Crnk Documentation

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Crnk is a native resource-oriented rest library where resources, their relationships and repositories are the main building blocks. In that regard Crnk differ quite dramatically from most REST library out there and opens up many new possibilities. It allows you to rapidly build REST APIs without having to worry about lower protocol details and lets you instead focus on what matters: your application. On the HTTP/REST layer it supports multiple formats. By default it follows the JSON:API specification and recommendations. But there is also a similar, more basic endpoint targeting simpler applications. Crnk come with support for:

- client and server implementation.
- standardized url handling such as `/api/persons?filter[title]=John` and `/api/persons/{id}`
- sorting, filtering, paging of resources
- attaching link and meta information to resources.
- inserting, updating and deleting of resources.
- support to request complex object graphs in a single request with JSON:API inclusions.
- support for partial objects with sparse field sets.
- atomically create, update and delete multiple with jsonpatch.com.
- a flexible module API to choose and extend the feature set of Crnk.
- eased testing with the client implementation providing type-safe stubs to access server repositories.
- repositories providing runtime/meta information about Crnk to implement, for example, documentation and UI automation.
- generation of type-safe client stubs (currently Typescript as target language implemented)
- binding of Angular components with ngrx-json-api to Crnk endpoints.
- filters and decorates to intercept and modify all aspects of an application and Crnk.
- a module API to build and plugin-in reusable Crnk modules. Crnk comes with number of such (optional) modules to integrate with third-party libraries and frameworks.

Crnk is small, modular and lightweight. It integrates well with many popular frameworks and APIs:

- CDI: resolve repositories and extensions with CDI.
- Spring: run Crnk with Spring, including support for Spring Boot, ORM, Security and Sleuth.
- Reactor: for support of reactive programming.
- Servlet API: run Crnk as servlet.
- JAXRS: run Crnk as feature.
- JPA: expose entities as JSON:API resources.
- bean validation: properly marshal validation and constraints exceptions.

- Zipkin, Brave, Spring Sleuth: trace all your calls.

While Crnk follows the JSON:API specification, it is not limited to that. Have a look at the http://www.crnk.io/[roadmap> for more information.

1. Examples

Crnk comes with various examples. There is a main example application in a dedicated repository available from crnk-example. It **shows an end-to-end example** with Crnk, Angular, Spring Boot and ngrx-json-api.

And there are various simpler example applications that show the integration of Crnk into various frameworks like:

- `spring-boot-example`
- `spring-boot-minimal-example` showcasing a minimal setup of Crnk with Spring Boot.
- `spring-boot-microservice-example` showcasing how to connect two separate JSON:API endpoints through a relationship with crnk-client.
- `wildfly-example`
- `dropwizard-mongo-example`
- `dropwizard-simple-example`
- `jersey-example`
- `dagger-vertx-example` showcasing a very lightweight setup with Dagger, Vert.x, Proguard, OpenJ9 VM having a small size, startup time and memory footprint.

available from crnk-integration-examples.

The impatient may also directly want to jump to ResourceRepository, but it is highly recommended to familiarize one self with the architecture and annotations as well. Unlike traditional REST libraries, Crnk comes with a lot of built-in semantics that allow to automate otherwise laborious tasks.

2. Architecture

Resources, **relationships** and **repositories** are the central building blocks of Crnk:

- Resources hold data as value fields, meta information and link information.
- Relationships establish links between resources.
- **resource repositories** and **relationship repositories** implement access to resources and relationships.

A Crnk application models its API as resources and relationships. It is not uncommon for

applications to also have a few remaining service-oriented APIs. Later chapters will show how Crnk integrates with other libraries like JAX-RS or Spring MVC to achieve this. Based on such a model, an application implements repositories to provide access trough that model.

Currently implemented is the JSON:API specification to access that model as part of the `crnk-core` project. The JSON:API specification provide all the essential building blocks like sorting, filtering, paging, document formats, linking and error handling to access resources and relationships. But other implementations, such as GraphQL or different kinds of REST/JSON:APIs, are possible as well. With JSON:API, an incoming request is processed as follows:

- A Crnk interceptor is called from the underlying framework. This might be, for example, from a Servlet environment, JAX-RS or Spring MVC.
- The request is deserialized to Crnk data structures like `Document`, `Resource`, `ResourceIdentifier` or `ErrorData`.
- The type of request is determined: whether it is a `POST`, `PATCH`, `GET` or `DELETE` request and whether it is a resource or relationship request.
- The request is forwarded to the appropriate repository.
- `GET` requests can ask for inclusions of further, related resources. Result resources will then trigger further requests to other repositories. This can happen either manually from within the initially called repository or automatically by Crnk (explained in detail in later chapters).
- The result resources are merged into response document and returned to the underlying framework for delivery. Possible exceptions are handled as and mapped as well.

A benefit of Crnk is its flexibility how to set all this up:

- Resources and relationships can be defined with simple Java Beans and annotations or programmatically. The later allows virtually any kind of customization at runtime, like setting up repositories dynamically. One example is `crnk-data-jpa` that is able to expose any JPA entity as JSON:API resource.
- Resources and relationships can be entirely decoupled concerns. For example, an independent relationship repository `C` can introduce a relationship between a resource `a` and resource `b` implemented by resource repositories `A` and `B`. For example, an audit component could intercept and log any modifications. Access to it is provided by introducing a new relationship `history` onto each resource.
- Information about resources, relationships and repositories are available trough a Java API and JSON:API endpoint.
- Filters and decorators allow to intercept and modify every step along the request chain. This can be used, for example, to enforce security, collect metrics or do tracing.

To facilitate the setup, Crnk comes with a small module API. Independent functionality can be assembled as module and then just included into the application. Crnk comes with a number of modules on its own:

- `crnk-data-jpa`
- `crnk-validation`
- `crnk-operations`

- various Spring modules
- ...

Such modules can make use of filters, decorators, decoupled resources and relationships and various other features. Everything together fosters the use of the **composite pattern** where larger applications can be assembled from smaller parts, some from third-party modules and others manually implemented.

The part of `crnk-core` taking care of all this is denoted as the `engine`. The subsequent chapters explain how to setup and use Crnk.

3. Setup

Crnk integrates well with many popular framework. The example applications outline various different possible setups. But application are also free to customize their setup to their liking. There are three main, orthogonal aspects of Crnk that need configuration:

1. The integration into a web framework like JAXRS or the Servlet API to be able to process requests.
2. The discovery of repositories, modules, exception mappers, etc. Usually by a dependency injection framework. But can also happen manually.
3. The selection of third-party modules to reuse. For a list of modules provided by Crnk see the <modules> chapter.

The subsequent sections explain various possibilities resp. how to implement a custom one. The [reactive] chapter further outlines how to setup Crnk in an asynchronous/reactive setting.

3.1. Requirements

Crnk library requires minimum Java 8 (as of Crnk 2.4) to build and run. In the future it will come with support for both the current major Java releases (9, 10, 11, etc.) and the current long-term support version that gets released every three years.

3.2. Repository

Crnk Maven artifacts are available from Bintray/JCenter.

https://bintray.com/crnk-project

In Gradle it looks like:

```
repositories {
   jcenter()
}
```

Note that due to performance/reliability issues, releases are only intermittently pushed to Maven Central. It is highly recommended for project to go with JCenter as well.

Stable releases hosted on Bintray/JCenter are also available from:

https://bintray.com/crnk-project/maven https://dl.bintray.com/crnk-project/maven/

Most recent builds are available from (for a limited period of time):

https://bintray.com/crnk-project/mavenLatest https://dl.bintray.com/crnk-project/mavenLatest/

3.3. BOM

With `io.crnk:crnk-bom` a Maven BOM is provided that manages the dependencies of all crnk artifacts. In Gradle the setup then looks as follows:

```
buildscript {
    dependencies {
        classpath "io.spring.gradle:dependency-management-plugin:1.0.4.RELEASE"
    }
}

gradle.beforeProject { Project project ->
    project.with {
        apply plugin: 'io.spring.dependency-management'
        dependencyManagement {
            imports {
                mavenBom "io.crnk:crnk-bom:$CRNK_VERSION"
            }
        }
    }
}
```

The crnk modules can then simply be used without having to specify a version:

```
dependencies {
    compile 'io.crnk:crnk-rs'
    compile 'io.crnk:crnk-setup-spring-boot2'
    ...
}
```

3.4. Logging

Crnk makes use of SLF4J to do logging. Make sure to have the API properly setup. For example by making use of Logback or one of the many bridges to other Logging frameworks.

TIP	Set `io.crnk` to `DEBUG` if you encounter any issues during setup or later at runtime.

3.5. Integration with JAX-RS

Crnk allows integration with JAX-RS environments through the usage of JAX-RS specification. JAX-RS 2.0 is required for this integration. Under the hood there is a @PreMatching filter which checks each request for JSON:API processing. The setup can look as simple as:

3.5.1. CrnkFeature

```
@ApplicationPath("/")
    public class MyApplication extends Application {

        @Override
        public Set<Object> getSingletons() {
            CrnkFeature crnkFeature = new CrnkFeature();
            return Collections.singleton((Object)crnkFeature);
        }
    }
```

`CrnkFeature` provides various accessors to customize the behavior of Crnk. A more advanced setup may look like:

```
public class MyAdvancedCrnkFeature implements Feature {

    @Inject
    private EntityManager em;

    @Inject
    private EntityManagerFactory emFactory;

    ...

    @Override
    public boolean configure(FeatureContext featureContext) {
        // also map entities to JSON:API resources (see further below)
        JpaModule jpaModule = new JpaModule(emFactory, em, transactionRunner);
        jpaModule.setRepositoryFactory(new ValidatedJpaRepositoryFactory());

        // limit all incoming requests to 20 resources if not specified otherwise
        DefaultQuerySpecUrlMapper urlMapper = new DefaultQuerySpecUrlMapper();
        urlMapper.setDefaultLimit(20L);

        ServiceLocator serviceLocator = ...
        CrnkFeature feature = new CrnkFeature();
        feature.addModule(jpaModule);
        feature.getBoot().setUrlMapper(urlMapper);

        featureContext.register(feature);
        return true;
    }
}
```

Crnk will install a JAX-RS filter that will intercept and process any Crnk-related request.

Note that depending on the discovery mechanism in use (like Spring or CDI), modules like this JpaModule can be picked up automatically and do not manual registration.

3.5.2. Exception mapping for JAX-RS services

In many cases Crnk repositories are used along regular JAX-RS services. In such scenarios it can be worthwhile if Crnk repositories and JAX-RS services make use of the same exception handling and response format. To make use of the JSON:API resp. Crnk exception handling in JAX-RS services, one can add the **ExceptionMapperBridge** to the JAX-RS application. The constructor of `ExceptionMapperBridge` takes `CrnkFeature` as parameter.

For an example have a look at the next section which make use of it together with `JsonApiResponseFilter`.

3.5.3. Use JSON:API format with JAX-RS services

Similar to `ExceptionMapperBridge` in the previous section, it is possible for JAX-RS services to return

resources in JSON:API format with **JsonApiResponseFilter**. `JsonApiResponseFilter` wraps primitive responses with a `data` object; resource objects with `data` and `included` objects. The constructor of `JsonApiResponseFilter` takes `CrnkFeature` as parameter.

To determine which JAX-RS services should be wrapped, `JsonApiResponseFilter` checks whether the `@Produce` annotation delivers JSON:API. The produce annotation can be added, for example, to the class:

ScheduleRepository.java

```
@Path("schedules")
@Produces(HttpHeaders.JSONAPI_CONTENT_TYPE)
```

And the JAX-RS application setup looks like:

JsonApiResponseFilterTestBase.java

```
    @ApplicationPath("/")
    class TestApplication extends ResourceConfig {

        TestApplication(JsonApiResponseFilterTestBase instance, boolean
enableNullResponse) {
            instance.setEnableNullResponse(enableNullResponse);

            property(CrnkProperties.RESOURCE_SEARCH_PACKAGE, "io.crnk.rs.resource");
            property(CrnkProperties.NULL_DATA_RESPONSE_ENABLED,
Boolean.toString(enableNullResponse));

            CrnkFeature feature = new CrnkFeature();
            feature.addModule(new TestModule());

            register(new JsonApiResponseFilter(feature));
            register(new JsonapiExceptionMapperBridge(feature));
            register(new JacksonFeature());

            register(feature);
        }
    }
```

Note that:

- `CrnkProperties.NULL_DATA_RESPONSE_ENABLED` determines whether null responses should be wrapped as JSON:API responses.
- Make use of proper service discovery instead of `CrnkProperties.RESOURCE_SEARCH_PACKAGE` in real applications.

3.5.4. JAX-RS service interoperability

It is possible to implement repositories that host both JAX-RS and JSON-API methods to complement

JSON API repositories with non-resource based services. Have a look at the Crnk Client chapter for an example.

3.6. Integration with Servlet API

There are two ways of integrating crnk using Servlets:

- Adding an instance of `CrnkServlet`
- Adding an instance of `CrnkFilter`

3.6.1. Integrating using a Servlet

There is a `CrnkServlet` implementation allowing to integrate Crnk into a Servlet environment. It can be configured with all the parameters outlined in the subsequent sections. Many times application will desire to do more advanced customizations, in this case one can extends `CrnkServlet` and get access to `CrnkBoot`. The code below shows a sample implementation:

SampleCrnkServlet.java

```
public class SampleCrnkServlet extends CrnkServlet {

    @Override
    protected void initCrnk(CrnkBoot boot) {
        // do your configuration here
    }
}
```

The newly created servlet must be added to the `web.xml` file or to another deployment descriptor. The code below shows a sample `web.xml` file with a properly defined and configured servlet:

```
  <web-app>
    <servlet>
      <servlet-name>SampleCrnkServlet</servlet-name>
      <servlet-class>io.crnk.servlet.SampleCrnkServlet</servlet-class>
      <init-param>
        <!-- can typically be ommitted and is auto-detected -->
        <param-name>crnk.config.core.resource.domain</param-name>
        <param-value>http://www.mydomain.com</param-value>
      </init-param>
    </servlet>
    <servlet-mapping>
      <servlet-name>SampleCrnkServlet</servlet-name>
      <url-pattern>/api/v1/ *</url-pattern>
    </servlet-mapping>
  </web-app>
```

`init-param` allow to pass configuration flags to Crnk. For a list of properties see here.

3.6.2. Integrating using a filter

Integrating Crnk as a Servlet filter works in a very similar fashion as for servlets:

SampleCrnkFilter.java

```
public class SampleCrnkFilter extends CrnkFilter {

    @Override
    protected void initCrnk(CrnkBoot boot) {
        // do your configuration here
    }
}
```

The newly created filter must be added to `web.xml` file or other deployment descriptor. A code below shows a sample `web.xml` file with properly defined and configured filter

```
  <web-app>
    <filter>
      <filter-name>SampleCrnkFilter</filter-name>
      <filter-class>io.crnk.servlet.SampleCrnkFilter</filter-class>
      <init-param>
        <!-- can typically be ommitted and is auto-detected -->
        <param-name>crnk.config.core.resource.domain</param-name>
        <param-value>http://www.mydomain.com</param-value>
      </init-param>
    </filter>
  </web-app>
```

`init-param` allow to pass configuration flags to Crnk. For a list of properties see here.

3.7. Integration with Spring and Spring Boot

Crnk provides with:

- `io-crnk:crnk-setup-spring` support for plain Spring 4 and 5.
- `io-crnk:crnk-setup-spring-boot1` support for Spring Boot 1.x. This module is considered being deprecated and will be removed in the future.
- `io-crnk:crnk-setup-spring-boot2` support for Spring Boot 2.x.

There is a `CrnkCoreAutoConfiguration` in `crnk-setup-spring-boot2` that outlines the basic setup that can easily be applied to a Spring-only setup without Spring Boot using `crnk-setup-spring`:

- It uses the `CrnkFilter` servlet filter to process requests.
- Service discovery is performed with `SpringServiceDiscovery` using the Spring `ApplicationContext`.

`io-crnk:crnk-setup-spring-boot1` and `io-crnk:crnk-setup-spring-boot2` host Spring Boot auto configurations that are enabled if the presence of the particular Crnk module and/or Spring component. Each auto configuration can be enabled and disabled and may host further properties to reconfigure it. The following auto configurations are available:

- `CrnkHomeAutoConfiguration`
- `CrnkCoreAutoConfiguration`
- `CrnkValidationAutoConfiguration`
- `CrnkJpaAutoConfiguration`
- `CrnkMetaAutoConfiguration`
- `CrnkOperationsAutoConfiguration`
- `CrnkUIAutoConfiguration`
- `CrnkSecurityAutoConfiguration`
- `CrnkSpringMvcAutoConfiguration`
- `CrnkErrorControllerAutoConfiguration`
- `CrnkTomcatAutoConfiguration`

The most important one is `CrnkCoreAutoConfiguration` to setup the core of Crnk. Its main properties are:

application.properties

```
crnk.enabled=true
crnk.domain-name=http://localhost:8080
crnk.path-prefix=/api
crnk.default-page-limit=20
crnk.max-page-limit=1000
crnk.allow-unknown-attributes=false
crnk.return404-on-null=true
```

See CrnkCoreProperties and the various auto configurations for more information. Next to configuration properties there is also the possibility to provide a `Configurer` implementation to gain programmatic access to module configurations. The following `Configurer` are available:

- `CrnkBootConfigurer`
- `JpaModuleConfigurer`
- `SecurityModuleConfigurer`
- `MetaModuleConfigurer`

Next to all the auto configurations there are also a number of further Spring-specific modules:

- `SpringSecurityModule` provides a mapping of Spring Security exception types to JSON:API errors that complements the Spring-independent `SecurityModule`. Auto configuration is provided by `CrnkSecurityAutoConfiguration`. It sets up `SecurityModule` and `SpringSecurityModule`. By default access to all repositories is blocked. A bean of type `SecurityModuleConfigurer` can be added to grant access to repositories.
- `SpringTransactionRunner` lets all requests run in a transaction. If the request completes, the

transaction is committed. In case of an error, the transaction is rolled back.

- Spring MVC Module makes Spring MVC services available in the Crnk Home Module next to the JSON:API repositories to have a list of all offered services. Auto configuration is provided by `CrnkSpringMvcAutoConfiguration`.
- With `CrnkErrorController` configured by `CrnkErrorControllerAutoConfiguration` additionally a new error controller is provided that returns errors in JSON:API format. `crnk.spring.mvc.errorController=false` allows to disable the controller.

3.8. Integration with Vert.x

CAUTION	Reactive programming support has been introduced in Crnk 2.6 and is still considered experimental with some limitations. Please also provide feedback about this Vert.x integration.

Crnk integrates with Vert.x RxJava 2 using `crnk-reactive` and `crnk-setup-vertx`. More information about reactive programming is available here. To make use of Crnk with Vert.x, make sure you have the following dependencies specified:

```
    compile 'io.crnk:crnk-setup-vertx'
    compile 'io.vertx:vertx-rx-java2'
```

An example Vert.x vehicle may then look like:

CrnkVerticle.java

```
public class CrnkVerticle extends AbstractVerticle {

    private static final Logger LOGGER = LoggerFactory.getLogger(CrnkVerticle.class);

    public ReactiveTestModule testModule = new ReactiveTestModule();

    private int port;

    private CrnkVertxHandler handler;

    public CrnkVerticle(int port) {
        this.port = port;

        handler = new CrnkVertxHandler((boot) -> {
            boot.addModule(HomeModule.create());
            boot.addModule(testModule);
        });
    }

    @Override
    public void start() {
        HttpServer server = vertx.createHttpServer();

        server.requestStream().toFlowable()
                .flatMap(request -> handler.process(request))
                .subscribe((response) -> LOGGER.debug("delivered response {}",
response), error -> LOGGER.debug("error occured", error));
        server.listen(port);
    }

    public CrnkBoot getBoot() {
        return handler.getBoot();
    }
}
```

`CrnkVertxHandler` holds the Crnk setup. Its constructor takes a `Consumer<CrnkBoot>` that allows the customization of Crnk. The example makes use of it to register two modules. `CrnkVertxHandler.process` is the main method that allows to process `HttpServerRequest` objects of Vert.x.

3.9. Tomcat Setup

There is a bit of a controversy about which characters to encode or not encode in URLs based on RFC 7230 and RFC 3986. JSON:API is affected in that regard due to the use of [and]. Browser vendors have yet to endorse those RFCs. But unfortunately, Tomcat already started to enforce the

RFCs from their side. As such it is useful to relax the [and] characters to simplify development with JSON:API, like entering URLs manually in the browser. For this purpose `relaxedPathChars` can be set to `[]`, for more information see:

https://stackoverflow.com/questions/41053653/tomcat-8-is-not-able-to-handle-get-request-with-in-query-parameters

The Spring Boot auto configuration already does this out-of-the-box.

IMPORTANT	There is no weakened security out of this as long as parameters are not used in some obscure fashion.

3.10. Discovery with CDI

To enable CDI support, add `io.crnk:crnk-cdi` to your classpath. Crnk will then pickup the `CdiServiceDiscovery` implementation and use it to discover its modules and repositories. Modules, repositories, etc. will then be picked up if they are registered as CDI beans.

