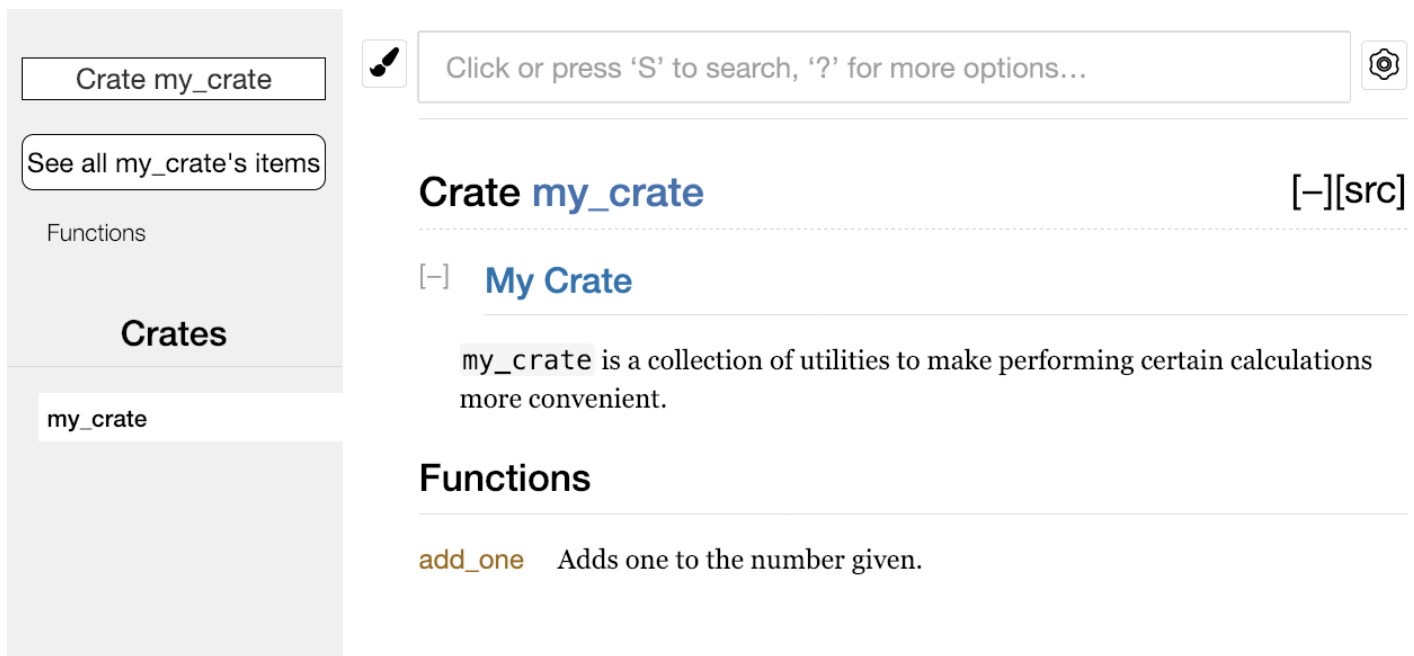


Figure 14-2: Rendered documentation for `my_crate`, including the comment describing the crate as a whole

Documentation comments within items are useful for describing crates and modules especially. Use them to explain the overall purpose of the container to help your users understand the crate's organization.

## Exporting a Convenient Public API with `pub use`

The structure of your public API is a major consideration when publishing a crate. People who use your crate are less familiar with the structure than you are and might have difficulty finding the pieces they want to use if your crate has a large module hierarchy.