By default `Cdi.current()` is used to obtain a `BeanManager`. The application may also make use of `CdiServiceDiscovery.setBeanManager(…)` to set a custom one. The various integrations like `CrnkFeature` provide a `setServiceDiscovery` method to set a customized instance.

WARNING	`Cdi.current()` has shown to be unreliable in some cases when doing EAR deployment. In such cases it is highly recommended to set the `BeanManager` manually.

3.11. Discovery with Guice

A `GuiceServiceDiscovery` implementation is provided. The various integrations like `CrnkFeature` provide a `setServiceDiscovery` method to set the instance. For an example have a look at the dropwizard example application (https://github.com/crnk-project/crnk-framework/tree/master/crnk-integration-examples/dropwizard-simple-example).

3.12. Discovery with Spring

The Spring integration comes with a `SpringServiceDiscovery` that makes use of the Spring `ApplicationContext` to discover beans.

3.13. Discovery without a dependency injection framework

WARNING	This mechanism is considered to be rather deprecated and a lightweight dependency injection framework like guice or the setup of manual modules is recommended instead.

If no dependency injection framework is used, Crnk can also discover beans on its own. For this

purpose, the `org.reflections:reflections` library has to be added to the classpath and the `CrnkProperties.RESOURCE_SEARCH_PACKAGE` be defined. In JAX-RS this may look like:

```
@ApplicationPath("/")
    public class MyApplication extends Application {

        @Override
        public Set<Object> getSingletons() {
            CrnkFeature crnkFeature = new CrnkFeature();
            crnkFeature.getBoot().setServiceLocator(...);
            return Collections.singleton((Object)crnkFeature);
        }

        @Override
        public Map<String, Object> getProperties() {
            Map<String, Object> map = new HashMap<>();
            map.put(CrnkProperties.RESOURCE_SEARCH_PACKAGE, "com.myapplication.model")
            return map;
        }
    }
```

A `JsonServiceLocator` service locator can be provided to control the instatiation of object. By default the default constructor will be used. The `CrnkProperties.RESOURCE_SEARCH_PACKAGE` property is passed to define which package should be searched for beans. Multiple packages can be passed by specifying a comma separated string of packages i.e. com.company.service.dto,com.company.service.repository. It will pick up any public non-abstract class that makes use of Crnk interfaces, like repositories, exception mappers and modules.

3.14. No Discovery

It is also possible to make use of no discovery mechanism at all. In this case it is still possible to add repositories and other features through modules. A simple example looks like:

DropwizardService

```
        SimpleModule module = new SimpleModule("example");
        module.addRepository(new ProjectRepository());

        CrnkFeature crnkFeature = new CrnkFeature();
        crnkFeature.addModule(module);

        environment.jersey().register(crnkFeature);
```

Have a look at the various [modules] chapters for more information.

3.15. Implement a custom discovery mechanism

Application can bring along there own implementation of `ServiceDiscovery`. For more information see here.

3.16. CrnkBoot

`CrnkBoot` is a class shared among all the different integrations that takes care of setting up and starting Crnk. Every integration will provide access to it:

- `CrnkFeature.getBoot()` for JAX-RS.
- `@Autowired CrnkBoot boot` for Spring.
- `CrnkServlet.getBoot()` or `CrnkServlet.initBoot(⋯)` in case of a subclass.
- `CrnkVertxHandler.getBoot()` for Vert.x.

`CrnkBoot` allows for virtually any kind of customization not directly provided by the integration itself, such as Spring Boot auto configurations and properties. Some possibilities:

- `getObjectMapper` allows access to the used Jackson instance.
- `addModule` allows to add a module. See <modules> and <moduledev,module development> chapters for more information.
- `setServiceDiscovery` sets a custom service discovery mechanism.
- `setPropertiesProvider` allows to set how properties are resolved.
- `getQuerySpecDeserializer` and `setQuerySpecDeserializer` allows to reconfigure how parameters are parsed. Note that in some areas JSON:API only provides reocmmendations and Crnk follows those recommendations by default. So depending on your use cases, you may want to configure or implement some aspects differently.
- `setMaxPageLimit` allows to set the maximum number of allowed resources that can be fetched with a request by limiting pagination.
- `setDefaultPageLimit` allows to set a default page limit if none is specified by the request. **Highly recommended** to be used as people frequently browse repositories on there own with a web browser and fail to provide pagination. As a result, your entire database may get downloaded and may bring down your servers depending on the datasize.
- `setWebPathPrefix` like `/api` to specify the path from where the JSON:API endpoint is available.
- `setUrlMapper` to provide a new url mapping implementation to customize how Crnk generates links.
- `getResourceRegistry` to access the available JSON:API resources and repositories.
- `setAllowUnknownAttributes` to ignore unknown filter and sort attributes.
- `setAllowUnknownParameters` to ignore query parameters not specified by JSON:API (`filter`, `sort`, etc.).

IMPORTANT	Appropriate page limits are vital to protect against denial-of-service attacks when working with large data sets! Such attacks may not be of malicious nature, but normal users using a browser and just omitting to specify pagination parameters.

3.17. Properties

Any of the integrations allows API access to customize Crnk. There are also a number of configuration flags provided by `CrnkProperties`:

- `crnk.config.core.resource.domain` Domain name as well as protocol and optionally port number used when building links objects in responses i.e. http://crnk.io. The value must not end with `/`. If the property is omitted, then they are extracted from the incoming request, which should work well for most use cases.
- `crnk.config.web.path.prefix` Default prefix of a URL path used in two cases:
  - When building `links` objects in responses
  - When performing method matching An example of a prefix `/api/v1`.
- `crnk.config.include.paging.packagingEnabled` enables pagination for inclusions. Disabled by default. Be aware this may inadvertently enable pagination for included resources when doing paging on root resources if data structures are cyclic. See `CrnkProperties.INCLUDE_PAGING_ENABLED` fore mor information.
- `crnk.config.lookup.behavior.default` specifies the default lookup behavior for relationships. For more information see @JsonApiRelation.
- `crnk.config.include.behavior` with possible values `BY_TYPE` (default) and `BY_ROOT_PATH`. `BY_ROOT_PATH` specifies that an inclusion can only requested as path from the root resource such as `include[tasks]=project.schedule`. While `BY_TYPE` can further request inclusions by type directly such as `include[tasks]=project&include[projects]=schedule`. For simple object structures they are semantically the same, but they do differ for more complex ones, like when multiple attributes lead to the same type or for cycle structures. In the later case BY_TYPE inclusions become recursive, while BY_ROOT_PATH do not. Note that the use of BY_TYPE outmatches BY_ROOT_PATH, so BY_TYPE includes everything BY_ROOT_PATH does and potentially more. For more information see `CrnkProperties.INCLUDE_BEHAVIOR`.
- `crnk.config.resource.immutableWrite` with values IGNORE (default) or FAIL. Determines how to deal with field that cannot be changed upon a PATCH or POST request. For more information see `CrnkProperties.RESOURCE_FIELD_IMMUTABLE_WRITE_BEHAVIOR`.
- `crnk.config.resource.response.return_404` with values true and false (default). Enforces a 404 response should a repository return a null value. This is common practice, but not strictly mandated by the JSON:API specification. In general it is recommended for repository to throw `ResourceNotFoundException`.
- `crnk.config.serialize.object.links` to serialize links as objects. See http://jsonapi.org/format/#document-links. Disabled by default.

- `crnk.config.resource.request.rejectPlainJson` whether to reject GET requests with `application/json` accept headers and enforce `application/vnd.api+json`. Disabled by default.
- `crnk.config.resource.request.allowUnknownAttributes` lets Crnk ignore unknown filter and sort parameters. Disabled by default.
- `crnk.config.serialize.object.links` determines whether links should be serialized as simple string (default) or as objects (with a `self` attribute holding the url).
- `crnk.config.resource.request.rejectPlainJson` determines whether Crnk should reject `application/json` requests to JSON-API endpoints. Disabled by default. The JSON-API specification mandates the use of the `application/vnd.api+json` MIME-Type. In cases where frontends or intermediate proxies prefer the `application/json` MIME-Type, that type can be sent in the `Accept` header instead. If an application wants to serve a different response depending on whether the client's `Accept` header contains `application/vnd.api+json` or `application/json`, this option can be enabled. This *does not affect the payload `Content-Type`. `POST` and `PATCH` requests must still use `Content-Type: application/vnd.api+json` to describe their request body
- If `crnk.enforceIdName` is set to `true` all `@JsonApiId` annotated fields will be named `id` on the rest layer (for sorting, filtering, etc.) regardless of its Java name. By default this is not enabled for historic reasons. But enabling it more closely reflects the JSON:API specification and is recommended to do so. It likely will be enabled in Crnk 3 by default.

3.18. Serving Directory Listings with the Home Module

The `HomeModule` provides a listing of available resources in each directory (such as the root `/api/`). Note that directory paths always end with a '/' and the `HomeModule` will process the request if there is no resource or relationship repository serving that particular path.

The `HomeModule` supports two kinds of formats that can be choosen upon creation. A JSON:API-style format where a links node holds all links to child directories and repositories. And a JSON HOME format as specified by JSON Home.

```
        HomeModule metaModule = HomeModule.create();
        ...
```

In the Spring Boot example applications it looks like:

```
{
  "links" : {
    "meta" : "http://localhost:8080/api/meta/",
    "projects" : "http://localhost:8080/api/projects",
    "resourcesInfo" : "http://localhost:8080/api/resourcesInfo",
    "schedule" : "http://localhost:8080/api/schedule",
    "scheduleDto" : "http://localhost:8080/api/scheduleDto",
    "tasks" : "http://localhost:8080/api/tasks"
  }
}
```

Notice the `meta` entry with a trailing '/' that allows to move to subdirectory `http://localhost:8080/api/meta/`:

```
{
  "links" : {
    "arrayType" : "http://localhost:8080/api/meta/arrayType",
    "attribute" : "http://localhost:8080/api/meta/attribute",
    "dataObject" : "http://localhost:8080/api/meta/dataObject",
    "element" : "http://localhost:8080/api/meta/element",
    "resource" : "http://localhost:8080/api/meta/resource",
    "type" : "http://localhost:8080/api/meta/type"
    ...
  }
}
```

3.19. Setting up the Crnk UI

WARNING	The UI is currently in an early stage. Feature requests and PRs welcomed!

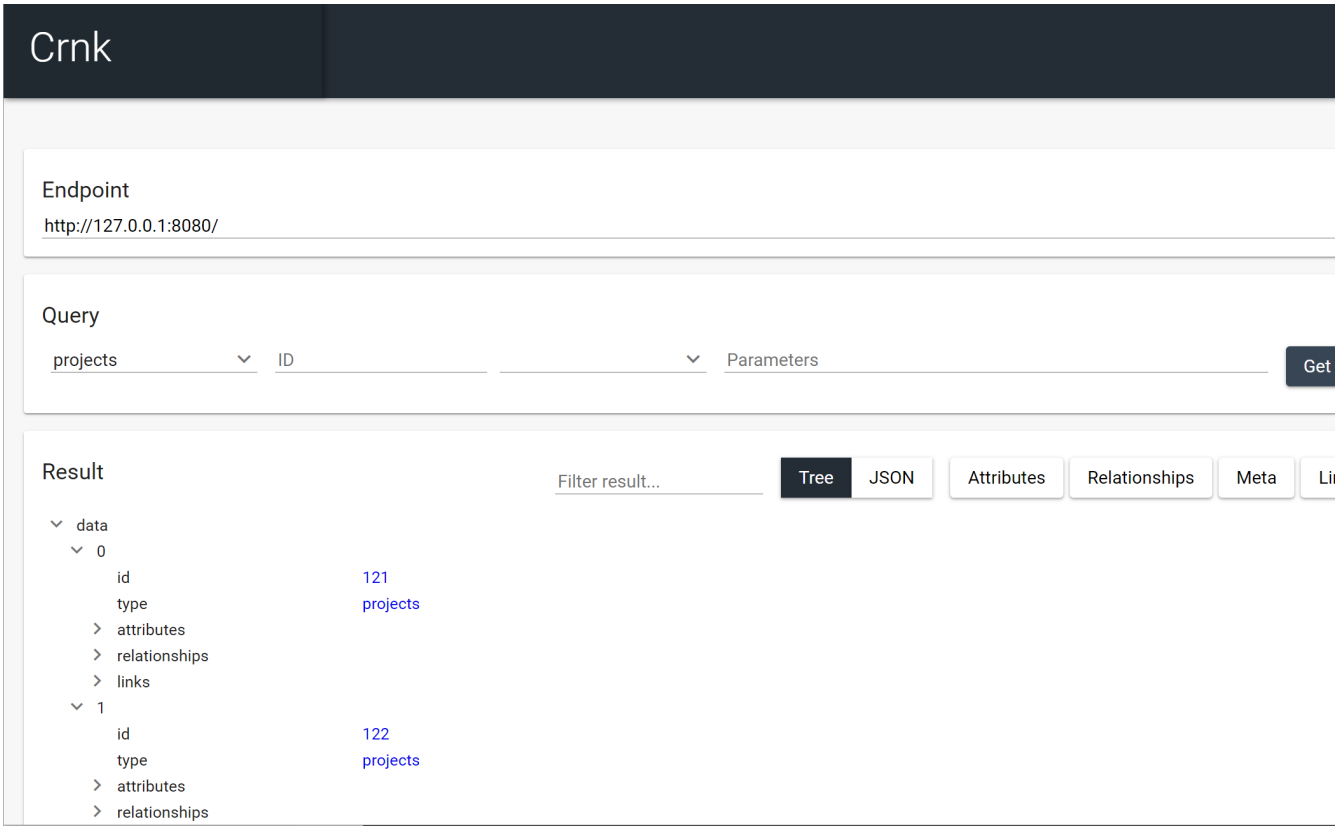
The UI module makes `crnk-ui` accessible trough the module system. It allows to browse and edit all the repositories and resources. The setup looks like:

```
        UIModule operationsModule = UIModule.create(new UIModuleConfig());
        ...
```

By default the user interface is accessible from the `/browse/` directory next to all the repositories. Have a look at the Spring Boot example application to see a working example.

This module is currently in incubation. Please provide feedback.

An example from the Spring Boot example application looks like:



4. Resource

A resource as defined by JSON:API holds the actual data. The engine part of `crnk-core` is agnostic to how such resources are actually implemented (see the [architecture] and [modules] chapters). This chapter describes the most common way Java Beans and annotations. See here for more information how setup resources and repositories programmatically at runtime.

4.1. JsonApiResource

It is the most important annotation which defines a resource. It requires type parameter to be defined that is used to form a URLs and type field in passed JSONs. According to JSON:API standard, the name defined in type can be either plural or singular

The example below shows a sample class which contains a definition of a resource.

```
@JsonApiResource(type = "tasks")
public class Task {
  // fields, getters and setters
}
```

where `type` parameter specifies the resource's name.

By default the type of a resource in a JSON:API document and its name within URLs match, for example:

```
{
  "links": {
    "self": "http://localhost/api/tasks",
  },
  "data": [{
    "type": "tasks",
    "id": "1",
    "attributes": {
      "title": "Some task"
    }
  }
}
```

The optional `resourcePath` allows to define separate values, typically with `resourcePath` being plural and `type` being singular:

```
  @JsonApiResource(type = "task", resourcePath = "tasks")
  public class Task {
    // fields, getters and setters
  }
```

resulting in (notice the self link does not change, but type does):

```
{
  "links": {
    "self": "http://localhost/api/tasks",
  },
  "data": [{
    "type": "task",
    "id": "1",
    "attributes": {
      "title": "Some task"
    }
  }
}
```

The optional `pagingSpec` parameter allows to set the desired paging specification:

```
@JsonApiResource(type = "tasks", pagingSpec = OffsetLimitPagingSpec.class)
public class Task {
  // fields, getters and setters
}
```

There is built-in support for `OffsetLimitPagingSpec` (default) or `NumberSizePagingSpec`. The paging spec must be backed by a matching `PagingBehavior` implementation. More detailed information about pagination can be found at Pagination section.

The optional `subTypes` parameter allows to specify an inheritance relationship to other resources:

```
@JsonApiResource(type = "task", subTypes = SpecialTask.class)
public class Task {
  // fields, getters and setters
}

@JsonApiResource(type = "specialTask", resourcePath = "task")
public class SpecialTask extends Task{
  // fields, getters and setters
}
```

In this case the `SpecialTask` extends `Task` but shares the same `resourcePath`, meaning `SpecialTask` does not bring along a repository implementation (see next chapter), but is served by the task repository. For a more information have a look at the [inheritance] section.

@JsonApiResource has properties to configure the allowed access modes to a resource: sortable, filterable, postable, readable, patchable and deletable. An example looks like:

```
  @JsonApiResource(type = "tasks",
          postable = false, readable = false, patchable = false, deletable = false,
          sortable = false, filterable = false
  )
  public static class AccessDeniedTestResource {

      @JsonApiId
      public String id;

      public String value;

  }
```

The properties match the ones from @JsonApiField and provide the base line for it. For example, if a resource does not allow filtering, none of its fields will either. If one of those properties is attempted to be violated, an error is thrown.

4.2. JsonApiId

Defines a field which will be used as an identifier of a resource. Each resource requires this annotation to be present on a field which type implements `Serializable` or is of primitive type.

The example below shows a sample class which contains a definition of a field which contains an identifier.

```
@JsonApiResource(type = "tasks")
public class Task {
@JsonApiId
private Long id;

// fields, getters and setters
}
```

4.3. JsonApiRelation

Indicates a relationship to either a single value or collection of resources. The type of such fields must be a valid resource. The next example showcases a bi-directional relationship between `Task` and `Project`:

```
@JsonApiResource(type = "tasks")
public class Task {

    @JsonApiRelation
    private Project project;

    ...
}

@JsonApiResource(type = "tasks")
public class Task {

    @JsonApiRelation(mappedBy="project")
    private Set<Task> tasks;

    ...
}
```

The `project` and `tasks` field are linked through the `mappedBy` property by pointing from the non-owning to the owning field of the relationship. `project` as owning field will be used for all read and update operations. The semantics of `mappedBy` matches with the concepts of, for example, JPA-related annotations. It is typical for single-valued fields like `project` to be the owner. Such fields are usually backed by something like a column in a database and are simple to read and write. In

contrast, multi-valued fields like `tasks` can only be obtained by issuing a query against the single-valued counter-part.

@JsonApiRelation comes with a number of attributes to customize its behavior. @JsonApiRelation as complementary annotation is introduced in the subsequent section.

```
@JsonApiRelation(serialize = SerializeType.ONLY_ID)
private Project project;
```

The optional `serialize` parameter specifies how an association should be serialized when making a request. There are two things to consider. Whether related resources should be added to the `include` section of the response document. And whether the id of related resources should be serialized along with the resource in the corresponding `relationships.[name].data` section. Either `LAZY`, `ONLY_ID` or `EAGER` can be specified:

- `LAZY` only serializes the ID and does the inclusion if explicitly requested by the `include` URL parameter. This is the default.
- `ONLY_ID` always serializes the ID, but does only to an inclusion if explicitly requested by the `include` URL parameter.
- `EAGER` always both serializes the ID and does an inclusion. Be aware of performance implication when enabling this.

```
@JsonApiRelation(lookUp = LookupIncludeBehavior.AUTOMATICALLY_ALWAYS)
private Project project;
```

JSON:API comes with support for inclusions based on the `include` parameter. It allows to request complex object graphs where also related resources can be fetched. There are two possibilities of how this is implemented. Either the requested repository also directly returns related resources with the returned ones. Or Crnk can take-over that work by doing nested calls to adjacent `ResourceRepository`, `OneRelationshipRepository` and `ManyRelationshipRepository` implementations. The behavior is controlled by the optional `lookUp` parameter. There are four options:

- `NONE` makes the requested repository responsible for returning related resources.
- `AUTOMATICALLY_WHEN_NULL` will let Crnk lookup related resources if not already done by the requested repository.
- `AUTOMATICALLY_ALWAYS` will force Crnk to always lookup related resource regardless whether it is already done by the requested repository.
- `DEFAULT` attempts to find the optimal setting automatically. If a custom relationship repository is found, `@JsonApiRelationId` is in use or `@JsonApiRelation.repositoryBehavior` fetches from the opposite side, then `AUTOMATICALLY_WHEN_NULL` is chosen, otherwise it falls back to `NONE`. This default behavior should be sufficient for most use cases.