In Chapter 7, we covered how to make items public using the `pub` keyword, and bring items into a scope with the `use` keyword. However, the structure that makes sense to you while you're developing a crate might not be very convenient for your users. You might want to organize your structs in a hierarchy containing multiple levels, but then people who want to use a type you've defined deep in the hierarchy might have trouble finding out that type exists. They might also be annoyed at having to enter `use`

```
my_crate::some_module::another_module::UsefulType; rather than use
my_crate::UsefulType; .
```

The good news is that if the structure *isn't* convenient for others to use from another library, you don't have to rearrange your internal organization: instead, you can re-export items to make a public structure that's different from your private structure by using `pub use`. Re-exporting takes a public item in one location and makes it public in another location, as if it were defined in the other location instead.

For example, say we made a library named `art` for modeling artistic concepts. Within this library are two modules: a `kinds` module containing two enums named `PrimaryColor` and `SecondaryColor` and a `utils` module containing a function named `mix`, as shown in Listing 14-3:

Filename: `src/lib.rs`



```
//! # Art
//!
//! A library for modeling artistic concepts.

pub mod kinds {
    /// The primary colors according to the RYB color model.
    pub enum PrimaryColor {
        Red,
        Yellow,
        Blue,
    }

    /// The secondary colors according to the RYB color model.
    pub enum SecondaryColor {
        Orange,
        Green,
        Purple,
    }
}

pub mod utils {
    use crate::kinds::*;

    /// Combines two primary colors in equal amounts to create
    /// a secondary color.
    pub fn mix(c1: PrimaryColor, c2: PrimaryColor) -> SecondaryColor {
        // --snip--
    }
}
```

Listing 14-3: An `art` library with items organized into `kinds` and `utils` modules

Figure 14-3 shows what the front page of the documentation for this crate generated by `cargo doc` would look like:

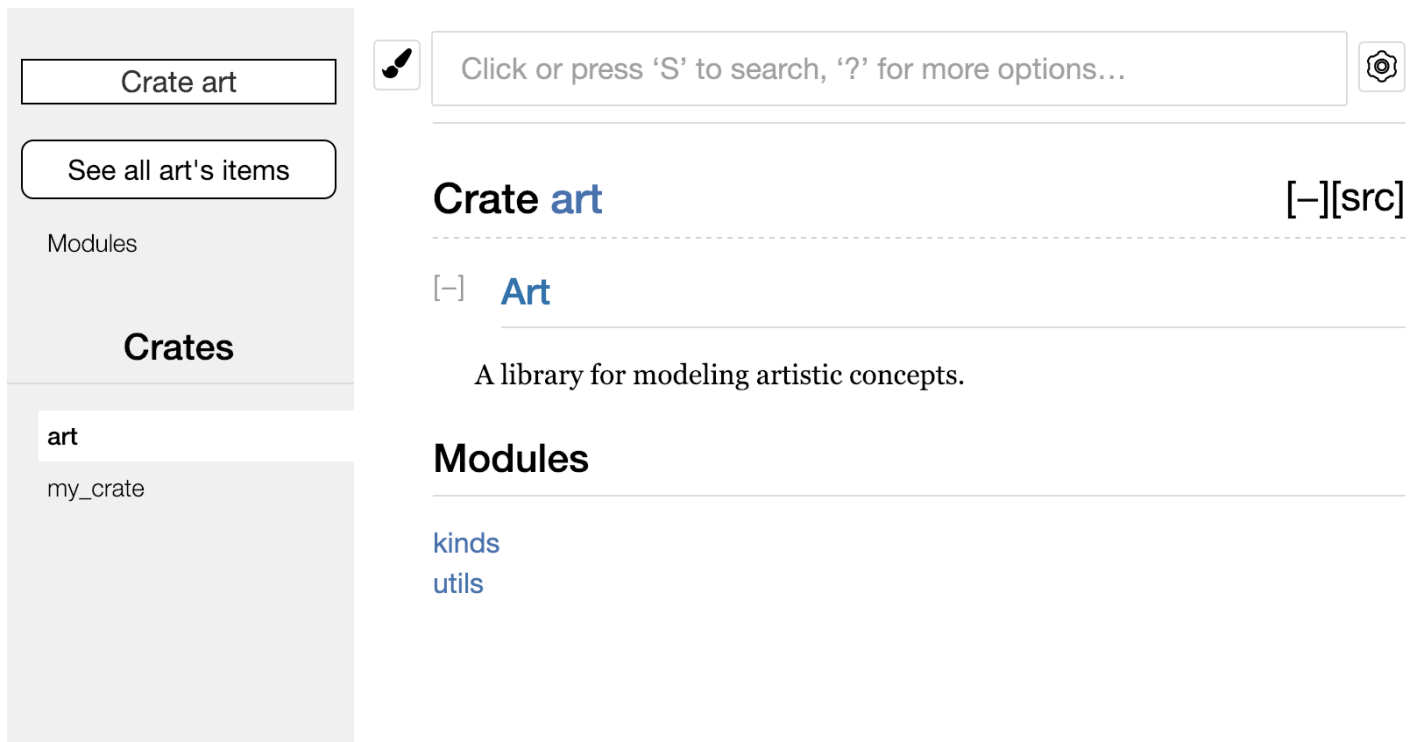


Figure 14-3: Front page of the documentation for `art` that lists the `kinds` and `utils` modules

Note that the `PrimaryColor` and `SecondaryColor` types aren't listed on the front page, nor is the `mix` function. We have to click `kinds` and `utils` to see them.

Another crate that depends on this library would need `use` statements that bring the items from `art` into scope, specifying the module structure that's currently defined. Listing 14-4 shows an example of a crate that uses the `PrimaryColor` and `mix` items from the `art` crate:

Filename: `src/main.rs`

```
use art::kinds::PrimaryColor;
use art::utils::mix;

fn main() {
    let red = PrimaryColor::Red;
    let yellow = PrimaryColor::Yellow;
    mix(red, yellow);
}
```

Listing 14-4: A crate using the `art` crate's items with its internal structure exported

The author of the code in Listing 14-4, which uses the `art` crate, had to figure out that `PrimaryColor` is in the `kinds` module and `mix` is in the `utils` module. The module structure of the `art` crate is more relevant to developers working on the `art` crate than to those using it. The internal structure doesn't contain any useful information for someone trying to understand how to use the `art` crate, but rather causes confusion because developers who

use it have to figure out where to look, and must specify the module names in the `use` statements.

To remove the internal organization from the public API, we can modify the `art` crate code in Listing 14-3 to add `pub use` statements to re-export the items at the top level, as shown in Listing 14-5:

Filename: `src/lib.rs`

```
//! # Art
//!
//! A library for modeling artistic concepts.

pub use self::kinds::PrimaryColor;
pub use self::kinds::SecondaryColor;
pub use self::utils::mix;

pub mod kinds {
    // --snip--
}

pub mod utils {
    // --snip--
}
```

Listing 14-5: Adding `pub use` statements to re-export items

The API documentation that `cargo doc` generates for this crate will now list and link re-exports on the front page, as shown in Figure 14-4, making the `PrimaryColor` and `SecondaryColor` types and the `mix` function easier to find.

The screenshot shows the front page of the documentation for the `art` crate. On the left, a sidebar contains a search bar, a link to 'See all art's items', and a list of 'Re-exports' and 'Modules'. The main content area features the crate name 'art' with a source link, a description 'A library for modeling artistic concepts.', and sections for 'Re-exports' and 'Modules'. The 'Re-exports' section lists 'PrimaryColor' and 'SecondaryColor'. The 'Modules' section lists 'kinds' and 'utils'.

Figure 14-4: The front page of the documentation for `art` that lists the re-exports

The `art` crate users can still see and use the internal structure from Listing 14-3 as demonstrated in Listing 14-4, or they can use the more convenient structure in Listing 14-5, as shown in Listing 14-6:

Filename: `src/main.rs`

```
use art::mix;
use art::PrimaryColor;

fn main() {
    // --snip--
}
```

Listing 14-6: A program using the re-exported items from the `art` crate

In cases where there are many nested modules, re-exporting the types at the top level with `pub use` can make a significant difference in the experience of people who use the crate. Another common use of `pub use` is to re-export definitions of a dependency in the current crate to make that crate's definitions part of your crate's public API.