There are many different ways how a relationship may end-up being implemented. In the best case, no implementation is necessary at all and requests can be dispatches to one of the two related resource repositories. The `repositoryBehavior` allows to configure behavior:

- `CUSTOM` expects a custom implementation.
- `FORWARD_OWNER` forward any relationship request to the owning resource repository, the repository that defines the requested relationship field. GET requests will fetch the owning resources and grab the related resources from there (with the appropriate inclusion parameter). This assumes that the owning resource properties hold the related resources (or at least there IDs in case of `JsonApiRelationId`, see below). POST, PATCH, DELETE requests will update the properties of the owning resource accordingly and invoke a save operation on the owning resource repository. An implementation is provided by `ImplicitOwnerBasedRelationshipRepository`.
- `FORWARD_GET_OPPOSITE_SET_OWNER` works like `FORWARD_OWNER` for PATCH, POST, DELETE methods. In contrast, GET requests are forwarded to the opposite resource repository. For example, if there is a relationship between `Task` and `Project` with the `project` and `tasks` relationship fields. To get all tasks of a project, the task repository will be queried with a `project.id=<projectId>` filter parameter. Relational database are one typical example where this pattern fits nicely. In contract to `IMPLICIT_FROM_OWNER` only a single resource repository is involved with a slightly more complex filter parameter, giving performance benefits. An implementation is provided by `RelationshipRepositoryBase`.
- `FORWARD_OPPOSITE` the opposite to `FORWARD_OWNER`. Querying works like `IMPLICIT_GET_OPPOSITE_MODIFY_OWNER`.
- `DEFAULT` makes use of `FORWARD_OWNER` if the relationship makes use of `@JsonApiRelationId` (see below), `lookUp=NONE` or `lookUp=DEFAULT`. `FORWARD_OPPOSITE` if `mappedBy` points to another field. `CUSTOM` if a matching relationship repository is found. For all other scenarios it it expects a custom implementation.

The forwarding behaviors are implemented by `ForwardingRelationshipRepository`.

The subsequent two resources show case a number of scenarios:

```
@JsonApiResource(type = "task")
public class Task {
    @JsonApiId
    public String id;

    @JsonApiRelation // not backed by repository
    public Project project;

    @JsonApiRelation // backed by repository
    public List<Task> subTasks;
}

@JsonApiResource(type = "project")
public class Project {
    @JsonApiId
    public String id;

    @JsonApiRelation(mappedBy = "project")
    public Set<Task> tasks;

    @JsonApiRelationId
    public Project parentId;

    @JsonApiRelation
    public Project parent;
}

class SubTaskRepository extends OneRelationshipRepositoryBase {
    @Override
    public RelationshipMatcher getMatcher() {
        RelationshipMatcher matcher = new RelationshipMatcher();
        matcher.rule().field("subTasks").add();
        return matcher;
    }
    ...
}
```

- `parent` has a `@JsonApiRelationId` backed by `parentId`. This triggers the use of `RelationshipRepositoryBehavior.FORWARD_OWNER` and `LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL`. Only `parentId` must be populated by the project resource repository, `project` can then be looked up on the opposite resource repository (which in this case is the same repository).
- `project` just carries an empty `@JsonApiRelation` and has no relationship repository backing it. This triggers the assumption that the resource repository can handle all requests, translating to `LookupIncludeBehavior.NONE` and `RelationshipRepositoryBehavior.FORWARD_OWNER`.
- `tasks` declares a `mappedBy` to its owner `project`. Accordingly all requests go with `RelationshipRepositoryBehavior.FORWARD_OPPOSITE` to the opposite task resource repository. Inclusions are resolved automatically with `LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL`.

- `subTasks` is backed by the `SubTaskRepository` relationship repository. This sets `RelationshipRepositoryBehavior.CUSTOM` and performs look-ups on that repository with `LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL` to compute the inclusions.

IMPORTANT	It likely takes a moment to familiarize oneself with all configuration options of `@JsonApiRelation` and the subsequent `@JsonApiRelationId`. But at the same time it is one area where a native resource-oriented REST library like Crnk can provide significant benefit and reduce manual work compared to more classical REST libraries like Spring MVC or JAX-RS.

IMPORTANT	If you run into problems in this area, set `io.crnk` to `DEBUG` in your logger. It will print information such as:

```
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.project: using configured
LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.projects: using configured
LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.tasks: choosing default
RelationshipRepositoryBehavior: mappedBy enforces FORWARD_OPPOSITE
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.tasks: setting up opposite/opposite
forwarding repository
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.tasks:
RelationshipRepositoryBehavior.FORWARD_OPPOSITE enforces
LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL to resolve relationship from opposite
side
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.project: choosing default
RelationshipRepositoryBehavior: relationId field enforces FORWARD_OWNER
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.project: setting up owner/owner
forwarding repository
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.projects: choosing default
RelationshipRepositoryBehavior: relationId field enforces FORWARD_OWNER
20:04:50 DEBUG io.crnk.test.mock.models.Schedule.projects: setting up owner/owner
forwarding repository
```

4.4. JsonApiRelationId

Fields annotated with `@JsonApiRelation` hold fully-realized related resources. There are situations where the id of a related resource is available for free or can be obtained much more cheaply then fetching the entire related resource. In this case resources can make use of fields annotated with `@JsonApiRelationId`. The complement `@JsonApiRelation` fields by holding there ID only. An example looks like:

```
@JsonApiResource(type = "schedules")
public class Schedule {
  ...

  @JsonApiRelationId
  private Long projectId;

  @JsonApiRelation
  private Project project;

  public Long getProjectId() {
    return projectId;
  }

  public void setProjectId(Long projectId) {
    this.projectId = projectId;
    this.project = null;
  }

  public Project getProject() {
    return project;
  }

  public void setProject(Project project) {
    this.projectId = project != null ? project.getId() : null;
    this.project = project;
  }
}
```

Notice that: - `Schedule` resource holds both a `project` and `projectId` field that point to the same related resource. - setters must set both properties to make sure they stay in sync. If only the ID is set, the object must be nulled. - `propertyId` will never show in requests and responses. It can be considered to be `transient`. - Bi-directional relationships can simply make use of `@JsonRelationId(mappedBy="project")` on the other side.

By default, the naming convention for `@JsonApiRelationId` field is to end with a `Id` or `Ids` suffix. Crnk will the pair those two objects automatically. Trailing `s` are ignored for multi-valued fields, meaning that `projectIds` matches with `projects`. But it is also possible to specify a custom name, for example:

```
@JsonApiRelationId
private Long projectFk;

@JsonApiRelation(idField = "projectFk")
private Project project;
```

If a `@JsonApiRelationId` field cannot be matched to a `@JsonApiRelation` field, an exception will be thrown.

`@JsonApiRelationId` fields are used for:

- `GET` requests to fill-in the `data` section of a relationship.
- `POST` and `PATCH` requests to fill-in the new value without having to fetch and set the entire related resource.

Further (substantial) benefit for `@JsonApiRelationId` fields is that no `RelationshipRepository` must be implemented. Instead Crnk will automatically dispatch relationship requests to the owning and opposite `ResourceRepository`. This allows to focus on the development of `ResourceRepository`. See RelationshipRepository for more information.

4.5. JsonApiMetaInformation

Field or getter annotated with `JsonApiMetaInformation` are marked to carry a `MetaInformation` implementation. See http://jsonapi.org/format/#document-meta for more information about meta data. Example:

```
@JsonApiResource(type = "projects")
public class Project {

    ...

    @JsonApiMetaInformation
    private ProjectMeta meta;

    public static class ProjectMeta implements MetaInformation {

        private String value;

        public String getValue() {
            return value;
        }

        public void setValue(String value) {
            this.value = value;
        }
    }
}
```

4.6. JsonApiLinksInformation

Field or getter annotated with `JsonApiLinksInformation` are marked to carry a `LinksInformation` implementation. See http://jsonapi.org/format/#document-links for more information about linking. Example:

```
    @JsonApiResource(type = "projects")
    public class Project {

        ...

        @JsonApiLinksInformation
        private ProjectLinks links;

        public static class ProjectLinks implements LinksInformation {

            private String value;

            public String getValue() {
                return value;
            }

            public void setValue(String value) {
                this.value = value;
            }
        }
    }
```

By default links are serialized as:

```
"links": {
  "self": "http://example.com/posts"
}
```

With `crnk.config.serialize.object.links=true` links get serialized as:

```
"links": {
  "self": {
    "href": "http://example.com/posts",
  }
}
```

4.7. JsonApiField

Field or getter annotated with `@JsonApiField` allows to define the behavior of an individual attribute. Example:

```
@JsonApiResource(type = "projects")
public class Project {

    ...

    @JsonApiField(postable = true, patchable = false)
    private Long projectId;

    ...
}
```

Following options are supported:

- `sortable` defines whether a field can be sorted.
- `filterable` defines whether a field can be filtered.
- `postable` defines whether a field can be set with a POST request.
- `patchable` defines whether a field can be changed with a PATCH request.
- `deletable` defines whether a multi-valued relationship field can be changed with a DELETE request.
- `readable` defines whether a field can be read with a GET request.
- `patchStrategy` defines the behavior of value with PATCH request. It can be either `MERGE` if you want the value be merged with an original one or `SET` if you want the value be totaly replaced with a new one.

The same fields are available from `@JsonApiResource` to configure a default for all fields of that resource.

4.8. Jackson annotations

Crnk comes with (partial) support for Jackson annotations. Currently supported are:

Annotation	Description
`@JsonIgnore`	Excludes a given attribute from serialization.
`@JsonProperty.value`	Renames an attribute during serialization.
`@JsonProperty.access`	Specifies whether an object can be read and/or written.
`@JsonAnyGetter` and `@JsonAnySetter`	To map dynamic data structures to JSON.

Support for more annotations will be added in the future. PRs welcomed.

4.9. Nested Resources

WARNING	This feature is experimental and will be refined in subsequent releases.

A resource may be nested and belong to a parent resource. URLs then look like:

- `http://example.com/posts/1/header` (single)
- `http://example.com/posts/1/comments/2` (multiple)

Here a `post` resource holds two nested relationships: `header` and `comments`. Both of those relationships have resources that cannot exist without the `post` itself. The former case the relationship holds a single resource, while the later there might be multiple comments.

Nested resources are implemented like any other resource, most notably by providing a resource repository. The subsequent two section go into detail how to setup such resources.

4.9.1. Single Nested Resources

Single nested resources share the identifier with the parent resource. From the example aboce:

`http://example.com/posts/1/header`

Both the `post` and its `header` share the identifier `1`. A resource looks like:

PostHeader.java

```
@JsonApiResource(type = "header", nested = true)
public class PostHeader {

    @JsonApiId
    @JsonApiRelationId
    private String postId;

    private String value;

    @JsonApiRelation(opposite = "header", lookUp = LookupIncludeBehavior
.AUTOMATICALLY_WHEN_NULL,
            repositoryBehavior = RelationshipRepositoryBehavior.FORWARD_OWNER)
    private Post post;

}
```

Notice the `nested = true` and that the ID also serves as `@JsonApiRelationId` to point to the parent `post`. This two properties introduce the singular nesting to the resource. The repository itself can then be implemented like any other repository.

4.9.2. Multiple Nested Resources

To nest multiple resource below a parent, structured identifier can be used:

PostCommendId.java

```
@JsonSerialize(using = ToStringSerializer.class)
public class PostCommentId implements Serializable {

    @JsonApiId
    private String id;

    @JsonApiRelationId
    private String postId;

    public PostCommentId() {
    }

    public PostCommentId(String idString) {
        String[] elements = idString.split("\\-");
        postId = elements[0];
        id = elements[1];
    }

    public PostCommentId(String postId, String id) {
        this.postId = postId;
        this.id = id;
    }

    public String getId() {
        return id;
    }

    public void setId(String id) {
        this.id = id;
    }

    public String getPostId() {
        return postId;
    }

    public void setPostId(String postId) {
        this.postId = postId;
    }

    public int hashCode() {
        return toString().hashCode();
    }

    public boolean equals(Object object) {
        return object instanceof PostCommentId && object.toString().equals(toString()
);
    }

    public String toString() {
```

```
        return postId + "-" + id;
    }
}
```

The id is setup of two parts:

- the local identifier of the child resource, annotated with `@JsonApiId`. It must be unique among all nested resources having the same parent.
- the identifier of the parent resource, annotated with a `@JsonApiRelationId`. The nested resource must have matching relationship field (in this case `parent`)`.

`PostCommentId` further implements `public PostCommentId(String idString)`, `toString`, `hashCode` and `equals` and carries the `@JsonSerialize(using = ToStringSerializer.class)` annotation to deal with String serialization and equality.

The resource itself looks like:

PostComment.java

```
@JsonApiResource(type = "comment", nested = true)
public class PostComment {

    @JsonApiId
    private PostCommentId id;

    private String value;

    @JsonApiRelation(opposite = "comments", lookUp = LookupIncludeBehavior
.AUTOMATICALLY_WHEN_NULL,
            repositoryBehavior = RelationshipRepositoryBehavior.FORWARD_OWNER)
    private Post post;

}
```

4.9.3. Usage

For an example have a look at `NestedRepositoryClientTest` and its parent class. Depending on the use of [JsonApiExposed] it is or is not be possible to also directly access `http://example.com/comments` without going through the parents.

When creating new resources with CrnkClient, the nested identifier must be set to let CrnkClient access the postId to compute URLs.

WARNING	Nesting is currently limited to a single level (and the possibility to have further relationships on the nested resource).

5. Repositories

The modelled resources and relationships must be complemented by a corresponding repository implementation. This is achieved by implementing one of those two repository interfaces:

- ResourceRepository for resources.
- RelationshipRepository resp. BulkRelationshipRepository for relationships.

The repositories are used to serve `POST`, `GET`, `PATCH` and `DELETE` requests as specified by JSON:API specification. The repository contract closely resembles the JSON:API specification. Subsequent sections and chapters outline various possibilities to speed-up and potentially reuse existing repository implementations.

IMPORTANT	When accessing repositories, do not forget to use the `application/vnd.api+json` content type.

5.1. ResourceRepository

`ResourceRepository` is the main interface used to operate on resources with `POST`, `GET`, `PATCH` and `DELETE` requests. The interface takes two generic arguments:

1. The type of a resource. Typically this is a plain Java Bean making use of the JSON:API annotations. But may also be something entirely different (see [architectures> and <<modules]). One other example is the `io.crnk.core.engine.document.Resource` class used to setup dynamically types repositories.
2. The type of the resource's identifier. Typically a primitive type like `String`, `long` or `UUID`. But if necessary can also be a more complex type that serializes to a URL-friendly String.

The methods of `ResourceRepository` look as follows:

- `findOne(ID id, QuerySpec querySpec)` Search one resource with a given ID. If a resource cannot be found, a ResourceNotFoundException exception should be thrown that translates into a `404` HTTP error status. The returned resource must adhere to the behavior as specifies by the various annotations (more details in the [resource] chapter), most notably the inclusion of relationships as requested by the passed `querySpec` as long as `LookupIncludeBehavior` does not specify otherwise. More details about `QuerySpec` follow in subsequent sections.
- `findAll(Iterable<ID>ids, QuerySpec querySpec)` Allows to bulk request multiple resources, but otherwise work exactly like the preceding `findOne` method.
- `findAll(QuerySpec querySpec)` Search for all resources according to the passed `querySpec` including sorting, filtering, paging, field sets and inclusions. A `ResourceList` must be returned that carries the result resources, links information and meta information.
- `create(S resource)` Called by `POST` requests. The request body is deserialized and passed as `resource` parameter. The method may or may not have to generate an ID for the newly created resource. The request body may specify relationship data to point to other resources. During

deserialization, those resources are looked up and the `@JsonApiRelation` annotated fields set accordingly. For relationships making use of `@JsonApiRelationId` annotation, only the identifier will be set without the resource annotation, allowing to improve for performance. The `create` method has to save those relationships, but it does and must not perform any changes on the related resources. For bulk inserting and updating resources, have a look at the operations module. The method must return the updated resource, most notably with a valid identifier.

- `save(S resource)` Saves a resource upon a `PATCH` request. The general semantics is identical to the `create(…)` method, with two notable exceptions. First, resources are updated but are not allowed to be inserted. A `ResourceNotFoundException` must be thrown if the resource does not exist. Second, the `PATCH` request allows for partial updates. Internally Crnk will get the current state of a resource, patch it and pass it to this `save` method. A `ResourceModificationFilter` can be registered to collect information about modified fields and relationships and this way, for example, distinguish patched from un-patched fields.
- `delete(ID id)` Removes a resource identified by id parameter. A `ResourceNotFoundException` must be thrown if the resource does not exist.

The ResourceRepositoryBase is a base class that takes care of some boiler-plate, like implementing findOne with findAll. An implementation can then look as simple as:

Task.java

```
@JsonApiResource(type = "tasks")
public class Task {

    @JsonApiId
    private Long id;

    @JsonProperty("name")
    private String name;

    @Size(max = 20, message = "Description may not exceed {max} characters.")
    private String description;

    @JsonApiRelationId
    private Long projectId;

    @JsonApiRelation(opposite = "tasks", lookUp =
LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL,
            repositoryBehavior = RelationshipRepositoryBehavior.FORWARD_OWNER,
            serialize = SerializeType.ONLY_ID)
    private Project project;

   ...
}
```

and

TaskRepositoryImpl.java

```
@Component
public class TaskRepositoryImpl extends ResourceRepositoryBase<Task, Long> implements
TaskRepository {

    // for simplicity we make use of static, should not be used in real applications
    private static final Map<Long, Task> tasks = new ConcurrentHashMap<>();

    private static final AtomicLong ID_GENERATOR = new AtomicLong(4);

    public TaskRepositoryImpl() {
        super(Task.class);
    }

    @Override
    public <S extends Task> S save(S entity) {
        if (entity.getId() == null) {
            entity.setId(ID_GENERATOR.getAndIncrement());
        }
        tasks.put(entity.getId(), entity);
        return entity;
    }

    @Override
    public <S extends Task> S create(S entity) {
        if (entity.getId() != null && tasks.containsKey(entity.getId())) {
            throw new BadRequestException("Task already exists");
        }
        return save(entity);
    }

    @Override
    public Class<Task> getResourceClass() {
        return Task.class;
    }

    @Override
    public Task findOne(Long taskId, QuerySpec querySpec) {
        Task task = tasks.get(taskId);
        if (task == null) {
            throw new ResourceNotFoundException("Task not found!");
        }
        return task;
    }

    @Override
    public ResourceList<Task> findAll(QuerySpec querySpec) {
        return querySpec.apply(tasks.values());
    }


    @Override
```

```
    public void delete(Long taskId) {
        tasks.remove(taskId);
    }
}
```

The example is taken from crnk-integration-examples/spring-boot-example. (the basic Spring boot example from crnk-framework, not the dedicated full-blown one from crnk-example).

Together with matching project repository, some URLs to checkout:

```
http://127.0.0.1:8080/api/tasks
http://127.0.0.1:8080/api/tasks/1
http://127.0.0.1:8080/api/tasks/1
http://127.0.0.1:8080/api/tasks/1/project
http://127.0.0.1:8080/api/tasks/1/relationships/project
http://127.0.0.1:8080/api/tasks?sort=-name
http://127.0.0.1:8080/api/tasks?sort=-id,name
http://127.0.0.1:8080/api/tasks?sort=-id,name
http://127.0.0.1:8080/api/tasks?sort=id&page[offset]=0&page[limit]=2
http://127.0.0.1:8080/api/tasks?filter[name]=Do things
http://127.0.0.1:8080/api/tasks?filter[name][EQ]=Do things
http://127.0.0.1:8080/api/tasks?filter[name][LIKE]=Do%
http://127.0.0.1:8080/api/tasks?filter[name][EQ]=SomeTask,OtherTask
http://127.0.0.1:8080/api/tasks?fields=name
http://127.0.0.1:8080/api/projects
http://127.0.0.1:8080/api/tasks?include=project
http://127.0.0.1:8080/api/browse/
```

You may notice that:

- links get automatically created.
- `totalResourceCount` and pagination links are added to the response if the `page` parameter is applied.
- related `project` gets automatically resolved from `projectId`. No relationship repository is implemented here due to the use of `@JsonApiRelationId` (see below).
- the response gets automatically truncated with the `fields` parameter, ideally suited for bandwidth sensitive applications.
- multiple values can be separated by comma, typically repositories will then use an `OR` and accept and resource matching any of the values.

This is one small example that **shows the power of native resource-oriented REST libraries**. Implementing a similar API with more classical REST libraries can be a substantial amount of work.

There is further a `ReadOnlyResourceRepositoryBase` base class that does not allow to override the create, delete and update methods. `crnk-meta` accordingly reports insertable, updateable, deltable for such repositories as false.

5.2. Query parameters with QuerySpec

Crnk passes JSON:API query parameters to repositories trough a QuerySpec parameter. It holds request parameters like sorting and filtering specified by JSON:API. The subsequent sections will provide a number of example.

NOTE

Not everything is specified by JSON:API. For some request parameters only recommendations are provided as different applications are likely to be in need of different semantics and implementations. For this reason the engine part in `crnk-core` makes use of `QueryAdapter` and allows implementations other than QuerySpec (like the legacy `QueryParams`). The mapping of HTTP request parameters to QuerySpec and back is implemented by `QuerySpecUrlMapper` that may can also be extended, customized or replaced.

For example showing its use URLs also have a look at the ResourceRepository section.