Creating a useful public API structure is more of an art than a science, and you can iterate to find the API that works best for your users. Choosing `pub use` gives you flexibility in how you structure your crate internally and decouples that internal structure from what you present to your users. Look at some of the code of crates you've installed to see if their internal structure differs from their public API.

## Setting Up a Crates.io Account

Before you can publish any crates, you need to create an account on [crates.io](https://crates.io) and get an API token. To do so, visit the home page at [crates.io](https://crates.io) and log in via a GitHub account. (The GitHub account is currently a requirement, but the site might support other ways of creating an account in the future.) Once you're logged in, visit your account settings at <https://crates.io/me/> and retrieve your API key. Then run the `cargo login` command and paste your API key when prompted, like this:

```
$ cargo login
abcdefghijklmnopqrstuvwxyz012345
```

This command will inform Cargo of your API token and store it locally in `~/.cargo/credentials`. Note that this token is a *secret*: do not share it with anyone else. If you do share it with anyone for any reason, you should revoke it and generate a new token on [crates.io](https://crates.io).

## Adding Metadata to a New Crate

Let's say you have a crate you want to publish. Before publishing, you'll need to add some metadata in the `[package]` section of the crate's *Cargo.toml* file.

Your crate will need a unique name. While you're working on a crate locally, you can name a crate whatever you'd like. However, crate names on [crates.io](https://crates.io) are allocated on a first-come, first-served basis. Once a crate name is taken, no one else can publish a crate with that name. Before attempting to publish a crate, search for the name you want to use. If the name has been used, you will need to find another name and edit the `name` field in the *Cargo.toml* file under the `[package]` section to use the new name for publishing, like so:

Filename: Cargo.toml

```
[package]
name = "guessing_game"
```

Even if you've chosen a unique name, when you run `cargo publish` to publish the crate at this point, you'll get a warning and then an error:

```
$ cargo publish
Updating crates.io index
warning: manifest has no description, license, license-file, documentation,
homepage or repository.
See https://doc.rust-lang.org/cargo/reference/manifest.html#package-metadata for
more info.
--snip--
error: failed to publish to registry at https://crates.io
```

Caused by:

```
the remote server responded with an error: missing or empty metadata fields:
description, license. Please see https://doc.rust-
lang.org/cargo/reference/manifest.html for how to upload metadata
```

This errors because you're missing some crucial information: a description and license are required so people will know what your crate does and under what terms they can use it. In *Cargo.toml*, add a description that's just a sentence or two, because it will appear with your crate in search results. For the `license` field, you need to give a *license identifier value*. The [Linux Foundation's Software Package Data Exchange \(SPDX\)](https://spdx.org/licenses/) lists the identifiers you can use for this value. For example, to specify that you've licensed your crate using the MIT License, add the `MIT` identifier:

Filename: Cargo.toml

```
[package]
name = "guessing_game"
license = "MIT"
```

If you want to use a license that doesn't appear in the SPDX, you need to place the text of that license in a file, include the file in your project, and then use `license-file` to specify the name of that file instead of using the `license` key.

Guidance on which license is appropriate for your project is beyond the scope of this book. Many people in the Rust community license their projects in the same way as Rust by using a dual license of `MIT OR Apache-2.0`. This practice demonstrates that you can also specify multiple license identifiers separated by `OR` to have multiple licenses for your project.

With a unique name, the version, your description, and a license added, the *Cargo.toml* file for a project that is ready to publish might look like this:

Filename: Cargo.toml

```
[package]
name = "guessing_game"
version = "0.1.0"
edition = "2021"
description = "A fun game where you guess what number the computer has chosen."
license = "MIT OR Apache-2.0"
```

```
[dependencies]
```

[Cargo's documentation](#) describes other metadata you can specify to ensure others can discover and use your crate more easily.