5.2.1. API

The QuerySpec API looks like (further setters available as well):

```
    public class QuerySpec {
        public <T> List<T> apply(Iterable<T> resources){...}

        public Long getLimit() {...}

        public long getOffset() {...}

        public PagingSpec getPagingSpec() {...}

        public List<FilterSpec> getFilters() {...}

        public List<SortSpec> getSort() {...}

        public List<IncludeFieldSpec> getIncludedFields() {...}

        public List<IncludeRelationSpec> getIncludedRelations() {...}

        public QuerySpec getQuerySpec(Class<?> resourceClass) {...}

        ...
    }
```

There are `Spec` class for all major features:

- `FilterSpec`
- `SortSpec`
- `IncludeFieldSpec`
- `IncludeRelationSpec`

- `PagingSpec`

More information is given in the subsequent sections.

QuerySpec provides a method `apply` that allows in-memory sorting, filtering and paging on any `java.util.Collection`. It is useful for testing, mocking and on smaller datasets to keep the implementation of a repository as simple as possible.

5.2.2. Basic Filtering

NOTE	The JSON:API specification does not a mandate a specific filtering semantic. Instead it provides a recommendation that comes by default with Crnk. Depending on the data store in use, application may choose to extend or replace that default implementation by extending or replacing `DefaultQuerySpecUrlMapper`.

Resource filtering can be achieved by providing parameters which start with `filter`:

- `GET /tasks?filter[name]=Super task` to filter by name with the default `EQ` operator.
- `GET /tasks?filter[name][EQ]=Super task` to filter by name with the `EQ` operator.
- `GET /tasks?filter[name][EQ]=SomeTask,OtherTask` to filter by multiple `OR`-ed values.
- `GET /tasks?filter[name][LIKE]=Super%` to filter by name with the `LIKE` operator using `%` as wildcard.
- `GET /tasks?filter[address.plz][EQ]=Super task` to filter by attribute `name` within a structured or related attributes `address`.
- `GET /tasks?filter[address.city][EQ]=Super task` to filter by attribute `city` within a structured or related attributes `address`.
- `GET /tasks?filter[name]=Super task&filter[dueDate][GT]=2015-10-01`
- `GET /tasks?filter[name]=null` to filter by `name` being equals `null`.
- `GET /tasks?filter[tasks][name]=Super task` is the longer version of `/tasks/?filter[name]=Super task` where the `tasks` type is explicitly stated. See the subsequent [inclusion] section how to use this to perform filtering of related resources.

A filter parameter is represented by a `FilterSpec`. It holds the path to the attribute, the operator and the filter value. The attribute specifies what gets filtered. The operator specifies how it is filtered. And the value specifies after what should be filtered.

An example looks like:

```
FilterSpec filterSpec = PathSpec.of("person", "address",
"city").filter(FilterOperator.EQ, "Zurich");
Filterspec filterSpec = new FilterSpec(PathSpec.of("person.address.city"),
FilterOperator.NEQ, "Zurich");
```

The filter value `FilterSpec.value` is strongly typed. Typically (by default) it is assumed that the filter

value matches the attribute type and Crnk will attempt to parse passed String-based filter value accordingly. There are exceptions, for example, the LIKE filter operator always requires the filter value to be a string to support wildcards for not just String types, but also Enums and other types (the underlying `FilterOperator` implementation can specify this with `getFilterType(⋯)`).

Operators within `FilterSpec` are represented by the `FilterOperator` class. By default, QuerySpec uses the `EQ` operator if no operator was provided. Crnk comes with a set of default filters:

Name	Descriptor
`EQ`	equals operator where values match exactly.
`NEQ`	not equals where values do not match.
`LIKE`	where the value matches the specified pattern. It is usually not case-sensitive and makes use of `%` as wildclard, but may different depending on the underlying implementation.
`LT`	lower than the specified value
`LE`	lower than or equals the specified value
`GT`	greater than the specified value
`GE`	greater than or equals the specified value

By default the filtering process is quite opinionated and should fit many typical patterns. But there also many possibilities to customize its behavior to the use case at hand. For this purpose [CrnkBoot] offers access to the `DefaultQuerySpecUrlMapper` with `CrnkBoot.getUrlMapper()` and `TypeParser` with `CrnkBoot.getModuleRegistry().getTypeParser()` (or `ModuleContext`). For example:

- `TypeParser` allows to register and override the parsing of Strings to other classes. By default it has has built-in parsers for various JRE classes. Custom `StringMapper` can be registered. As fallback it will make use of the `ObjectMapper` of Jackson (which in most cases will be also the default).
- `DefaultQuerySpecUrlMapper.setIgnoreParseExceptions(⋯)` allows to ignore if parsing of a filter value fails. In this case the filter value is left as String and it is assumed the repository itself will take care of the parsing.
- `CrnkBoot.setAllowUnknownAttributes` ignore unknown attributes and passes them as is to the repositories to handle them. More information in the [properties] section.
- The application is free to implements custom `FilterOperator`. Next to the name a `matches` method can be implemented to support in-memory filtering with `QuerySpec.apply`. Otherwise, it is up to the repository implementation to handle the various filter operators; usually by translating them to datastore-native query expressions. Custom operators can be registered with `DefaultQuerySpecUrlMapper.addSupportedOperator(..)`. The default operator can be overridden by setting `DefaultQuerySpecUrlMapper.setDefaultOperator(⋯)`. For more information see `QuerySpecUrlMapper`.

5.2.3. Nested Filtering

WARNING This feature is experimental. Please provide feedback.

The url patterns from the previous section allow to `AND` multiple filter conditions. For scenarios where this is insufficient, it is also possible to specify more complex filter specifications through JSON. The subsequent example filters projects by either their `name` being equals `Great Project` or its `id` being smaller or equals 122.

```
http://127.0.0.1:8080/projects?filter={"OR": {"name": "Great Project", "LE": {"id":
122}}}
```

The following rules apply:

- JSON field names matching an operator can be used in two different ways: to setup arbitrary nesting of `AND`, `OR`, `NOT` or to specify an operator for field, name pair like `{"id": 122}`.
- JSON field names matching a resource field name can also be used in two different ways: to filter the attribute by the specified value or to setup nested attributes.

Some further examples:

1. To require a single attribute to equal a value:

   ```
   {"name": "test"}
   ```

2. To require a single attribute to equal a value from within a set:

   ```
   {"id": [12, 13, 14]}
   ```

3. To filter by multiple attributes with the `OR` operator:

   ```
   { "OR": [ {"id": [12, 13, 14]}, {"completed": "true"} ] }
   ```

4. To filter by multiple attributes with the `AND` operator:

   ```
   { "AND": [ {"id": [12, 13, 14]}, {"completed": "true"} ] }
   ```

   or more simply:

   ```
   {"id": [12, 13, 14], "completed": "true" }
   ```

5. To nest `AND`, `OR`, `NOT` operators:

```
{"name": "Great Task", "OR": {"id": 122, "name": "Other Task"}}
```

6. To filter an attribute `name` on relationship `assignee`:

```
{"assignee": {"name": "test"}}
```

5.2.4. Sorting

Sorting information for the resources can be achieved by providing `sort` parameter.

`GET /tasks?sort=name,-shortName` `GET /tasks?sort=assignee.firstName,assignee.lastName`

- Sorting parameters are represented by `SortSpec` within `QuerySpec` similar to `FilterSpec` above.
- `-` is used to denote to sort in descending order.

An example in Java looks like:

```
SortSpec sortSpec = PathSpec.of("person", "address", "city").sort(Direction.ASC);
SortSpec sortSpec = new SortSpec(PathSpec.of("person.address.city"), Direction.DESC);
```

5.2.5. Pagination

Offset/Limit Paging

Crnk comes by default with support for offset/limit paging:

`GET /tasks?page[offset]=0&page[limit]=10`

The parameters are then available with `QuerySpec.getPaging(type)` or the shortcuts `QuerySpec.getLimit` and `QuerySpec.getOffset`.

Number/Size Paging

Support for number/size-based paging can be enabled by registering the `NumberSizePagingBehavior` in one of two ways:

- register `NumberSizePagingBehavior.createModule()`
- register `NumberSizePagingBehavior` directly to service discovery.

Paging parameters can then look like:

`GET /tasks?page[number]=1&page[size]=10`

Internally Crnk is able to translate between offset/limit and number/size-based paging. If a repository has been implemented with offset/limit paging, it works equally well when number/size paging is used. The conversion takes place automatically when invoking `QuerySpec.getPaging(desiredPagingType)`.

Pagination Links

JSON:API specifies `first`, `previous`, `next` and `last` links (see http://jsonapi.org/format/#fetching-pagination). The `PagedLinksInformation` interface provides a Java representation of those links that can be implemented and returned by repositories along with the result data. There is a default implementation named `DefaultPagedLinksInformation`.

There are two ways to let Crnk compute pagination links automatically:

1. The repository returns meta information implementing `PagedMetaInformation`. With this interface the total number of (potentially filtered) resources is passed to Crnk, which in turn allows the computation of the links.
2. The repository returns meta information implementing `HasMoreResourcesMetaInformation`. This interface only specifies whether further resources are available after the currently requested resources. This lets Crnk compute all except the `last` link.

Note that for both approaches the repository has to return either no links or links information implementing `PagedLinksInformation`. If the links are already set, then the computation will be skipped.

The potential benefit of the second over the first approach is that it might be easier to just determine whether more resources are available rather than counting all resources. This is typically achieved by querying `limit + 1` resources.

Custom strategies

`OffsetLimitPagingBehavior` and `OffsetLimitPagingSpec` and `NumberSizePagingBehavior` and `NumberSizePagingSpec` are two implementations of `PagingBehavior` and `PagingSpec`. Applications are free to add further implementations or replace the existing ones. In order to do so, you would have to perform the following actions:

- Provide an instance of a custom `PagingBehavior` implementation.
- Register the `PagingBehavior` to Spring. There are two possibilities:
  - through the service discovery mechanism like CDI or Spring.
  - through a new module with:

```
SimpleModule module = new SimpleModule("myPaging");
module.addPaginationBehavior(new MyPaginationBehavior());
```

- Make use of the new pagination strategy for your resources:
  - by default the first pagination behavior will become the default for all resources.

- by explicitly specify which resource makes use of which paging specification with @JsonApiResource.pagingSpec.

For examples have a look at the `OffsetLimitPagingBehavior` and `OffsetLimitPagingSpec` or `NumberSizePagingBehavior` and `NumberSizePagingSpec` implementations.

There is the possibility for a `PagingBehavior` to serve multiple `PagingSpec`. This is used, for example, by `NumberSizePagingBehavior` to translate `number` and `size` to `offset` and `limit` for repositories that are based on `OffsetLimitPagingSpec`.

5.2.6. Sparse Fieldsets

Information about fields to include in the response can be achieved by providing `fields` parameter:

```
GET /tasks?fields=name,description
```

5.2.7. Inclusion of Related Resources

Information about relationships to include in the response can be achieved by providing an `include` parameter. Examples:

- `GET /tasks?include=project` performs an inclusion of `project`.
- `GET /tasks?include=assignee,project` performs an inclusion of `project` and `assignee`.
- `GET /tasks?include=assignee.address` performs a nested inclusion of `assignee` within `owner`.
- `GET /tasks/1?include=project` performs an inclusion of `project` for the task with id `1`.

It is not only possible to include related resources, but also to use all other query features like sorting and filtering. In this case the parameters must be prefixed with the resource type such as `[project]` to sort and filter the related project:

```
GET /tasks?include=project&sort[project]=name&filter[project][name]=someProject
```

It is important to note that the requested main resource is NOT affected by `[project]`. To rather sort all tasks by the related project make use of:

```
GET /tasks?include=project&sort=project.name&filter[project.name]=someProject
```

Internally QuerySpec holds the value for a given resource type. If parameters for other resource types, multiple QuerySpec instances are used. Repositories are then accessed with the QuerySpec matching the repository. The QuerySpec for a particular resource type can be obtained with `QuerySpec.getRelatedSpec(Class)` on the root QuerySpec.

5.2.8. URL Mapping

The mapping of request parameters to QuerySpec and back is implemented by `QuerySpecUrlMapper`. With `DefaultQuerySpecUrlMapper` there is a default implementation that follows the JSON:API

specification and recommendations and introduces some further defaults as documented in the previous sections (like the filter operators) where the recommendations do not go far enough. The used `QuerySpecUrlMapper` can be obtained from `CrnkBoot.getUrlMapper()` and `CrnkClient.getUrlMapper()`. Matching setter allow to setup a custom implementation.

`DefaultQuerySpecUrlMapper` comes with a number of customization options:

- `setAllowUnknownAttributes(boolean) DefaultQuerySpecUrlMapper` validates all passed parameters against the domain model and fails if one of the attributes is unknown. This flag allows to disable that check in case this should be necessary.
- `setAllowUnknownParameters(boolean) DefaultQuerySpecUrlMapper` validates all passed parameters to be one of the following types: `filter`, `sort`, `page`, `fields` or `include`. In case of any custom query parameter `ParametersDeserializationException` will be thrown. This flag allows to disable that check and ignore any unknown ones.
- `setIgnoreParseExceptions(boolean) DefaultQuerySpecUrlMapper` attempts to convert all filter parameters to their proper type based on the attribute type to be filtered. In some scenarios like dates this behavior may be undesirable as applications introduce expressions like 'now`. Enabling this flag will let `DefaultQuerySpecDeserializer` ignore such values and provide them as `String` within `FilterSpec`.
- `setEnforceDotPathSeparator(boolean)` DefaultQuerySpecUrlMapper makes use of a dotted URL convetion like `task[project.name]=myProject`. But for historic reasons it also accepts `task[project][name]=myProject`. The later is not recommended to be used anymore because there is danger of introducing ambiguity when resources and attributes are named equally. By enabling this flag, support for the historic format gets removed and no ambiguity can occur. While not being the default, it is recommended to do so. With the next major version, the default will change.
- `setMapJsonNames` Whether to map JSON to Java names for `QuerySpec`. Enabled by default. Typically JSON and Java names are equal, but, for example, fields can be renamed with the `@JsonProperty` annotation.
- `addSupportedOperator` Adds a new `FilterOperator`. See [filtering] for more information.
- `setDefaultOperator` Sets the default `FilterOperator`. See [filtering] for more information.

Some of those methods are also available from some of the integrations like `CrnkFeature` for convenience.

5.3. Relationship Repositories

IMPORTANT	Before getting started with the development of relationship repositories, familiarize yourself with @JsonApiRelation. In various scenarios, a custom implementation is unnecessary! In many cases `@JsonApiRelationId` provides the simplest solution to a relationship. Any opposite relationship can then make use of `@JsonApiRelation.mappedBy`.

Each relationship defined in Crnk (annotation @JsonApiRelation) must have a relationship

repository defined implementing `OneRelationshipRepository` or `ManyRelationshipRepository`. The repository implements the methods necessary to work with a relationship. They provide the methods to work with single-valued and multi-valued relationships:

- `getMatcher()` Provides a `RelationshipMatcher` instance that specifies which relationships it is able provide. It can match against source and target types and fields in any combination. Note that this is a default method that access the legacy `getSourceResourceClass` and `getTargetResourceClass` by default. Implementation of those methods can be omitted if a matcher is available.
- `setRelation(T source, D_ID targetId, String fieldName)` Sets a resource defined by targetId to a field fieldName in an instance source. If no value is to be set, null value is passed.
- `setRelations(T source, Iterable<D_ID> targetIds, String fieldName)` Sets resources defined by targetIds to a field fieldName in an instance source. This is a all-or-nothing operation, that is no partial relationship updates are passed. If no values are to be set, empty Iterable is passed.
- `addRelations(T source, Iterable<D_ID> targetIds, String fieldName)` Adds relationships to a list of relationships.
- `removeRelations(T source, Iterable<D_ID> targetIds, String fieldName)` Removes relationships from a list of relationships.
- `findOneRelations(Collection<T_ID> sourceIds, String fieldName, QuerySpec querySpec)` Finds the single-valued relationship for sources with the ids `sourceIds`.
- `findManyRelations(Collection<T_ID> sourceIds, String fieldName, QuerySpec querySpec)` Finds the multi-valued relationship for sources with the ids `sourceIds`.

All of the methods in this interface have a `fieldName` as last parameter in case multiple fields are served by the same repository. The `findOneRelations` and `findManyRelations` methods gain access to the source class through `querySpec.getResourceClass`, whereas the other methods directly obtain a `source` instance.

5.3.1. Example

HistoryRelationshipRepository

```
@Component
public class HistoryRelationshipRepository extends
ManyRelationshipRepositoryBase<Object, Serializable, History, UUID> {

    @Override
    public RelationshipMatcher getMatcher() {
        return new RelationshipMatcher().rule().target(History.class).add();
    }

    @Override
    public Map<Serializable, ResourceList<History>>
findManyRelations(Collection<Serializable> sourceIds, String fieldName, QuerySpec
querySpec) {
        Map<Serializable, ResourceList<History>> map = new HashMap<>();
        for (Serializable sourceId : sourceIds) {
            DefaultResourceList list = new DefaultResourceList();
            for (int i = 0; i < 10; i++) {
                History history = new History();
                history.setId(UUID.nameUUIDFromBytes(("historyElement" +
i).getBytes()));
                history.setName("historyElement" + i);
                list.add(history);
            }
            map.put(sourceId, list);
        }
        return map;
    }
}
```

5.3.2. RelationshipMatcher

With `RelationshipRepository.getMatcher()` one has a lot of flexibility about which kind of relationships a repository is serving. Rules can look like:

RelationshipMatcherTest

```
new RelationshipMatcher().rule().source("projects").add().matches(field)
new RelationshipMatcher().rule().target(Task.class).add().matches(field)
new RelationshipMatcher().rule().target(Tasks.class).add().matches(field)
new RelationshipMatcher().rule().field("tasks").add().matches(field)
new RelationshipMatcher().rule().oppositeField("project").add().matches(field)
```

One can implement, for example, a history relationship repository that introduces a history relationship for every other resource as done in the example from the previous section.

5.3.3. Self and Related Links

The JSON:API specification from http://jsonapi.org/format/#fetching-relationships mandates two relationship links:

- `"self": "http://example.com/articles/1/relationships/author"`
- `"related": "http://example.com/articles/1/author"`

While the `related` link returns full resources, the `self` link only returns the `type` and `id`:

```
HTTP/1.1 200 OK
Content-Type: application/vnd.api+json

{
  "links": {
    "self": "/articles/1/relationships/author",
    "related": "/articles/1/author"
  },
  "data": {
    "type": "people",
    "id": "12"
  }
```

Behind the scenes, Crnk invokes the same relationship repository implementation , but the QuerySpec will specify whether only the identifier is required through the `includedFields` property.

5.3.4. ForwardingRelationshipRepository

NOTE	Also have a look at @JsonApiRelation.repositoryBehavior before getting started to use this base class.

In many cases, relationship operations can be mapped back to resource repository operations. Making the need for a custom relationship repository implementation redundant. `@JsonApiRelationId` fields is one example where Crnk will take care of this automatically. But there are many other scenarios where application apply similar techniques. A findManyTargets request might can be served by filtering the target repository. Or a relationship can be set by invoking the save operation on either the source or target resource repository (usually you want to save on the single-valued side). The `ForwardingRelationshipRepository` is a base class that takes care of exactly such use cases. `ForwardingRelationshipRepository` knows to `ForwardingDirection`: `OWNER` and `OPPOSITE`. The former forwards requests to the resource repository of the owning side of a relationship, while the later forwards to the opposite side. `ForwardingDirection` is set separately for `GET` and modification operations (`POST`, `PATCH`, `DELETE`).

An example to create such a repository looks like:

```
RelationshipMatcher taskProjectMatcher = new RelationshipMatcher();
taskProjectMatcher.rule().source(Task.class).target(Project.class).add();

new ForwardingRelationshipRepository(
  Task.class, taskProjectMatcher, ForwardingDirection.OWNER, ForwardingDirection.OWNER
);
```

Note that to access the opposite side for `GET` operations, relations must be set up bidirectionally with the `opposite` attribute (to allow filtering in that direction):

```
    @JsonApiResource(type = "tasks")
    public class Task {

        @JsonApiRelation(opposite = "tasks", lookUp =
LookupIncludeBehavior.AUTOMATICALLY_WHEN_NULL)
        private Project project;

        ...
    }
```

5.4. ResourceList

ResourceRepository and RelationshipRepository return lists of type ResourceList. The ResourceList can carry, next to the actual resources, also meta and links information:

- `getLinks()` Gets the links information attached to this lists.
- `getMeta()` Gets the meta information attached to this lists.
- `getLinks(Class<L> linksClass)` Gets the links information of the given type attached to this lists. If the given type is not found, null is returned.
- `getMeta(Class<M> metaClass)` Gets the meta information of the given type attached to this lists. If the given type is not found, null is returned.

There is a default implementation named DefaultResourceList. To gain type-safety, improved readability and crnk-client support, application may provide a custom implementation extending ResourceListBase:

```
    class ScheduleList extends ResourceListBase<Schedule, ScheduleListMeta,
ScheduleListLinks> {

    }

    class ScheduleListLinks implements LinksInformation {

        public String name = "value";

        ...
    }

    class ScheduleListMeta implements MetaInformation {

        public String name = "value";

        ...
    }
```

This implementation can then be added to a repository interface declaration and used by both servers and clients:

```
    public interface ScheduleRepository extends ResourceRepository<Schedule, Long> {

        @Override
        public ScheduleList findAll(QuerySpec querySpec);

    }
```

5.5. Error Handling

Processing errors in Crnk can be handled by throwing an exception and providing a corresponding exception mapper which defines mapping to a proper JSON:API error response.

5.5.1. Throwing an exception...

Here is an example of throwing an Exception in the code:

```
  if (somethingWentWrong()) {
    throw new SampleException("errorId", "Oops! Something went wrong.")
  }
```

Sample exception is nothing more than a simple runtime exception:

```
public class SampleException extends RuntimeException {

  private final String id;
  private final String title;

  public ExampleException(String id, String title) {
    this.id = id;
    this.title = title;
  }

  public String getId() {
    return id;
  }

  public String getTitle() {
    return title;
  }
}
```

5.5.2. ...and mapping it to JSON:API response

Class responsible for mapping the exception should:

- implement ExceptionMapper interface
- available trough the used discovery mechanism or added trough a module.

Sample exception mapper:

TestExceptionMapper.java

```
package io.crnk.test.mock;

import io.crnk.core.engine.document.ErrorData;
import io.crnk.core.engine.error.ErrorResponse;
import io.crnk.core.engine.error.ExceptionMapper;
import io.crnk.core.repository.response.JsonApiResponse;

import java.util.List;

public class TestExceptionMapper implements ExceptionMapper<TestException> {

    public static final int HTTP_ERROR_CODE = 499;

    @Override
    public ErrorResponse toErrorResponse(TestException cve) {
        ErrorData error = ErrorData.builder().setDetail(cve.getMessage()).build();
        return
ErrorResponse.builder().setStatus(HTTP_ERROR_CODE).setSingleErrorData(error).build();
    }

    @Override
    public TestException fromErrorResponse(ErrorResponse errorResponse) {
        JsonApiResponse response = errorResponse.getResponse();
        List<ErrorData> errors = (List<ErrorData>) response.getEntity();
        StringBuilder message = new StringBuilder();
        for (ErrorData error : errors) {
            String title = error.getDetail();
            message.append(title);
        }
        return new TestException(message.toString());
    }

    @Override
    public boolean accepts(ErrorResponse errorResponse) {
        return errorResponse.getHttpStatus() == HTTP_ERROR_CODE;
    }
}
```

On the server-side an exception should be mapped to an `ErrorResponse` object with `toErrorResponse`. It consists of an HTTP status and `ErrorData` (which is consistent with JSON:API error structure). On the client-side an `ExceptionMapper` returning `true` upon `accept(…)` is used to map an `ErrorResponse` back to an exception with `fromErrorResponse`.

Note that the exception mapper is reponsible for providing the logging of exceptions with the appropriate log levels. Also have a look at the subsequent section about the validation module that takes care of JSR-303 bean validation exception mapping.

5.6. Meta Information

NOTE	With ResourceList and @JsonApiMetaInformation meta information can be returned directly. A MetaRepository implementation is no longer necessary.

There is a special interface which can be added to resource repositories to provide meta information: `io.crnk.core.repository.MetaRepository`. It contains a single method `MetaInformation getMetaInformation(Iterable<T> resources)` which return meta information object that implements the marker `interface io.crnk.response.MetaInformation`.

If you want to add meta information along with the responses, all repositories (those that implement `ResourceRepository` and `RelationshipRepository`) must implement `MetaRepository`.

When using annotated versions of repositories, a method that returns a `MetaInformation` object should be annotated with `JsonApiMeta` and the first parameter of the method must be a list of resources.

5.7. Links Information

NOTE	With ResourceList and @JsonApiLinksInformation links information can be returned directly. A LinksRepository implementation is usually not necessary.

There is a special interface which can be added to resource repositories to provide links information: `io.crnk.core.repository.LinksRepository`. It contains a single method `LinksInformation getLinksInformation(Iterable<T> resources)` which return links information object that implements the marker `interface io.crnk.response.LinksInformation`.

If you want to add meta information along with the responses, all repositories (those that implement `ResourceRepository` and `RelationshipRepository`), must implement `LinksRepository`.

When using annotated versions of repositories, a method that returns a `LinksInformation` object should be annotated with `JsonApiLinks` and the first parameter of the method has to be a list of resources.

5.8. Inheritance

There are two different kinds of inheritance supported:

5.8.1. Inheritance with a repository per type

Each subtype is served by its own resource repository and each repository has its own URL.

```
@JsonApiResource(type = "task")
public class Task {
  // fields, getters and setters
}

@JsonApiResource(type = "specialTask")
public class SpecialTask extends Task{
  // fields, getters and setters
}
```

There is no special configuration necessary. But repositories of super types must also return resources of subtypes if they match the specified id or filter parameters.

5.8.2. Inheritance with a single repository per type hierarchy

In this case all resources share a repository implementation and URL (except for the identifier part). An example may look like:

```
@JsonApiResource(type = "task", subTypes = SpecialTask.class)
public class Task {
  // fields, getters and setters
}

@JsonApiResource(type = "specialTask", resourcePath = "task")
public class SpecialTask extends Task{
  // fields, getters and setters
}
```

The `SpecialTask` extends `Task` but is configured to use the same `resourcePath`, meaning `SpecialTask` does not have a repository implementation on its own, but is served by the repository of `Task`. For a more detailed example have a look at `InheritanceWithoutSubtypeRepositoryClientTest`.

5.9. Payload Size Optimizations

Self and related links can make up to 60% of the response payload size and not always are those links of use. Crnk offers a `Crnk-Compact: true` header that can be sent along with the request. In this case the computation of those links is omitted. Further relationships without data are completely omitted.

5.10. Repository Decoration

Sometimes it is useful to augment a repository with further features. There are different situations where that can makes sense:

- the main repository implementation comes from a third-party library and can/should not

directly be modified.

- the feature is unrelated to the main repository feature set, for example, cross-cutting concerns like security, caching, tracing and metrics.

`RepositoryDecoratorFactory` allows to do exactly that. It puts a **decorating** resource or relationship repository inbetween the Crnk engine and the main repository. It implements the same interface contract as the main repository, intercept all requests and can do arbitrary modifications. The modifications may or may not include calling the main repository.

An example can look like:

ApprovalRepositoryDecorator.java

```
    public static final RepositoryDecoratorFactory createFactory(ApprovalManager
approvalManager) {
        return repository -> {
            if (repository instanceof ResourceRepository && ((ResourceRepository)
repository).getResourceClass() == Schedule.class) {
                return new ApprovalRepositoryDecorator(approvalManager,
(ResourceRepository) repository);
            }
            return repository;
        };
    }
```

The particular example, for example, intercepts the `save` operation and may trigger an approval workflow:

ApprovalRepositoryDecorator.java

```
    @Override
    public <S extends T> S save(S entity) {
        if (approvalManager.needsApproval(entity, HttpMethod.PATCH)) {
            return approvalManager.requestApproval(entity, HttpMethod.PATCH);
        } else {
            return super.save(entity);
        }
    }
```

5.11. ResourceFieldContributor

The `ResourceFieldContributor` interface allows to dynamically introduce new fields to resources without actually touching them. This is useful, for example, if you have a JPA entity exposed with crnk-data-jpa and want to add further fields like that mentioned history relationship from the earlier relationship example. `ResourceFieldContributor` can be implemented by a repository or obtained from the regular service discovery mechanism.

Any type of field can be added: meta, links, attribute and relationship fields. For relationship fields

an application may make use of `RelationshipMatcher` to provide repository serving those fields. Notice the `accessor` property that is used to obtain the value of that field (make sure this method is efficient to execute). An example is given by the `HistoryRelationshipRepository` in crnk-integration-examples/spring-boot-example:

HistoryFieldContributor

```
@Component
public class HistoryFieldContributor implements ResourceFieldContributor {

    @Override
    public List<ResourceField> getResourceFields(ResourceFieldContributorContext
context) {
        // this method could be omitted if the history field is added regularly to
Project and Task resource. This would be
        // simpler and recommended, but may not always be possible. Here we
demonstrate doing it dynamically.
        InformationBuilder.FieldInformationBuilder fieldBuilder =
context.getInformationBuilder().createResourceField();
        fieldBuilder.name("history");
        fieldBuilder.genericType(new TypeToken<List<History>>() {
        }.getType());
        fieldBuilder.oppositeResourceType("history");
        fieldBuilder.fieldType(ResourceFieldType.RELATIONSHIP);

        // field values are "null" on resource and we make use of automated lookup to
the relationship repository
        // instead:

fieldBuilder.lookupIncludeBehavior(LookupIncludeBehavior.AUTOMATICALLY_ALWAYS);
        fieldBuilder.accessor(new ResourceFieldAccessor() {
            @Override
            public Object getValue(Object resource) {
                return null;
            }

            @Override
            public void setValue(Object resource, Object fieldValue) {
            }

            @Override
            public Class getImplementationClass() {
                return List.class;
            }
        });
        return Arrays.asList(fieldBuilder.build());
    }
}
```

- `getRelationshipFields` introduces the field dynamically instead of statically.

- `getMatcher` attaches the repository to the historized resources.
- `findManyTarget` implements the lookup of history elements.

5.12. @JsonApiExposed

A repository may be annotated with `@JsonApiExposed(false)`. In this case the repository is only available internally to other repositories, not externally on the JSON:API endpoint. There are different use cases for this:

- Have a look at the micro-service example application to see how remote repositories can be linked to local ones.
- nested resources can be made accessible only through their parent, such as `http://example.com/posts/1/comments/2` and no longer `http://example.com/comments`

6. Client

There is a client implementation for Java and Android projects to allow communicating with JSON-API compliant servers.

6.1. Setup

The basic setup is:

```
CrnkClient client = new CrnkClient("http://localhost:8080/api");
```

Four underlying http client libraries are supported. Add one of those library to the classpath and Crnk will pick it up automatically. A custom `HttpAdapter` can also set passed to `CrnkClient.setHttpAdapter(…)`.

- OkHttp that is popular for Java and Android development. Implemented by `io.crnk.client.http.okhttp.OkHttpAdapter`.
- Apache Http Client implemented by `io.crnk.client.http.apache.HttpClientAdapter`.
- `RestTemplate` from Spring provides a Spring abstraction of other HTTP libraries. Spring application benefit from using this over the underlying native implementation to share the setup configuration setup. It is used by default if the presence of Spring is detected. Implemented by `io.crnk.spring.client.RestTemplateAdapter`.
- `InMemoryHttpAdapter` to directly connect a client to a server without a TCP transport layer or HTTP server. This **implementation is well suited for unit testing** as no server must be setup, making unit tests simpler and faster to write, execute and debug. In contrast to invoking a repository directly on the server, `InMemoryHttpAdapter` request still pass through the entire Crnk serialization layer and are processed like any other HTTP request.

```
String url = "http://localhost:8080/api";
CrnkClient client = new CrnkClient(url);
client.setHttpAdapter(new InMemoryHttpAdapter(crnkBoot, url));
```

WARNING	For Spring a **reasonable HTTP client implementation must underlie** `RestTemplate` in order for `crnk-client` to work properly. For example, the default Java implementation does not support the `PATCH` method and as such no resources can be updated. To explicitly set HTTP implementation use:

```
RestTemplateAdapter adapter = (RestTemplateAdapter) client.getHttpAdapter();
RestTemplate template = adapter.getImplementation();
template.setRequestFactory(new OkHttp3ClientHttpRequestFactory());
```

or

```
client.setHttpAdapter(new RestTemplateAdapter(customRestTemplate));
```

6.2. Usage

The client has three main methods:

- `CrnkClient#getRepositoryForInterface(Class)` to obtain a resource repository stub from an existing repository interface.
- `CrnkClient#getRepositoryForType(Class)` to obtain a generic resource repository stub from the provided resource type.
- `CrnkClient#getRepositoryForType(Class, Class)` to obtain a generic relationship repository stub from the provided source and target resource types.

The interface of the repositories is as same as defined in `Repositories`_ section.

An example of the usage:

```
CrnkClient client = new CrnkClient("http://localhost:8080/api");
ResourceRepository<Task, Long> taskRepo = client.getRepositoryForType(Task.class);
List<Task> tasks = taskRepo.findAll(new QuerySpec(Task.class));
```

Have a look at, for example, the QuerySpecClientTest to see more examples of how it is used.

6.3. URL handling

Crnk client and server share the URL handling. `QuerySpecUrlMapper` performs the mapping of HTTP request parameters to QuerySpec. For more information see url mapping.

6.4. Modules

`CrnkClient` can be extended by modules:

```
CrnkClient client = new CrnkClient("http://localhost:8080/api");
client.addModule(ValidationModule.create());
```

Typical use cases include:

- adding exception mappers
- registering new types of resources (like JPA entities by the `JpaModule`)
- intercepting requests for monitoring
- adding security tokens to requests
- setup the `PlainJsonFormatModule`

Many modules allow a registration both on server and client side. The client part then typically makes use of a subset of the server features, like exception mappers and resource registrations.

There is a mechanism to discover and register client modules automatically:

```
CrnkClient client = new CrnkClient("http://localhost:8080/api");
client.findModules();
```

`findModules` makes use of `java.util.ServiceLoader` and looks up for `ClientModuleFactory`. `JpaModule`, `ValidationModule`, `MetaModule`, `SecurityModule` implement such a service registration. In contrast, `BraveModule` needs a Brave instance and does not yet allow a fully automated setup.

6.5. Type-Safety

It is possible to work with `CrnkClient` in a fully type-safe manner.

In a first step an interface for a repository is defined:

ScheduleRepository.java

```
public interface ScheduleRepository extends ResourceRepository<Schedule, Long> {
    @Override
    ScheduleList findAll(QuerySpec querySpec);

    class ScheduleList extends ResourceListBase<Schedule, ScheduleListMeta,
ScheduleListLinks> {

    }

    class ScheduleListLinks extends DefaultPagedLinksInformation implements
LinksInformation {

        public String name = "value";
    }

    class ScheduleListMeta extends DefaultPagedMetaInformation {

        public String name = "value";

    }
}
```

And then it can be used like:

QuerySpecClientTest.java

```
        ScheduleRepository scheduleRepository = ((ClientTestContainer)
testContainer).getClient().getRepositoryForInterface(ScheduleRepository.class);

        Schedule schedule = new Schedule();
        schedule.setId(13L);
        schedule.setName("mySchedule");
        scheduleRepository.create(schedule);

        QuerySpec querySpec = new QuerySpec(Schedule.class);
        ScheduleList list = scheduleRepository.findAll(querySpec);
        Assert.assertEquals(1, list.size());
        ScheduleListMeta meta = list.getMeta();
        ScheduleListLinks links = list.getLinks();
        Assert.assertNotNull(meta);
        Assert.assertNotNull(links);
```

6.6. HTTP customization

`CrnkClient#getHttpAdapter()` gives access to the `HttpAdapter`. There are two ways to customize HTTP

requests:

- A `HttpAdapterListener` can be added with `addListener` to `HttpAdapter`. `HttpAdapterListener` allows to intercept both requests and responses and perform changes.
- The `HttpAdapter` interface can be cast to used implementation, which in turn gives access to the native builder/listener mechanisms to perform any kind of advanced customization.

Typical use cases to customize the HTTP requests and responses are:

- add custom request headers (security, tracing, etc.)
- collect statistics
- ...

Some examples:

- crnk-monitor-brave4 for an advanced example.
- How to add headers to OkHttp request interceptor.

6.7. JAX-RS interoperability

The interface stubs from the previous section can also be used to make calls to JAX-RS. For example, the `ScheduleRepository` can be complemented with a JAX-RS annotation:

ScheduleRepository.java

```
@Path("schedules")
@Produces(HttpHeaders.JSONAPI_CONTENT_TYPE)
```

and further JAX-RS services can be added:

ScheduleRepository.java

```
    @GET
    @Path("repositoryAction")
    @Produces(MediaType.TEXT_HTML)
    String repositoryAction(@QueryParam(value = "msg") String msg);

    @GET
    @Path("repositoryActionJsonApi")
    String repositoryActionJsonApi(@QueryParam(value = "msg") String msg);

    @GET
    @Path("repositoryActionWithJsonApiResponse")
    String repositoryActionWithJsonApiResponse(@QueryParam(value = "msg") String msg);

    @GET
    @Path("repositoryActionWithResourceResult")
    Schedule repositoryActionWithResourceResult(@QueryParam(value = "msg") String
msg);

    @GET
    @Path("repositoryActionWithException")
    Schedule repositoryActionWithException(@QueryParam(value = "msg") String msg);

    @GET
    @Path("repositoryActionWithNullResponse")
    @Produces(MediaType.TEXT_HTML)
    String repositoryActionWithNullResponse();

    @GET
    @Path("repositoryActionWithNullResponseJsonApi")
    String repositoryActionWithNullResponseJsonApi();

    @GET
    @Path("{id}/resourceAction")
    String resourceAction(@PathParam("id") long id, @QueryParam(value = "msg") String
msg);
```

To make this work a dependency to `org.glassfish.jersey.ext:jersey-proxy-client` must be added and `JerseyActionStubFactory` registered with `CrnkClient`:

AbstractClientTest.java

```
        client.setActionStubFactory(JerseyActionStubFactory.newInstance());
```

Then a client can make use the Crnk stubs and it will transparently switch between JSON-API and JAX-RS calls:

JsonApiActionResponseTest.java

```
        String result = scheduleRepository.repositoryAction("hello");
        Assert.assertEquals("repository action: hello", result);
```

WARNING	Due to limited configurability of the Jersey Proxies it is currently not possible to reuse the same HTTP connections for both types of calls. We attempt to address that in the future. Be aware of this when you, for example, add further request headers (like security), as it has to be done in two places (unfortunately).

7. Formats

By default Crnk follows the JSON:API specification to establish a REST endpoint. This chapter outlines the support for formats other than JSON:API.

7.1. Plain JSON

The relationships and inclusions mechanisms of JSON:API allow to built powerful applications. But sometimes those advanced features can also make simpler applications harder to write. For example, clients do not have direct access to relationships, but rather have the resolve them through their identifiers.

`crnk-format-plain-json` hosts the `PlainJsonFormatModule` that allows to setup a simpler, non-JSON:API format. The module can be applied both to CrnkBoot and CrnkClient. An example looks like:

http://localhost:8080/tasks/12

```
{
  "data" : {
    "id" : "12",
    "type" : "tasks",
    "name" : "someTask",
    "schedule" : {
      "data" : null,
      "links" : {
        "self" : "http://localhost:8080/tasks/12/relationships/schedule",
        "related" : "http://localhost:8080/tasks/12/schedule"
      }
    },
    "project" : {
      "data" : {
        "id" : "1",
        "type" : "projects",
        "name" : "someProject"
      },
      "links" : {
        "self" : "http://localhost:8080/tasks/12/relationships/project",
        "related" : "http://localhost:8080/tasks/12/project"
      }
    }
  }
}
```

Most notably the project relationship is directly inlined within the task. And a resource is written in a more flat manner without the `attributes` and `relationships` containers. Contributions to add more flexibility to the module are always welcome.

Note that the JSON:API endpoint remains fully functional. The HTTP `Accept` and `Content-Type` headers are used to select the format. As such, the Crnk client continues to make use of the JSON:API format. Related to this there is a `format` attribute for the Typescript generator to select the desired format for generation:

```
crnkGen{

  typescript{
    ...
    format = 'PLAINJSON' // or 'JSONAPI'
  }
}
```

8. Reactive Programming

WARNING	Initial support is available, but still considered (very) experimental. The implementation is expected to mature over the coming weeks. Breaking changes to the reactive API might be possible. The traditional API is left unchanged.

The `ReactiveModule` of `crnk-reactive` bring support for reactive programming to Crnk. It allows to build more responsive, elastic, resilient, message-driven applications (see https://www.reactivemanifesto.org/). https://projectreactor.io/ was chosen as library.

IMPORTANT	Traditional and reactive-style programming APIs are considered being equally important and will both be supported the coming years.

`crnk-reactive` brings along three new interfaces that act as reactive counter-parts of the traditional resource and relationship interfaces:

- `ReactiveResourceRepository`
- `ReactiveOneRelationshipRepository`
- `ReactiveManyRelationshipRepository`

The differences to the traditional ones are:

- Single and multi-valued relationships are served by different interfaces (minor cleanup, usually one or the other is necessary).
- `ResourceField` instead of a simple `String` give more detailed information about the accessed relationship.
- Most importantly, `reactor.core.publisher.Mono` is used as return type to enable reactive programming.

NOTE that:

- A potential future V3 version of the traditional interfaces will align the first two differences.
- `Mono` rather than `Flux` is used for list return types since meta and links information must be returned as well, not just a sequence of resources. For large number of resources, the JSON:API pagination mechanisms can be applied.
- Internally the traditional and reactive repositories are served by the same Crnk engine and share virtually all of the code base. The difference lies in the used `ResultFactory` implementation. `ImmediateResultFactory` is used by the traditional API. `MonoResultFactory` by reactive setups.