## Publishing to Crates.io

Now that you've created an account, saved your API token, chosen a name for your crate, and specified the required metadata, you're ready to publish! Publishing a crate uploads a specific version to [crates.io](#) for others to use.

Be careful, because a publish is *permanent*. The version can never be overwritten, and the code cannot be deleted. One major goal of [crates.io](#) is to act as a permanent archive of code so that builds of all projects that depend on crates from [crates.io](#) will continue to work. Allowing version deletions would make fulfilling that goal impossible. However, there is no limit to the number of crate versions you can publish.

Run the `cargo publish` command again. It should succeed now:

```
$ cargo publish
  Updating crates.io index
  Packaging guessing_game v0.1.0 (file:///projects/guessing_game)
  Verifying guessing_game v0.1.0 (file:///projects/guessing_game)
  Compiling guessing_game v0.1.0
(file:///projects/guessing_game/target/package/guessing_game-0.1.0)
  Finished dev [unoptimized + debuginfo] target(s) in 0.19s
  Uploading guessing_game v0.1.0 (file:///projects/guessing_game)
```

Congratulations! You've now shared your code with the Rust community, and anyone can easily add your crate as a dependency of their project.

## Publishing a New Version of an Existing Crate

When you've made changes to your crate and are ready to release a new version, you change the `version` value specified in your *Cargo.toml* file and republish. Use the [Semantic Versioning](#)

[rules](#) to decide what an appropriate next version number is based on the kinds of changes you've made. Then run `cargo publish` to upload the new version.

## Deprecating Versions from Crates.io with `cargo yank`

Although you can't remove previous versions of a crate, you can prevent any future projects from adding them as a new dependency. This is useful when a crate version is broken for one reason or another. In such situations, Cargo supports *yanking* a crate version.

Yanking a version prevents new projects from depending on that version while allowing all existing projects that depend on it to continue. Essentially, a yank means that all projects with a *Cargo.lock* will not break, and any future *Cargo.lock* files generated will not use the yanked version.

To yank a version of a crate, in the directory of the crate that you've previously published, run `cargo yank` and specify which version you want to yank. For example, if we've published a crate named `guessing_game` version 1.0.1 and we want to yank it, in the project directory for `guessing_game` we'd run:

```
$ cargo yank --vers 1.0.1
    Updating crates.io index
    Yank guessing_game@1.0.1
```

By adding `--undo` to the command, you can also undo a yank and allow projects to start depending on a version again:

```
$ cargo yank --vers 1.0.1 --undo
    Updating crates.io index
    Unyank guessing_game@1.0.1
```

A yank *does not* delete any code. It cannot, for example, delete accidentally uploaded secrets. If that happens, you must reset those secrets immediately.



# Cargo Workspaces

In Chapter 12, we built a package that included a binary crate and a library crate. As your project develops, you might find that the library crate continues to get bigger and you want to split your package further into multiple library crates. Cargo offers a feature called *workspaces* that can help manage multiple related packages that are developed in tandem.

## Creating a Workspace

A *workspace* is a set of packages that share the same *Cargo.lock* and output directory. Let's make a project using a workspace—we'll use trivial code so we can concentrate on the structure of the workspace. There are multiple ways to structure a workspace, so we'll just show one common way. We'll have a workspace containing a binary and two libraries. The binary, which will provide the main functionality, will depend on the two libraries. One library will provide an `add_one` function, and a second library an `add_two` function. These three crates will be part of the same workspace. We'll start by creating a new directory for the workspace:

```
$ mkdir add
$ cd add
```

Next, in the *add* directory, we create the *Cargo.toml* file that will configure the entire workspace. This file won't have a `[package]` section. Instead, it will start with a `[workspace]` section that will allow us to add members to the workspace by specifying the path to the package with our binary crate; in this case, that path is *adder*:

Filename: Cargo.toml

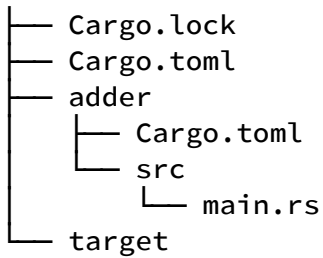
```
[workspace]

members = [
    "adder",
]
```

Next, we'll create the *adder* binary crate by running `cargo new` within the *add* directory:

```
$ cargo new adder
    Created binary (application) `adder` package
```

At this point, we can build the workspace by running `cargo build`. The files in your *add* directory should look like this:



The workspace has one *target* directory at the top level that the compiled artifacts will be placed into; the `adder` package doesn't have its own *target* directory. Even if we were to run `cargo build` from inside the *adder* directory, the compiled artifacts would still end up in *add/target* rather than *add/adder/target*. Cargo structures the *target* directory in a workspace like this because the crates in a workspace are meant to depend on each other. If each crate had its own *target* directory, each crate would have to recompile each of the other crates in the workspace to place the artifacts in its own *target* directory. By sharing one *target* directory, the crates can avoid unnecessary rebuilding.

## Creating the Second Package in the Workspace

Next, let's create another member package in the workspace and call it `add_one`. Change the top-level *Cargo.toml* to specify the *add\_one* path in the `members` list:

Filename: Cargo.toml

```

[workspace]

members = [
    "adder",
    "add_one",
]

```

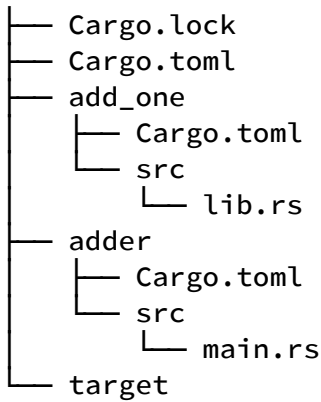
Then generate a new library crate named `add_one`:

```

$ cargo new add_one --lib
   Created library `add_one` package

```

Your *add* directory should now have these directories and files:



In the `add_one/src/lib.rs` file, let's add an `add_one` function:

Filename: `add_one/src/lib.rs`

```
pub fn add_one(x: i32) -> i32 {
    x + 1
}
```

Now we can have the `adder` package with our binary depend on the `add_one` package that has our library. First, we'll need to add a path dependency on `add_one` to `adder/Cargo.toml`.

Filename: `adder/Cargo.toml`

```
[dependencies]
add_one = { path = "../add_one" }
```

Cargo doesn't assume that crates in a workspace will depend on each other, so we need to be explicit about the dependency relationships.

Next, let's use the `add_one` function (from the `add_one` crate) in the `adder` crate. Open the `adder/src/main.rs` file and add a `use` line at the top to bring the new `add_one` library crate into scope. Then change the `main` function to call the `add_one` function, as in Listing 14-7.

Filename: `adder/src/main.rs`

```
use add_one;

fn main() {
    let num = 10;
    println!("Hello, world! {num} plus one is {}!", add_one::add_one(num));
}
```

Listing 14-7: Using the `add_one` library crate from the `adder` crate

Let's build the workspace by running `cargo build` in the top-level `add` directory!

```
$ cargo build
Compiling add_one v0.1.0 (file:///projects/add/add_one)
Compiling adder v0.1.0 (file:///projects/add/adder)
Finished dev [unoptimized + debuginfo] target(s) in 0.68s
```

To run the binary crate from the *add* directory, we can specify which package in the workspace we want to run by using the `-p` argument and the package name with `cargo run`:

```
$ cargo run -p adder
Finished dev [unoptimized + debuginfo] target(s) in 0.0s
Running `target/debug/adder`
Hello, world! 10 plus one is 11!
```

This runs the code in *adder/src/main.rs*, which depends on the *add\_one* crate.

## Depending on an External Package in a Workspace

Notice that the workspace has only one *Cargo.lock* file at the top level, rather than having a *Cargo.lock* in each crate's directory. This ensures that all crates are using the same version of all dependencies. If we add the *rand* package to the *adder/Cargo.toml* and *add\_one/Cargo.toml* files, Cargo will resolve both of those to one version of *rand* and record that in the one *Cargo.lock*. Making all crates in the workspace use the same dependencies means the crates will always be compatible with each other. Let's add the *rand* crate to the `[dependencies]` section in the *add\_one/Cargo.toml* file so we can use the *rand* crate in the *add\_one* crate:

Filename: *add\_one/Cargo.toml*

```
[dependencies]
rand = "0.8.5"
```

We can now add `use rand;` to the *add\_one/src/lib.rs* file, and building the whole workspace by running `cargo build` in the *add* directory will bring in and compile the *rand* crate. We will get one warning because we aren't referring to the *rand* we brought into scope:

```
$ cargo build
  Updating crates.io index
  Downloaded rand v0.8.5
  --snip--
  Compiling rand v0.8.5
  Compiling add_one v0.1.0 (file:///projects/add/add_one)
warning: unused import: `rand`
--> add_one/src/lib.rs:1:5
|
1 | use rand;
|     ^^^^
|
= note: `#[warn(unused_imports)]` on by default

warning: `add_one` (lib) generated 1 warning
  Compiling adder v0.1.0 (file:///projects/add/adder)
  Finished dev [unoptimized + debuginfo] target(s) in 10.18s
```

The top-level *Cargo.lock* now contains information about the dependency of `add_one` on `rand`. However, even though `rand` is used somewhere in the workspace, we can't use it in other crates in the workspace unless we add `rand` to their *Cargo.toml* files as well. For example, if we add `use rand;` to the *adder/src/main.rs* file for the `adder` package, we'll get an error:

```
$ cargo build
  --snip--
  Compiling adder v0.1.0 (file:///projects/add/adder)
error[E0432]: unresolved import `rand`
--> adder/src/main.rs:2:5
|
2 | use rand;
|     ^^^^ no external crate `rand`
```

To fix this, edit the *Cargo.toml* file for the `adder` package and indicate that `rand` is a dependency for it as well. Building the `adder` package will add `rand` to the list of dependencies for `adder` in *Cargo.lock*, but no additional copies of `rand` will be downloaded. Cargo will ensure that every crate in every package in the workspace using the `rand` package will be using the same version as long as they specify compatible versions of `rand`, saving us space and ensuring that the crates in the workspace will be compatible with each other.

If crates in the workspace specify incompatible versions of the same dependency, Cargo will resolve each of them, but will still try to resolve as few versions as possible.

## Adding a Test to a Workspace

For another enhancement, let's add a test of the `add_one::add_one` function within the `add_one` crate:

Filename: add\_one/src/lib.rs

```
pub fn add_one(x: i32) -> i32 {
    x + 1
}

#[cfg(test)]
mod tests {
    use super::*;

    #[test]
    fn it_works() {
        assert_eq!(3, add_one(2));
    }
}
```

Now run `cargo test` in the top-level *add* directory. Running `cargo test` in a workspace structured like this one will run the tests for all the crates in the workspace:

```
$ cargo test
   Compiling add_one v0.1.0 (file:///projects/add/add_one)
   Compiling adder v0.1.0 (file:///projects/add/adder)
   Finished test [unoptimized + debuginfo] target(s) in 0.27s
   Running unittests src/lib.rs (target/debug/deps/add_one-f0253159197f7841)

running 1 test
test tests::it_works ... ok

test result: ok. 1 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out;
finished in 0.00s

   Running unittests src/main.rs (target/debug/deps/adder-49979ff40686fa8e)

running 0 tests

test result: ok. 0 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out;
finished in 0.00s

   Doc-tests add_one

running 0 tests

test result: ok. 0 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out;
finished in 0.00s
```

The first section of the output shows that the `it_works` test in the `add_one` crate passed. The next section shows that zero tests were found in the `adder` crate, and then the last section shows zero documentation tests were found in the `add_one` crate.