8.1. Servlet Example

The subsequent example shows as simple reactive resource repository holding its data in-memory:

InMemoryReactiveResourceRepository.java

```
package io.crnk.test.mock.reactive;

import io.crnk.core.engine.information.resource.ResourceField;
import io.crnk.core.engine.internal.utils.PreconditionUtil;
import io.crnk.core.engine.registry.RegistryEntry;
import io.crnk.core.queryspec.QuerySpec;
import io.crnk.core.resource.list.ResourceList;
import io.crnk.reactive.repository.ReactiveResourceRepositoryBase;
import io.crnk.test.mock.TestException;
import io.crnk.test.mock.UnknownException;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import reactor.core.publisher.Mono;

import java.util.Map;
import java.util.concurrent.ConcurrentHashMap;

public class InMemoryReactiveResourceRepository<T, I> extends
ReactiveResourceRepositoryBase<T, I> {

    private static final Logger LOGGER =
LoggerFactory.getLogger(InMemoryReactiveResourceRepository.class);

    protected Map<I, T> resources = new ConcurrentHashMap<>();

    private long nextId = 0;

    public InMemoryReactiveResourceRepository(Class<T> clazz) {
        super(clazz);
    }


    @Override
    public Mono<T> findOne(I id, QuerySpec querySpec) {
        if ((Long) id == 10000L) {
            return Mono.error(new TestException("msg"));
        }
        if ((Long) id == 10001L) {
            return Mono.error(new UnknownException("msg"));
        }
        return super.findOne(id, querySpec);
    }


    @Override
    public Mono<ResourceList<T>> findAll(QuerySpec querySpec) {
        LOGGER.debug("findAll {}", querySpec);
        return Mono.fromCallable(() -> querySpec.apply(resources.values()));
    }

    @Override
```

```
    public Mono<T> create(T entity) {
        LOGGER.debug("create {}", entity);

        RegistryEntry entry = resourceRegistry.findEntry(getResourceClass());
        ResourceField idField = entry.getResourceInformation().getIdField();
        Long id = (Long) idField.getAccessor().getValue(entity);
        if (id == null) {
            idField.getAccessor().setValue(entity, nextId++);
        }
        return save(entity);
    }


    @Override
    public Mono<T> save(T entity) {
        LOGGER.debug("save {}", entity);
        RegistryEntry entry = resourceRegistry.findEntry(getResourceClass());
        ResourceField idField = entry.getResourceInformation().getIdField();
        I id = (I) idField.getAccessor().getValue(entity);
        PreconditionUtil.assertNotNull("no id specified", entity);
        if ((Long) id == 10000L) {
            return Mono.error(new TestException("msg"));
        }
        if ((Long) id == 10001L) {
            return Mono.error(new UnknownException("msg"));
        }
        resources.put(id, entity);
        return Mono.just(entity);
    }

    @Override
    public Mono<Boolean> delete(I id) {
        LOGGER.debug("delete {}", id);
        return Mono.fromCallable(() -> resources.remove(id) != null);
    }

    public Map<I, T> getMap() {
        return resources;
    }

    public void clear() {
        resources.clear();
    }
}
```

The following snipped shows how to setup the `ReactiveModule` together with `AsyncCrnkServlet` in Spring:

ReactiveServletTestApplication.java

```
    @Bean
    public AsyncCrnkServlet asyncCrnkServlet(SlowResourceRepository
slowResourceRepository) {
        SimpleModule slowModule = new SimpleModule("slow");
        slowModule.addRepository(slowResourceRepository);

        AsyncCrnkServlet servlet = new AsyncCrnkServlet();
        servlet.getBoot().addModule(new ReactiveModule());
        servlet.getBoot().addModule(testModule);
        servlet.getBoot().addModule(slowModule);

        return servlet;
    }

    @Bean
    public ServletRegistrationBean crnkServletRegistration(AsyncCrnkServlet servlet) {
        ServletRegistrationBean bean = new ServletRegistrationBean(servlet, "/api/*");
        bean.setLoadOnStartup(1);
        return bean;
    }

    @Bean
    public CrnkBoot crnkBoot(AsyncCrnkServlet servlet) {
        return servlet.getBoot();
    }
```

Ready-to-use integrations into Spring, Vert.x and Ratpack are planned for the near future.

8.2. Interacting with traditional repositories

Reactive and traditional repositories work well together side-by-side and can also be used in a mixed setting, for example when requesting the inclusion of related resources. Since the traditional repositories will block the caller, there are two mechanisms in place to remedy the issue:

1. A repository can be annotated with `ImmediateRepository`. In this case the traditional repository is marked as being non-blocking and can be safely invoked.
2. `ReactiveModule.setWorkerScheduler(⋯)` allows to set the scheduler to use to invoke traditional repositories. By default `Schedulers.elastic` is used where worker threads are spanned as necessary.

8.3. Roadmap and Limitations

- `DocumentFilter`, `RepositoryFilter` cannot be used in a reactive setup. Reactive counter-party will be available in the near future.
- `HttpRequestContextProvider.getRequestContext` can only be used in a non-reactive setting or while the reactive request is being setup. `HttpRequestContextProvider.getRequestContextResult`

must be used instead that makes use of the subscriber context of Reactor.

- `crnk-data-jpa` has not yet been ported yet. JDBC and JPA are blocking and require a transaction.
- Spring, Vert.x and Ratpack integrations are target for the near future.
- More testing will be necessary.

Contributions in any area welcomed. :basedir: ../../../..

9. Security

The resource-oriented nature of Crnk makes a number of quite powerful security schemes possible to authorize access to resources. The semantics of JSON:API with resources, relationships, fields and parameters provide much more information about an application compared to, for example, a more classical JAX-RS oder Spring MVC application. This in turn allows to automate and simplify many security-related topics, which in turn allows for a more robust authorization.

Authorization can happen on three levels:

- Resource-based authorization: only a subset of all resource types are accessible to the user.
- Field-based authorization: only a subset of the fields (attributes and relationships) of a resource are accessible to the user.
- Data-based authorization: only a subset of all resources of a given type are accessible to the user based on the contents of the resources. Typically denominated Dataroom access control (DAC).

Crnk comes with support for all three. The subsequent sections outline a number of different strategies how to apply them.

9.1. Authentication

Authorization requires to first know the calling user through authentication. Crnk is agnostic to the used authorization scheme and is usually provided by the underlying integration, for example, the `Principal` of JEE or the `SecurityContext` of Spring Security. They in turn are populated from a scheme like OAuth, JWT or SAML.

Crnk makes use of `SecurityProvider` to integrate with such systems and check access to roles for the current user:

SecurityProvider.java

```
package io.crnk.core.engine.security;

public interface SecurityProvider {

    boolean isUserInRole(String role);

    /**
     * @return true if the user has been logged in. If not, a {@link
io.crnk.core.exception.UnauthorizedException} rather than
     * {@link io.crnk.core.exception.ForbiddenException} is  thrown.
     */
    boolean isAuthenticated();
}
```

The JAX-RS and servlet integration of Crnk come both with a `SecurityProvider` implementation. Which in turn also provides an implementation for all integrations derived from them, such as Spring.

The `SecurityProvider` is accessible from the module API and can be used to perform both DAC and RBAC or any other kind of check.

9.2. Resource-based Access Control with the SecurityModule

There is a `SecurityModule` provided by `crnk-security` that intercepts all repository requests and perform access control. Currently it supports resource-based access control. A setup can looks as follows:

SecurityModuleIntTest.java

```
            Builder builder = SecurityConfig.builder();
            builder.permitRole("allRole", ResourcePermission.ALL);
            builder.permitRole("getRole", ResourcePermission.GET);
            builder.permitRole("patchRole", ResourcePermission.PATCH);
            builder.permitRole("postRole", ResourcePermission.POST);
            builder.permitRole("deleteRole", ResourcePermission.DELETE);
            builder.permitRole("taskRole", Task.class, ResourcePermission.ALL);
            builder.permitRole("taskReadRole", Task.class, ResourcePermission.GET);
            builder.permitRole("projectRole", Project.class, ResourcePermission.ALL);
            builder.permitAll(ResourcePermission.GET);
            builder.permitAll(Project.class, ResourcePermission.POST);
            module = SecurityModule.newServerModule(builder.build());

            CrnkFeature feature = new CrnkFeature();
            feature.addModule(module);
```

A builder is used to construct rules. Each rule grants access to either a given or all resources. Thereby `ResourcePermission` specifies the set of authorized methods: `GET`, `POST`, `PATCH`, `DELETE`.

Once the rules are defined, the runtime checks go well beyond more traditional approaches like JEE `@RolesAllowed` annotation. The rules are enforced in various contexts:

- Access to resource repositories are checked.
- Access to relationship repositories are checked based on the target (return) type.
- Relationship fields targeting resources the user is not authorized to see are omitted from results and cannot be modified.
- A request may span multiple repository accesses in case of inclusions with the `include` parameter. In this case every access is checked individually.
- `HomeModule` and `MetaModule` show only resources the user is authorized to see. In case of the `MetaModule` the `MetaAttribute` and `MetaResource` provide further information about what can be read, inserted, updated and deleted.
- (soon) Query parameters for sorting and filtering are checked against unauthorized access to related resources.

Internally the security module makes use of `ResourceFilter` to perform this task. More information about that is available in a subsequent section.

Is is up to the application how and when to configure the `SecurityModule`. The set of rules can be static or created dynamically. `SecurityModule.reconfigure(⋯)` allows to replace the security rules at runtime.

9.3. Role-based Access Control with ResourceFilter

The `SecurityModule` is only one example how to implement security. Underlying it is the `ResourceFilter` interface provided by the Crnk engine:

ResourceFilter.java

```
public interface ResourceFilter {
    FilterBehavior filterResource(ResourceInformation resourceInformation, HttpMethod
method);
    FilterBehavior filterField(ResourceField field, HttpMethod method);
}
```

`ResourceFilter` allows to restrict access to resources and fields. To methods `filterResource` and `filterField` can be implemented for this purpose. Both return a `FilterBehavior` which allows to distinguish between `NONE`, `IGNORE` and `FORBIDDEN`. For example, a field like a lock count can make use of `IGNORE` in order to be ignored for POST and PATCH requests (the current value on the server is left untouched). While access to an unauthorized resource or field results in a forbidden error with `FORBIDDEN`. An example is given by the `SecurityResourceFilter` of `SecurityModule` in 'crnk-security`. Since `ResourceFilter` methods are invoked often, it is important for them to return quickly.

There is a `ResourceFilterDirectory` that complements `ResourceFilter`. It allows to query the authorization status of a particular resource or field in context of the current request. The `ResourceFilterDirectory` makes use of per-request caching as the information may be accessed repeatedly for a request. It can be obtained with `ModuleContext.getResourceFilterDirectory(…)` from the module API. For example, the `MetaModule` and `HomeModule` make use of `ResourceFilterDirectory` to only list authorized elements.

9.4. Dataroom Access Control

Filtering of resources is one of the main building blocks of JSON:API. As such it is typically not too hard to implement DAC. The roles of a user can be checked and if necessary for filters specific to that user can be added. There are two possibilities to add such filters:

- by updating the repository filters.
- by implementing a repository decorator that intercepts the request before reaching the repository. For more information see Repository Decoration.

The `SecurityModule` comes with built-in support for DAC. An example looks like:

DataRoomFilterTest.java

```
Unresolved directive in security.adoc - include::../../../../crnk-
security/src/test/java/io/crnk/security/DataRoomFilterTest.java[tags=docs]
```

A `DataRoomFilter` can be passed to the `SecurityConfig`. It has to provide a `QuerySpec` of what the current caller is allowed to see. In the example here all callers are just allowed to see tasks named `foo`. Real-world scenarios access the user principal and roles to decide for a particular filter. The returned `QuerySpec` is applied to all repository operations: `GET`, `PATCH`, `POST` and `DELETE`:

Method	Descripton
`GET`	Added to the caller `QuerySpec` to filter by both caller and DataRoom filters.
`POST`	Verifies that the created resources matches with DataRoom filter. Checks are performed in memory with `QuerySpec.apply`.
`PATCH`	Equivalent to `POST` but further verifiers that the caller has access to the existing, unchanged resource. Implementors may further those to make involved fields immutable with `@JsonApiField(patchable=false)`.
`DELETE`	Verifies that deleted resources match DataRoom filtering by querying them before deletion.

IMPORTANT When accessing relationship repositories, only one side is checked for performance reasons. It is assumed that `DataRoomFilter` applies proper filters to both sides of a relationship. For `GET` it is the target side of the relationship (the returned resources), for `PATCH`, `POST` and `DELETE` the modified source side.

9.5. Adapt User Interfaces based on Authorizations

In many cases it is desired to adjust UIs based on the authorizations of a user to guide the user early what he is authorized to do. There are two mechanisms that are outlined in the next sections.

9.5.1. ResourcePermissionInformation

The `ResourcePermissionInformation` interface specializes `MetaInformation` to give access to the `ResourcePermission` of that particular element, either a list or a single resource. If either of the two carries a `MetaInformation` implementing `ResourcePermissionInformation`, then the `SecurityModule` will fill-in the `ResourcePermission` for the current request.

9.5.2. API

`SecurityModule.setExposeRepositories(true)` sets up repositories accessible through the `<contextPath>/security/` path. Currently supported are:

- `<contextPath>/security/role` to gain access to all configure roles.
- `<contextPath>/security/callerPermission` to gain access to all permissions of the current caller.

9.5.3. Home and Meta Module

- `HomeModule` and `MetaModule` hide resources the user is not authorized to see. Any UI can query their respective URLs to gain information about what the user is authorized to see.
- The `MetaAttribute` and `MetaResource` resources from the `MetaModule` further show information about which resources and fields can be inserted, updated and deleted. The resources are available from `/meta/attributes` and `/meta/resource` respectively.

9.6. Provide Authentication Information to the User

A frequent use case is to display user/login related information for a user. However, Crnk does not do authentication on its own and the set of provided information is typically application-specific. As such there is no direct support from Crnk, but a custom repository can look like:

LoginRepository.java

```
public class LoginRepository extends ResourceRepositoryBase<Login, String> {


    public LoginRepository() {
        super(Login.class);
    }

    @Override
    public ResourceList<Login> findAll(QuerySpec querySpec) {
        List<Login> logins = new ArrayList<>();
        SecurityContext context = SecurityContextHolder.getContext();
        if (context != null) {
            Authentication authentication = context.getAuthentication();
            Login me = new Login();
            me.setId("me");
            me.setUserName(authentication.getName());
            logins.add(me);
        }
        return querySpec.apply(logins);
    }
}
```

This particular example has been taken from crnk-example.

9.7. Exception Mapping

Crnk comes with four exceptions that are relevant in a security context:

- `io.crnk.core.exception.ForbiddenException` results in a HTTP `403` status code and forbids access to the requested element.
- `io.crnk.core.exception.UnauthorizedException` results in a HTTP `401` status code to trigger authentication.
- `io.crnk.core.exception.RepositoryNotFoundException` and `io.crnk.core.exception.ResourceNotFoundException` may be used in favor of `io.crnk.core.exception.ForbiddenException` to completely hide unauthorized resources with a status `404` indistinguishable from non-existing ones.

9.8. (Potential) Future Work

- Authorize access to fields with `SecurityModule`.
- Authorize sort and filter parameters.
- Resource annotations to configure `SecurityModule`.
- Deny rules for `SecurityModule`.
- Potentially give security-related information through `OPTIONS` requests.

- DAC support for `SecurityModule`.

10. Data Access

10.1. JPA

The JPA module allows to automatically expose JPA entities as JSON:API repositories. No implementation or Crnk-specific annotations are necessary.

The feature set includes:

- expose JPA entities to JSON:API repositories
- expose JPA relations as JSON:API repositories
- decide which entities to expose as endpoints
- sorting, filtering, paging, inclusion of related resources.
- all default operators of crnk are supported: `EQ`, `NEQ`, `LIKE`, `LT`, `LE`, `GT`, `GE`.
- filter, sort and include parameters can make use of the dot notation to join to related entities. For example, `sort=-project.name,project.id`, `filter[project.name][NEQ]=someValue` or `include=project.tasks`.
- support for entity inheritance by allowing sorting, filtering and inclusions to refer to attributes on subtypes.
- support for Jackson annotations to customize entity attributes on the JSON:API layer, see here.
- DTO mapping support to map entities to DTOs before sending them to clients.
- JPA Criteria API and QueryDSL support to issue queries.
- filter API to intercept and modify issued queries.
- support for computed attributes behaving like regular, persisted attributes.
- automatic transaction handling spanning requests and doing a rollback in case of an exception.
- `OptimisticLockExceptionMapper` mapped to JSON:API errors with `409` status code.
- `PersistenceException` and `RollbackException` are unwrapped to the usually more interesting exceptions like `ValidationException` and then translated to JSON:API errors.

Not yet supported are sparse field sets queried by tuple queries.

10.1.1. JPA Module Setup

To use the JPA module, two things are necessary:

- a set of existing entities
- matching JPA repositories that have to be setup

For an example have a look at spring-boot-example.

Entity

Any JPA entity can be used to expose as JSON:API resource:

ScheduleEntity.java

```
package io.crnk.example.springboot.domain.model;

import io.crnk.core.resource.annotations.JsonApiRelation;
import io.crnk.core.resource.annotations.JsonApiRelationId;
import io.crnk.core.resource.annotations.JsonApiResource;
import io.crnk.core.resource.annotations.SerializeType;

import javax.persistence.Column;
import javax.persistence.Entity;
import javax.persistence.FetchType;
import javax.persistence.Id;
import javax.persistence.JoinColumn;
import javax.persistence.JoinColumns;
import javax.persistence.ManyToMany;
import javax.persistence.ManyToOne;
import java.util.Set;

@JsonApiResource(type = "schedule")
@Entity
public class ScheduleEntity {

    @Id
    private Long id;

    private String name;

    @JsonApiRelationId()
    @Column(name = "creator_id")
    private String creatorId;

    @ManyToOne(fetch = FetchType.LAZY)
    @JoinColumns({@JoinColumn(name = "creator_id", insertable = false, updatable =
false)})
    @JsonApiRelation(serialize = SerializeType.ONLY_ID)
    private UserEntity creator;

    @ManyToMany(fetch = FetchType.LAZY)
    private Set<UserEntity> verifiers;

    public Long getId() {
        return id;
    }
```

```
    public void setId(Long id) {
        this.id = id;
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public String getCreatorId() {
        return creatorId;
    }

    public void setCreatorId(String creatorId) {
        this.creatorId = creatorId;
        this.creator = null;
    }

    public UserEntity getCreator() {
        return creator;
    }

    public void setCreator(UserEntity creator) {
        this.creator = creator;
        this.creatorId = creator != null ? creator.getLoginId() : null;
    }

    public Set<UserEntity> getVerifiers() {
        return verifiers;
    }

    public void setVerifiers(Set<UserEntity> verifiers) {
        this.verifiers = verifiers;
    }
}
```

- Entities are mapped to resources.
- Crnk understands all JPA-related annotations and in many cases, not Crnk-specific annotations are necessary.
- Embeddables are mapped to nested json structures.
- Embeddables used as primary keys are mapped to/from a simple string to remain addressable as resource id. The order of attributes thereby determines the position of the values in the string.
- Not supported are relationships within embeddables.

It is possible to add additional JSON:API related fields to entities by annotating them with `@javax.persistence.Transient` (or the other way around by marking it with `@JsonIgnore`).

JpaTransientTestEntity.java

```
@Entity
public class JpaTransientTestEntity extends TestMappedSuperclass {

    @Id
    private Long id;

    @Transient
    @JsonApiRelation(serialize = SerializeType.LAZY, lookUp = LookupIncludeBehavior
.NONE)
    private Task task;

    public Long getId() {
        return id;
    }

    public void setId(Long id) {
        this.id = id;
    }

    public Task getTask() {
        return task;
    }

    public void setTask(Task task) {
        this.task = task;
    }
}
```

`@JsonApiRelationId` is also supported for JPA entities:

```
    @Column(name="project_id")
    @JsonApiRelationId
    private Long projectId;

    @JsonApiRelation(serialize=SerializeType.ID_ONLY)
    @ManyToOne(fetch = FetchType.LAZY)
    @JoinColumn(name = "project_id", insertable = false, updatable = false)
    private Project project;
```

Notice that both fields are mapped to the same column. The `project` field must be made read-only with `insertable` and `updateable` to let JPA know that `projectId` is supposed to be used for write operations. In the example, `SerializeType.ID_ONLY` will trigger for `projectId` to always be written to the response in the relationship data section without having to fully load the related `project`.