We can also run tests for one particular crate in a workspace from the top-level directory by using the `-p` flag and specifying the name of the crate we want to test:

```
$ cargo test -p add_one
    Finished test [unoptimized + debuginfo] target(s) in 0.00s
    Running unittests src/lib.rs (target/debug/deps/add_one-b3235fea9a156f74)

running 1 test
test tests::it_works ... ok

test result: ok. 1 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out;
finished in 0.00s

Doc-tests add_one

running 0 tests

test result: ok. 0 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out;
finished in 0.00s
```

This output shows `cargo test` only ran the tests for the `add_one` crate and didn't run the `adder` crate tests.

If you publish the crates in the workspace to [crates.io](https://crates.io), each crate in the workspace will need to be published separately. Like `cargo test`, we can publish a particular crate in our workspace by using the `-p` flag and specifying the name of the crate we want to publish.

For additional practice, add an `add_two` crate to this workspace in a similar way as the `add_one` crate!

As your project grows, consider using a workspace: it's easier to understand smaller, individual components than one big blob of code. Furthermore, keeping the crates in a workspace can make coordination between crates easier if they are often changed at the same time.

## Installing Binaries with `cargo install`

The `cargo install` command allows you to install and use binary crates locally. This isn't intended to replace system packages; it's meant to be a convenient way for Rust developers to install tools that others have shared on [crates.io](https://crates.io). Note that you can only install packages that have binary targets. A *binary target* is the runnable program that is created if the crate has a `src/main.rs` file or another file specified as a binary, as opposed to a library target that isn't runnable on its own but is suitable for including within other programs. Usually, crates have information in the *README* file about whether a crate is a library, has a binary target, or both.

All binaries installed with `cargo install` are stored in the installation root's *bin* folder. If you installed Rust using *rustup.rs* and don't have any custom configurations, this directory will be `$HOME/.cargo/bin`. Ensure that directory is in your `$PATH` to be able to run programs you've installed with `cargo install`.

For example, in Chapter 12 we mentioned that there's a Rust implementation of the `grep` tool called `ripgrep` for searching files. To install `ripgrep`, we can run the following:

```
$ cargo install ripgrep
  Updating crates.io index
  Downloaded ripgrep v13.0.0
  Downloaded 1 crate (243.3 KB) in 0.88s
  Installing ripgrep v13.0.0
--snip--
  Compiling ripgrep v13.0.0
  Finished release [optimized + debuginfo] target(s) in 3m 10s
  Installing ~/.cargo/bin/rg
  Installed package `ripgrep v13.0.0` (executable `rg`)
```

The second-to-last line of the output shows the location and the name of the installed binary, which in the case of `ripgrep` is `rg`. As long as the installation directory is in your `$PATH`, as mentioned previously, you can then run `rg --help` and start using a faster, rustier tool for searching files!



## Extending Cargo with Custom Commands

Cargo is designed so you can extend it with new subcommands without having to modify Cargo. If a binary in your `$PATH` is named `cargo-something`, you can run it as if it was a Cargo subcommand by running `cargo something`. Custom commands like this are also listed when you run `cargo --list`. Being able to use `cargo install` to install extensions and then run them just like the built-in Cargo tools is a super convenient benefit of Cargo's design!

## Summary

Sharing code with Cargo and [crates.io](https://crates.io) is part of what makes the Rust ecosystem useful for many different tasks. Rust's standard library is small and stable, but crates are easy to share, use, and improve on a timeline different from that of the language. Don't be shy about sharing code that's useful to you on [crates.io](https://crates.io); it's likely that it will be useful to someone else as well!