JPA Repository Setup

To then expose an entity as resource, provide a repository implementation inheriting from `JpaEntityRepositoryBase`:

ScheduleRepositoryImpl.java

```
package io.crnk.example.springboot.domain.repository;

import io.crnk.example.springboot.domain.model.ScheduleEntity;
import io.crnk.data.jpa.JpaEntityRepositoryBase;
import org.springframework.stereotype.Component;

@Component
public class ScheduleRepositoryImpl extends JpaEntityRepositoryBase<ScheduleEntity,
Long> {

    public ScheduleRepositoryImpl() {
        super(ScheduleEntity.class);
    }
}
```

If no such repository is specified, Spring Boot will by default expose all entities if not configured otherwise.

JPA module Setup

Crnk provides a Spring Boot AutoConfiguration to setup the JPA Module. for more advanced use cases and other frameworks, the JPA module can also be setup manually:

```
    TransactionRunner transactionRunner = ...;

    JpaModuleConfig config = new JpaModuleConfig();

    // expose all entitities from provided EntityManagerFactory
    config.exposeAllEntities(entityManagerFactory);

    JpaModule jpaModule = JpaModule.createServerModule(config, em, transactionRunner(
));

    CrnkFeature feature = new CrnkFeature(...);
    feature.addModule(jpaModule);
```

- `exposeAllEntities` takes an `EntityManagerFactory` and exposes all registered entities as JSON:API repository.
- `JpaRepositoryConfig.Builder.setRepositoryDecorator` allows to setup a repository decorator that can intercept and change any request, like setting up additional links and meta information.
- The transactionRunner needs to be implemented by the application to hook into the transaction

processing of the used environment (Spring, JEE, etc.). This might be as simple as a Spring bean implementing `TransactionRunner` and carring a `@Transactional` annotation. The JPA module then ensures that every requests happens within such a transaction. Crnk comes with two default implementations: `SpringTransactionRunner` and `CdiTransactionRunner` that come are included in `crnk-setup-spring` and `crnk-cdi`.

10.1.2. Pagination

The JPA module implements both pagination approaches supported by Crnk. Setting `JpaModule.setTotalResourceCountUsed(true|false)` allows to decide whether the total number of resources should be counted or whether just the presence of a subsequent resource is checked (by querying `limit + 1` entities). By default the total resources are counted. Have a look at the [pagination] section for more information.

10.1.3. Criteria API and QueryDSL

The JPA module can work with two different query APIs, the default Criteria API and QueryDSL. `JpaModule.setQueryFactory` allows to choose between those two implementation. There is the `JpaCriteriaQueryFactory` and the `QuerydslQueryFactory`. By default the Criteria API is used. QueryDSL sits on top of JPQL and has to advantage of being easier to use.

10.1.4. Lazy and Eager Loading

JPA relationships can either be `EAGER` or `LAZY`. The former is mapped to Crnk serialization type `ID_ONLY` and the later to `LAZY`. If a relationship is supposed to be truly eager, `@JsonApiRelation(serializeType=SerializeType.EAGER)` can be used next to the JPA annotations.

Be careful with JPA since its default is `EAGER` loading. It is a typical source of performance issues.

10.1.5. Access with Crnk client

To setup a Crnk client with the JPA module use:

```
    client = new CrnkClient(getBaseUri().toString());

    JpaModule module = JpaModule.newClientModule();
    setupModule(module, false);
    client.addModule(module);

    ResourceRepositoryV2<TaskEntity, UUID> genericRepo = client.getRepositoryForType
(TypeEntity.class)
    TaskRepository typedRepo = client.getRepositoryForInterface(TaskRepository.class)
```

Have a look at https://github.com/crnk-project/crnk-framework/blob/master/crnk-data/crnk-data-jpa/src/test/java/io/crnk/data/jpa/data/JpaQuerySpecEndToEndTest.java within the `crnk-data-jpa` test cases to see how everything is used together with `crnk-client`.

There is also the possibility to specify a repository interface. The interface has the benefit of

providing proper typing of meta information, link information and list return type. An example can look like:

```
public interface TaskRepository extends ResourceRepositoryV2<TaskEntity, UUID> {

    static class TaskListLinks implements LinksInformation, SelfLinksInformation {

        public String someLink = "test";

    }

    public static class TaskListMeta implements MetaInformation {

        public String someMeta = "test";

    }

    public class TaskList extends ResourceListBase<TaskEntity, TaskListMeta,
TaskListLinks> {

    }

    @Override
    public TaskList findAll(QuerySpec querySpec);
}
```

On the server-side, the interface can be registered with:

```
  JpaRepositoryConfig.builder(PersonEntity.class)
          .setInterfaceClass(PersonRepository.class).build()
```

10.1.6. Customizing the exposed resources over the underlying entity model

Not always it is desired to have a 1:1 mapping between resources and entities. There are various techniques to customize the resource model:

- Make use of the Crnk and Jackson annotations like `@JsonApiResource`, `JsonApiRelationId`, `JsonApiRelation` and `@JsonIgnore` to modify the entities on the resource layer.
- Setup a DB view matching the desired resource and declare it as entity. This typically is the most efficient way to implement complex entity/resource mappings.
- Perform any kind of modification in your repository by overriding `findAll`, `save`, `create`, `delete`. Note that the repository itself must not necessarily return entity classes, but rather can also return a DTO.

10.1.7. Standalone Usage

The given snipped shows how to translate a QuerySpec to a JPA Criteria query without involving

repositories and Crnk:

```
        JpaCriteriaQueryFactory queryFactory = JpaCriteriaQueryFactory.newInstance(em
);

        PathSpec idAttr = PathSpec.of(TestEntity.ATTR_id);
        QuerySpec querySpec = new QuerySpec(TestEntity.class);
        querySpec.addFilter(idAttr.filter(FilterOperator.GT, 0L));
        querySpec.addSort(idAttr.sort(Direction.DESC));
        querySpec.includeRelation(PathSpec.of("oneRelatedValue"));

        JpaCriteriaQuery<TestEntity> query = queryFactory.query(TestEntity.class);
        JpaQueryExecutor<TestEntity> executor = query.buildExecutor(querySpec);
        List<TestEntity> resultList = executor.getResultList();
```

10.2. JSR 303 Validation Module

A `ValidationModule` provided by `io.crnk:crnk-validation` implements resource validation and provides exception mappers for `javax.validation.ValidationException` and `javax.validation.ConstraintViolationException`. Among others, it properly translates 'javax.validation.ConstraintViolation' instances to JSON:API errors. A JSON:API error can, among others, contain a source pointer. This source pointer allows a clients/UI to display the validation errors next to the corresponding input fields.

A translated exception can look like:

]

```
{
    "errors": [
        {
            "status": "422",
            "code": "javax.validation.constraints.NotNull",
            "title": "may not be null",
            "source": {
                "pointer": "data/attributes/name"
            },
            "meta": {
                "resourceId": "1",
                "type": "ConstraintViolation",
                "messageTemplate": "{javax.validation.constraints.NotNull.message}",
                "resourceType": "projects"
            }
        }
    ]
}
```

Notice the `422` status code used for such errors.

As mentioned above, resource validation mechanism enabled by default will be applied in case of one of the following request types: `POST`, `PUT` and `PATCH`. Once described behavior is unwanted, module should be defined in the following way:

```
{
    @Bean
    ValidationModule validationModule()
        return ValidationModule.create(false);
    }
}
```

10.3. Meta Module

This is a module that exposes the internal workings of Crnk as JSON:API repositories. It lets you browse the set of available resources, their types, their attributes, etc. For example, Crnk UI make use of the meta module to implement auto-completing of input fields.

NOTE There is currently no JSON:API standard for meta data. There are more general formats like Swagger and ALPS. At some point those might be supported as well (probably rather the later than the former). One can view them to be complementary to the `MetaModule` as the later is exactly tailored towards JSON:API, such as the accessability as regular JSON:API (meta) repository and data structures matching the standard. Most likely, any future standard implementation will built up on the information from the `MetaModule`.

10.3.1. Setup

A setup can look as follows:

```
        MetaModule metaModule = MetaModule.create();
        metaModule.addMetaProvider(new ResourceMetaProvider());
```

`ResourceMetaProvider` exposes all JSON:API resources and repositories as meta data. You may add further provides to expose more meta data, such as the `JpaMetaProvider`.

10.3.2. Examples

To learn more about the set of available resources, have a look at the `MetaElement` class and all its subclasses. Some of the most important classes are:

Path	Implementation	Description

/meta/element	MetaElement	Base class implemented by any meta element.
/meta/type	MetaType	Base class implemented by any meta type element.
/meta/primitiveType	MetaPrimitiveType	Represents primitive types like Strings and Integers.
/meta/arrayType	MetaArrayType	Represents an array type.
/meta/listType	MetaListType	Represents an list type.
/meta/setType	MetaSetType	Represents an set type.
/meta/mapType	MetaMapType	Represents an map type.
/meta/dataObject	MetaDataObject	Base type for any object holding data, like JPA entities or JSON:API resources.
/meta/attribute	MetaAttribute	Represents an attribute of a MetaDataObject.
/meta/resource	MetaResource	JSON:API resource representation extending MetaDataObject.
/meta/resourceRepository	MetaResourceRepository	JSON:API repository representation holding resources.

A MetaResource looks like:

]

```
{
    "id" : "resources.project",
    "type" : "meta/resource",
    "attributes" : {
      "name" : "Project",
      "resourceType" : "projects"
    },
    "relationships" : {
      "parent" : {
        ...
      },
      "interfaces" : {
        ...
      },
      "declaredKeys" : {
        ...
      },
      "children" : {
        ...
      },
      "declaredAttributes" : {
        ...
      },
      "subTypes" : {
        ...
      },
      "attributes" : {
        ...
      },
      "superType" : {
        ...
      },
      "elementType" : {
        ...
      },
      "primaryKey" : {
        ...
      }
    }
  }
```

A `MetaAttribute` looks like:

]

```
{
    "id" : "resources.project.name",
    "type" : "meta/resourceField",
    "attributes" : {
      "filterable" : true,
      "nullable" : true,
      "lazy" : false,
      "association" : false,
      "primaryKeyAttribute" : false,
      "sortable" : true,
      "version" : false,
      "insertable" : true,
      "meta" : false,
      "name" : "name",
      "updatable" : true,
      "links" : false,
      "derived" : false,
      "lob" : false,
      "cascaded" : false
    },
    "relationships" : {
      "parent" : {
        ...
      },
      "children" : {
        ...
      },
      "oppositeAttribute" : {
        ...
      },
      "type" : {
        ...
      }
    }
  }
```

10.3.3. Identifiers for Meta Elements

Of importance is the assignment of IDs to meta elements. For resources the resource type is used to compute the meta id and a `resources` prefix is added. In the example above, person gets a `resources.person` meta id. Related objects (DTOs, links/meta info) located in the same or a subpackage of a resource gets the same meta id prefix. A `ProjectData` sitting in a `dto` subpackage would get a `resources.dto.projectdata` meta id.

The meta ids are used, for example, by the Typescript generator to determine the file structure and dependencies of generated source files.

Applications are enabled to adapt the id generator process with:

```
new ResourceMetaProvider(idPrefix)
```

and

`ResourceMetaProvider.putIdMapping(String packageName, String idPrefix)`

to override the default `resources` prefix and assign a specific prefix for a package.

10.3.4. Extending the Meta Module

There is a `MetaModuleExtension` extension that allows other Crnk modules contribute `MetaProvider` implementation. This allows to:

- add `MetaFilter` implementations to intercept and modify meta elements upon initialization and request.
- add `MetaPartition` implementations to introduce new, isolated areas in the meta model, like a JPA meta model next to the JSON:API one (like for documentation purposes).

For more detailed information have a look at the current `ResourceMetaProvider`.

10.4. Activiti Module

NOTE	This module is in new and in incubation. Feedback and improvements welcomed.

There is an `ActivitiModule` for the Activiti workflow engine that offers an alternative REST API. The motivation of `ActivitiModule` is to:

- have a JSON:API compliant REST API to benefit from the resource-oriented architecture, linking, sorting, filtering, paging, and client-side tooling of JSON:API.
- have a type-safe, non-generic REST API that is tailored towards the use cases at hand. This means that for each process and task definition, there is a dedicated repository and resource type for it. The resource is comprised of both the static fields provided by Activiti (like `name`, `startTime` and `priority`) and the dynamic fields stored by the application as process/task/form variables. Mapping to static resp. dynamic fields is done automatically by the `ActivitiModule` and hidden from consumers. The repository implementations ensure a proper isolation of different types. And the application is enabled, for example, to introduce custom security policies for each resource with the `SecurityModule` or a `ResourceFilter`.

This setup differs substantially from the API provided by Activiti that is implemented in generic fashion.

10.4.1. Setup

The `ActivitiModule` comes within a small example application within the `src/main/test` directory that showcases its use. It sets up an approval flow where changes to the `Schedule` resource must be approved by a user.

The `ActivitiModule` implements four resource base classes that match the equivalent Activiti classes:

- `ExecutionResource`

- `FormResource`
- `ProcessInstanceResource`
- `TaskResource`

To setup a JSON:API repository for a process or task, the corresponding resource class can be subclassed and extended with the application specific fields. For example:

ApprovalProcessInstance.java

```
public abstract class ApprovalProcessInstance extends ProcessInstanceResource {

    private String resourceId;

    private String resourceType;

    public String getResourceId() {
        return resourceId;
    }

    ...
}
```

and

ScheduleApprovalProcessInstance.java

```
@JsonApiResource(type = "approval/schedule")
public class ScheduleApprovalProcessInstance extends ApprovalProcessInstance {

    public enum ScheduleStatus {
        DONE,
        SHIPPED
    }

    private ScheduleApprovalValues newValues;

    private ScheduleApprovalValues previousValues;

    private String stringValue;

    private int intValue;

    private ScheduleStatus status;

    public ScheduleStatus getStatus() {
        return status;
    }

    public void setStatus(ScheduleStatus status) {
        this.status = status;
    }


    public int getIntValue() {
        return intValue;
    }

    public void setIntValue(int intValue) {
        this.intValue = intValue;
    }

    public String getStringValue() {
        return stringValue;
    }

    public void setStringValue(String stringValue) {
        this.stringValue = stringValue;
    }

    ...
}
```

The example application makes use of an intermediate `ApprovalProcessInstance` base class to potentially share the approval logic among multiple entities in the future (if it would be real-world

use case). `ScheduleApprovalProcessInstance` has the static fields of Activiti and a number of custom, dynamic fields like `resourceType`, `resourceId` and `newValues`. The dynamic fields will be mapped to to process, task resp. form variables.

Notice the relation to `ApproveTask`, which is a task counter part extending from `TaskResource`. If a process has multiple tasks, you may introduce multiple such relationships.

Finally, the setup of the `ActiviModule` looks like:

ApprovalTestApplication.java

```
    public static ActivitiModule createActivitiModule(ProcessEngine processEngine) {
        ActivitiModuleConfig config = new ActivitiModuleConfig();

        ProcessInstanceConfig terminatationProcessConfig = config.addProcessInstance
(ImmediateTerminatationProcessInstance.class);
        terminatationProcessConfig.filterByProcessDefinitionKey(
"immediateTerminationFlow");

        ProcessInstanceConfig processConfig = config.addProcessInstance
(ScheduleApprovalProcessInstance.class);
        processConfig.historic(HistoricScheduleApprovalProcessInstance.class);
        processConfig.filterByProcessDefinitionKey("scheduleChange");
        processConfig.addTaskRelationship(
                "approveTask", ApproveTask.class, "approveScheduleTask"
        );
        TaskRepositoryConfig taskConfig = config.addTask(ApproveTask.class);
        taskConfig.historic(HistoricApproveTask.class);
        taskConfig.filterByTaskDefinitionKey("approveScheduleTask");
        taskConfig.setForm(ApproveForm.class);
        return ActivitiModule.create(processEngine, config);
    }
```

- `ActivitiModuleConfig` allows to register processes and tasks that then will be exposed as repositories.
- `ScheduleApprovalProcessInstance`, `ApproveTask` and the `approveTask` relationship are registered.
- `ApproveTask` is user task that is handled by submitting an `ApproveForm`.
- `filterByProcessDefinitionKey` and `filterByTaskDefinitionKey` ensure that the two repositories are isolated from other repositories for `GET`, `POST`, `PATCH` and `DELETE` operations.

One could imagine to make this configuration also available through an annotation-based API in the future as it is closely related to the resource classes and fields.

10.4.2. Example application

The example application goes a few steps further in the setup. The patterns of those steps might be of interest of consumers of the `ActivitiModule` as well.

The workflow looks as follows:

] .approval.bpmn20.xml

```
<?xml version="1.0" encoding="UTF-8"?>

<definitions id="approvalDefinitions"
             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
             targetNamespace="http://activiti.org/bpmn20"
             xmlns:activiti="http://activiti.org/bpmn"
             xmlns="http://www.omg.org/spec/BPMN/20100524/MODEL">


    <process id="scheduleChange" name="Approve schedule change" isExecutable="true">
        <documentation>
            This process is initiated when a user modifies a scheduleEntity trough the
JSON API endpoint.
        </documentation>

        <startEvent id="startScheduleChange" name="Start"
activiti:initiator="initiator"></startEvent>

        <userTask id="approveScheduleTask" name="Approve new Schedule">
            <extensionElements>
                <activiti:formProperty id="approved" name="Do you approve this change"
type="boolean" required="true" />
            </extensionElements>
        </userTask>

        <sequenceFlow id="startFlow" sourceRef="startScheduleChange"
targetRef="approveScheduleTask"></sequenceFlow>

        <sequenceFlow id="decideFlow" sourceRef="approveScheduleTask"
targetRef="approvalExclusiveGateway"></sequenceFlow>

        <serviceTask id="scheduleChangeApproved" name="Create schedule Account, send
Alerts"

activiti:expression="${approvalManager.approved(execution)}"></serviceTask>
        <serviceTask id="scheduleChangeDenied" name="send alert"

activiti:expression="${approvalManager.denied(execution)}"></serviceTask>

        <endEvent id="endEvent" name="End"></endEvent>

        <exclusiveGateway id="approvalExclusiveGateway" name="Exclusive
Gateway"></exclusiveGateway>

        <sequenceFlow id="approveFlow" sourceRef="approvalExclusiveGateway"
targetRef="scheduleChangeApproved">
            <conditionExpression xsi:type="tFormalExpression">
                <![CDATA[
```

```
                ${approved == true}
            ]]>
            </conditionExpression>
        </sequenceFlow>

        <sequenceFlow id="denyFlow" sourceRef="approvalExclusiveGateway"
targetRef="scheduleChangeDenied">
            <conditionExpression xsi:type="tFormalExpression">
                <![CDATA[
                ${approved == false}
            ]]>
            </conditionExpression>
        </sequenceFlow>
        <sequenceFlow id="flow5" sourceRef="scheduleChangeDenied"
targetRef="endEvent"></sequenceFlow>
        <sequenceFlow id="flow6" sourceRef="scheduleChangeApproved"
targetRef="endEvent"></sequenceFlow>
    </process>


    <process id="immediateTerminationFlow" name="Directly terminates"
isExecutable="true">
        <documentation>
            This process directly terminates
        </documentation>

        <startEvent id="quickStartEvent" name="Start"
activiti:initiator="initiator"></startEvent>

        <sequenceFlow id="quickStartFlow" sourceRef="quickStartEvent"
targetRef="quickEndEvent"></sequenceFlow>

        <endEvent id="quickEndEvent" name="End"></endEvent>

    </process>
</definitions>
```

There is a:

- `approveScheduleTask` task requires a form submission by a user.
- `approvalExclusiveGateway` checks whether the change was accepted.
- `scheduleChangeApproved` invokes `${approvalManager.approved(execution)}` whereas `approvalManager` is a Java object taking care of the approval handling and registered to `activiti.cfg.xml`.
- `approvalManager.approved(…)` reconstructs the original request and forwards it to Crnk again to save the approved changes. This means the regular `ScheduleRepository` implementation will be called in the same fashion as for a typical request. Real world use cases may also need to save and reconstruct the security context.

For the approval-related functionality a second module is registered:

ApprovalTestApplication.java

```
    public static SimpleModule createApprovalModule(ApprovalManager approvalManager) {
        FilterSpec approvalFilter = new FilterSpec(
                Arrays.asList("definitionKey"), FilterOperator.EQ, "scheduleChange"
        );
        List<FilterSpec> approvalFilters = Arrays.asList(approvalFilter);

        SimpleModule module = new SimpleModule("approval");
        module.addRepositoryDecoratorFactory(
                ApprovalRepositoryDecorator.createFactory(approvalManager)
        );
        module.addRepository(new ApprovalRelationshipRepository(Schedule.class,
                ScheduleApprovalProcessInstance.class, "approval",
                "approval/schedule", approvalFilters)
        );
        return module;
    }
```

- `ApprovalRepositoryDecorator` hooks into the request processing of the Crnk engine and intercepts all `PATCH` and `POST` requests for the `Schedule` resource. The decorator then may chooses to abort the request and start an approval flow instead with the help of `ApprovalManager`.
- `ApprovalRelationshipRepository` introduces an additional relationship between the actual resources and approval resources. It can be used, for example, by user interfaces to show the current status of an open approval workflow. `ApprovalRelationshipRepository.getResourceFields` declares the relationship field, meaning that the original application resource does not have to declare the relationship. This may or may not be useful depending on how much control there is over the original resource (for example there is no control over JPA entities).
- `historic(…)` method specify the historic resource counterparts to query the history.

The chosen setup leads to an approval system that is **fully transparent** to the actual repository implementations and can be added to any kind of repository.

`ApprovalIntTest` showcases the example workflow by doing a change, starting the approval process, submitting a form and then verifying the changes have been saved.

10.4.3. Limitations

- Currently the main entities of Activiti have been exposed. Configuration-related repositories could be exposed as well in the future.
- Historic repositories are still considered being experimental.
- Activiti has a limited query API that is inherited by the application. Potentially `crnk-data-jpa` could help out a bit in this area.
- Multi-tenancy is not yet done out-of-the-box.

- Activiti has been forked to Flowable. As of yet it is unclear whether one or both project will survive in the long-term.

10.5. Faceted Search

WARNING	This feature is new and considered experimental. Also have a look at the roadmap.

Faceted search is used by many UIs to allow users to quickly navigate data sets. For example, virtually every online shop makes use of the feature to show product categories and the number of products in that category. Those categories, denoted as facets, have a label, a set of values and a count for each value. Facets may also depend on each other, whereas later facets are filtered by preceding ones. With `FacetModule` Crnk provides an out-of-the-box solution to implement faceted search.

10.5.1. Setup

To setup faceted search, the `FacetModule` must be added to application. For Spring Boot there is a `CrnkFacetAutoConfiguration` in place. To then enable faceted search for an attribute, it can be annotated with `@Facet`:

FacetedProject.java

```
@JsonApiResource(type = "projects")
public class FacetedProject {

    @JsonApiId
    private Long id;

    @Facet
    private String name;

    @Facet
    private int priority;

}
```

Behind the scenes there are currently two implementations available that are automatically chosen based on the repository at hand:

- `InMemoryFacetProvider` that queries all resources and computes the facets in-memory. Only **suitable for small data sets**!
- `JpaFacetProvider` that makes use of SQL `GROUP BY` queries to efficiently compute facets. Used for any JPA-backed repository.

For very large data sets, the use of ElasticSearch is recommended (not yet implemented).

Applications are also free to implement their own `FacetProvider` implementation and register it through `FacetModuleExtension`.

10.5.2. Examples

All the facets are then available as regular, new JSON:API resource that can filtered, paged, sorted, etc. like any other resource:

] .http://127.0.0.1:8080/api/facet

```
{

  "data" : [ {
    "id" : "projects_name",
    "type" : "facet",
    "attributes" : {
      "values" : {
        "Some Project" : {
          "label" : "Some Project",
          "value" : "Some Project",
          "filterSpec" : {
            "path" : "name",
            "operator" : "EQ",
            "value" : "Some Project",
          },
          "count" : 1
        },
        ...
      },
      "name" : "name",
      "type" : "projects",
      "labels" : [ "Great Project", "Crnk Project", "Some Project", "JSON:API Project"
]
    },
  }]
}
```

Note that the values are ordered by their count in the `labels` attribute.

10.5.3. Nesting

To select values of facets and update the counts of subsequent facets use:

```
http://127.0.0.1:8080/api/facet?filter[values.priority][SELECT]=1,2
```

A facet value is selected through its label and the `SELECT` operator. In the given example, the priority gets restricted to `1` and `2`. This in turn restricts the counts of facets that follow the `priority` facet. To choose and order facets use:

```
http://127.0.0.1:8080/api/facet?filter[name]=priority,name
```

Facets are then ordered as specified by `filter[name]`.

For more examples, see `InMemoryFacetProviderTest`.

10.5.4. Grouping

To compute facets separately for each label of a particular facet, use the `GROUP` operator:

```
http://127.0.0.1:8080/api/facet?filter[values][GROUP]=priority,name
```

It works equivalent to SQL `GROUP BY` queries. In the example a count is computed for every pair of `priority` and `name` and returned as facet resource.

WARNING	the GROUP operator needs for further performance tuning.

10.5.5. Roadmap

- Limit number of facet values and introduce a "other" category.
- Configurable null handling.
- Data/time support.
- Range-based facets.
- Native Elastic Search implementation

Feedback and PRs welcomed!

11. Generation

Crnk allows the generation of:

- Typescript stubs for type-safe, client-side web development.
- Type-safe `QuerySpec` and `PathSpec` types.

Contributions for other languages like iOS would be very welcomed.

11.1. Java Annotation Processor

WARNING	This annotation processor is still experimental. Feedback welcomed.

`crnk-gen-java` provides an annotation processor to generate a type-safe API for the construction of `QuerySpec` and `PathSpec` objects. The annotation processor is setup like any other annotation

processor. In Gradle it looks like:

```
dependencies{
  annotationProcessor 'io.crnk:crnk-gen-java'
  ...
}
```

One may also has enable annotation processors in the IDE (most notable in IntelliJ IDEA). One can then make use of it like:

```
package test;

import io.crnk.core.queryspec.FilterOperator;
import io.crnk.core.queryspec.FilterSpec;
import io.crnk.core.queryspec.QuerySpec;
import io.crnk.core.queryspec.SortSpec;

import static test.UserPathSpec.*;

public class TypedQuerySpecTest {

    public QuerySpec createQuerySpec() {
        UserQuerySpec querySpec = new UserQuerySpec();
        querySpec.sort().loginId().desc();
        querySpec.filter().projects().id().filter(FilterOperator.EQ, 12);
        querySpec.field().loginId();
        querySpec.include().projects();
        return querySpec;
    }

    public FilterSpec createFilterSpec() {
        return userPathSpec.projects().id().filter(FilterOperator.EQ, 12);
    }

    public SortSpec createSortSpec() {
        return userPathSpec.projects().id().desc();
    }
}
```

More improvements to the generates types are thinkable in the future, such as limiting the set of fields depending on the use case (inclusions, field sets, sorting, filtering) depending on the capability of that particular field. Contributions welcomed.

11.2. Typescript

The Typescript generator allows the generation of:

- interfaces for resources and related objects (like nested objects and enumeration types).

- interfaces for result documents (i.e. resources and any linking and meta information).
- interfaces for links information.
- interfaces for meta information.
- methods to create empty object instances.

It can generate either plain Typescript interfaces or target ngrx-json-api. Support for other libraries/formats would be straightforward to add, contributions welcomed. A generated resource looks like in plain-text format:

```
import {
    ManyResourceRelationship,
    ManyResult,
    OneResourceRelationship,
    OneResult,
    Resource
} from './crnk';
import {DefaultPagedMetaInformation} from './default.paged.meta.information';
import {DefaultPagedLinksInformation} from
'./information/default.paged.links.information';
import {Projects} from './projects';
import {ScheduleStatus} from './schedule.status';
import {Tasks} from './tasks';

export interface Schedule extends Resource {
    name?: string;
    description?: string;
    taskSet?: ManyResourceRelationship<Tasks>;
    project?: OneResourceRelationship<Projects>;
    projects?: ManyResourceRelationship<Projects>;
    status?: OneResourceRelationship<ScheduleStatus>;
    delayed?: boolean;
    customData?: { [key: string]: string };
}
export interface ScheduleResult extends OneResult {
    data?: Schedule;
}
export module ScheduleListResult {
    export interface ScheduleListLinks extends DefaultPagedLinksInformation {
    }
    export interface ScheduleListMeta extends DefaultPagedMetaInformation {
    }
}
export interface ScheduleListResult extends ManyResult {
    data?: Array<Schedule>;
    links?: ScheduleListResult.ScheduleListLinks;
    meta?: ScheduleListResult.ScheduleListMeta;
}
export let createEmptySchedule = function(id: string): Schedule {
    return {
        id: id,
        type: 'schedule',
    };
};
```

and for ngrx-json-api:

```
import {DefaultPagedMetaInformation} from './default.paged.meta.information';
import {DefaultPagedLinksInformation} from
```

```
'./information/default.paged.links.information';
import {Projects} from './projects';
import {ScheduleStatus} from './schedule.status';
import {Tasks} from './tasks';
import {CrnkStoreResource} from '@crnk/angular-ngrx';
import {
    ManyQueryResult,
    OneQueryResult,
    ResourceRelationship,
    TypedManyResourceRelationship,
    TypedOneResourceRelationship
} from 'ngrx-json-api';

export module Schedule {
    export interface Relationships {
        [key: string]: ResourceRelationship;
        taskSet?: TypedManyResourceRelationship<Tasks>;
        project?: TypedOneResourceRelationship<Projects>;
        projects?: TypedManyResourceRelationship<Projects>;
        status?: TypedOneResourceRelationship<ScheduleStatus>;
    }
    export interface Attributes {
        name?: string;
        description?: string;
        delayed?: boolean;
        customData?: { [key: string]: string };
    }
}
export interface Schedule extends CrnkStoreResource {
    relationships?: Schedule.Relationships;
    attributes?: Schedule.Attributes;
}
export interface ScheduleResult extends OneQueryResult {
    data?: Schedule;
}
export module ScheduleListResult {
    export interface ScheduleListLinks extends DefaultPagedLinksInformation {
    }
    export interface ScheduleListMeta extends DefaultPagedMetaInformation {
    }
}
export interface ScheduleListResult extends ManyQueryResult {
    data?: Array<Schedule>;
    links?: ScheduleListResult.ScheduleListLinks;
    meta?: ScheduleListResult.ScheduleListMeta;
}
export let createEmptySchedule = function(id: string): Schedule {
    return {
        id: id,
        type: 'schedule',
        attributes: {
```

```
        },
        relationships: {
            taskSet: {data: []},
            project: {data: null},
            projects: {data: []},
            status: {data: null},
        },
    };
};
```

For an example have a look at the Crnk example application, see crnk-project/crnk-example.

There is a Gradle plugin to run Typescript (and other) generation. The setup looks like:

```
buildscript {
    dependencies {
        classpath "io.crnk:crnk-gen-gradle:${version}"
    }
}

apply plugin: 'crnk-gen'
crnkGen {
    runtime {
        configuration = 'typescriptGenRuntime'
    }

    // fork generation into new process to have clean environment
    forked = true

    // specify the package to look for resources
    resourcePackages = ['io.crnk.test']

    typescript {
        // enable Typescript generation within Gradle plugin
        enabled = true

        // specify output format
        format = 'PLAINJSON' // or 'JSONAPI'

        // specify location of generated sources
        genDir = file('src/resources')
    }
}
crnkGen.init()
```

Applying `crnk-gen` results in a new `generateTypescript` task to perform the generation.

11.3. Gradle customizations

Internally the Crnk Gradle plugin supports multiple ways of looking up the set of available resources and repositories to generate. The simplest way is by scanning the classpath for @JsonApiResource-annotated classes. More elaborate setups can also launch an application (e.g. with Spring or CDI) and extract the information from the running application. While the former is simpler to setup, the later can deal with all border cases like a repository being backed by something different than a @JsonApiResource-annotated class. For Spring this looks like:

```
crnkGen{

    // launch a Spring application to extract information about available resources
    runtime {
        configuration = 'typescriptGenRuntime'
        spring {
            profile = 'test'
            configuration = 'io.crnk.example.ExampleApplication'
            initializerMethod = 'someInitMethod' // optional
            defaultProperties['someKey'] = 'someValue'
        }
    }

    ...
}
crnkGen.init()
```

Typically a test profile is used to bring the Spring application up in order to then extract the repositories for generation.

11.4. Documentation with AsciiDoc

WARNING	This is still experimental. Feedback welcomed.

Documentation of REST APIs has a long history of various tooling. Swagger/OpenAPI there is the classical choice, but comes with a variety of disadvantages:

- Mechanisms used to extract information from an implementation often fail understand the full scope of it.
- Annotations for descriptions lead to a large amount of boiler-plate.
- Swagger UI is delivered as webapp and hard to enrich with custom information.

This triggered, for example, the development of swagger2markup to make is of AsciiDoc as output target. This in turn lets developers manually written and generated documentation and publish it as HTML and PDF in a potentially versioned manner.

Further progress iad made by spring-restdocs. Instead of attempting to write a specification, request and responses are captured from unit tests and enriched with documentation to then save

as AsciiDoc. This ensures 100% accurate documentation at all time since.

JSON:API enables developers to take a further leap. Since it provides a well-defined standard for many aspects of a REST endpoint, such as parameter handling, status codes and linking, it greatly simplifies the documentation task. Many things are covered by the standard and the documentation can focus on the essential aspects of the application. This in turn is realized by the AsciiDoc module of the Crnk generator.

The setup looks like:

```
crnkGen{
    runtime {
        configuration = 'typescriptGenRuntime'
    }

    // specify the package to look for resources
    resourcePackages = ['io.crnk.test']

    asciidoc {
        // enable Typescript generation within Gradle plugin
        enabled = true

        // title of generated document
        title = "Api Documentation"

        // specify location of generated sources
        genDir = file('build/generated/source/asciidoc')
    }
}
crnkGen.init()
```

This results in a `generateAsciidoc` task to perform the generation. The output directory then contains a collection of files that can either be included individually or together with the main `index.adoc`.

Descriptions for resources and fields are extracted from JavaDoc.

The generated documentation can be enriched with request/response examples from unit tests. An example looks like:

```
package io.crnk.gen.asciidoc;

import io.crnk.client.CrnkClient;
import io.crnk.client.http.inmemory.InMemoryHttpAdapter;
import io.crnk.core.boot.CrnkBoot;
import io.crnk.core.queryspec.FilterOperator;
import io.crnk.core.queryspec.PathSpec;
import io.crnk.core.queryspec.QuerySpec;
import io.crnk.core.repository.ResourceRepository;
```

```
import io.crnk.core.resource.list.ResourceList;
import io.crnk.format.plainjson.PlainJsonFormatModule;
import io.crnk.gen.asciidoc.capture.AsciidocCaptureConfig;
import io.crnk.gen.asciidoc.capture.AsciidocCaptureModule;
import io.crnk.test.mock.TestModule;
import io.crnk.test.mock.models.Task;
import io.crnk.test.mock.models.TaskStatus;
import org.junit.Assert;
import org.junit.Before;
import org.junit.Test;

import java.io.File;

public class AsciiDocCaptureTest {

    private ResourceRepository<Task, Long> repository;

    private AsciidocCaptureModule asciidoc;

    @Before
    public void setup() {
        CrnkBoot boot = setupServer();

        asciidoc = setupAsciidoc();
        CrnkClient client = setupClient(boot, asciidoc);
        repository = client.getRepositoryForType(Task.class);
    }

    private CrnkClient setupClient(CrnkBoot boot, AsciidocCaptureModule module) {
        String baseUrl = "http://127.0.0.1:8080/api";
        InMemoryHttpAdapter httpAdapter = new InMemoryHttpAdapter(boot, baseUrl);

        CrnkClient client = new CrnkClient(baseUrl);
        client.addModule(module);
        client.addModule(new PlainJsonFormatModule());
        client.setHttpAdapter(httpAdapter);
        return client;
    }

    private AsciidocCaptureModule setupAsciidoc() {
        File outputDir = new File("build/tmp/asciidoc/generated/source/asciidoc");
        AsciidocCaptureConfig asciidocConfig = new AsciidocCaptureConfig();
        asciidocConfig.setGenDir(outputDir);
        return new AsciidocCaptureModule(asciidocConfig);
    }

    private CrnkBoot setupServer() {
        CrnkBoot boot = new CrnkBoot();
        boot.addModule(new TestModule());
        boot.addModule(new PlainJsonFormatModule());
        boot.boot();
```

```
        return boot;
    }

    @Test
    public void checkAccess() {
        Task newTask = new Task();
        newTask.setName("Favorite Task");
        newTask.setStatus(TaskStatus.OPEN);

        Task createdTask = asciidoc.capture("Create new Task").call(() ->
repository.create(newTask));

        QuerySpec querySpec = new QuerySpec(Task.class);
        querySpec.addFilter(PathSpec.of("name").filter(FilterOperator.EQ, "Favorite
Task"));
        querySpec.setOffset(0);
        querySpec.setLimit(5L);
        ResourceList<Task> list = asciidoc.capture("Find Task by Name").call(() ->
repository.findAll(querySpec));
        Assert.assertNotEquals(0, list.size());

        createdTask.setName("Updated Task");
        asciidoc.capture("Update a Task").call(() -> repository.save(createdTask));

        asciidoc.capture("Delete a Task").call(() ->
repository.delete(createdTask.getId()));
    }
}
```

The example sets up a Crnk client and server. They are directly connected through `InMemoryHttpAdapter` to by-pass the HTTP layer and forgo the setup of a web server. The `AsciidocCaptureModule` is add to the client to do the capturing. To then capture a request:

```
asciidoc.capture("Create new Task").call(() -> repository.create(newTask));
```

If the output is matched with Crnk generator plugin, then the captured test cases will be picked up automatically. A full setup is available in the main crnk-example application.

12. Bulk Updates with Operations Module

By its nature RESTful applications are limited to the insertion, update and deletion of single resources. As such, developers have to design resources accordingly while having to consider aspects like transaction handling and atomicity. It is not uncommon to combine multiple data objects on the server-side and expose it as single resource to clients. It is a simple approach, but can also mean quite a substantial overhead when having to implement potentially redudant repositories. Furthermore, things like validation handling, relationships and supporting complex object graphs can get tricky when a single resource starts holding complex object graphs again.

For all the before mentioned reason support for jsonpatch.com is provided. It allows to send multiple insertions, updates and deletions with a single request and provides the results for each such executed operation. Note that numerous attempts and discussions have taken place and are still ongoing to establish a common JSON:API standard, but that does not seem to make much progress. With jsonpatch.com there is already an estabilished standard that fits well for many use cases.

The implementation is provided as `OperationsModule` and the setup looks like:

```
        OperationsModule operationsModule = OperationsModule.create();
        ...
```

Further filters can be applied to intercept incoming requests. Typically applications will make use of that to start a new transaction spanning all requests. This looks as follows:

AbstractOperationsTest.java

```
            operationsModule.addFilter(new TransactionOperationFilter());
```

There is further an operations client implementation that works along the regular JSON:API client implementation:

OperationsPostTest.java

```
        OperationsClient operationsClient = new OperationsClient(client);
        OperationsCall call = operationsClient.createCall();
        call.add(HttpMethod.POST, movie);
        call.add(HttpMethod.POST, person1);
        call.add(HttpMethod.POST, person2);
        call.execute();
```

An example request in JSON looks like:

```
[ {
  "op" : "POST",
  "path" : "movie",
  "value" : {
    "id" : "43e7903e-9b14-4610-96f5-69d6f2fa347d",
    "type" : "movie",
    "attributes" : {
      "title" : "test",
      ...
    },
    "relationships" : {
      ...
    }
  }
}, {
  "op" : "POST",
  "path" : "person",
  "value" : {
    "id" : "b25bfdbd-8dd6-4abd-a859-f1dedf85246b",
    "type" : "person",
    "attributes" : {
      "name" : "1",
      "version" : null
    }
  }
}, {
  "op" : "POST",
  "path" : "person",
  "value" : {
    "id" : "f9d2bda5-d2f4-4c0c-85c7-cc56b6ea91e6",
    "type" : "person",
    "attributes" : {
      "name" : "2",
      "version" : null
    }
  }
} ]
```

and an example response JSON looks as follows:

```
[ {
  "data" : {
    "id" : "43e7903e-9b14-4610-96f5-69d6f2fa347d",
    "type" : "movie",
    "attributes" : {
      "title" : "test",
      ...
    },
    "relationships" : {
      ..
    },
    "links" : {
      "self" : "http://localhost:58367/movie/43e7903e-9b14-4610-96f5-69d6f2fa347d"
    }
  },
  "status" : 201
}, {
  "data" : {
    "id" : "b25bfdbd-8dd6-4abd-a859-f1dedf85246b",
    "type" : "person",
    "attributes" : {
      "name" : "1",
      "version" : 0
    },
    "relationships" : {
      ...
    },
    "links" : {
      "self" : "http://localhost:58367/person/b25bfdbd-8dd6-4abd-a859-f1dedf85246b"
    }
  },
  "status" : 201
}, {
  "data" : {
    "id" : "f9d2bda5-d2f4-4c0c-85c7-cc56b6ea91e6",
    "type" : "person",
    "attributes" : {
      "name" : "2",
      "version" : 0
    },
    "relationships" : {
      ...
    },
    "links" : {
      "self" : "http://localhost:58367/person/f9d2bda5-d2f4-4c0c-85c7-cc56b6ea91e6"
    }
  },
  "status" : 201
} ]
```

Notice in the response a status code for each request. It is import for the `Content-Type` and `Accept` HTTP headers to have `application/json-patch+json`, otherwise the `OperationsModule` will ignore such requests.

The current limitations of the implementation are:

- So far does not support bulk `GET` operations.
- Does so far not support bulk update of relationships.

With support for `POST`, `PATCH` and `DELETE` operations the most important building blocks should be in place. The limitations are expected to be addressed at some point as well, contributions welcomed.

13. Monitoring

13.1. OpenTracing

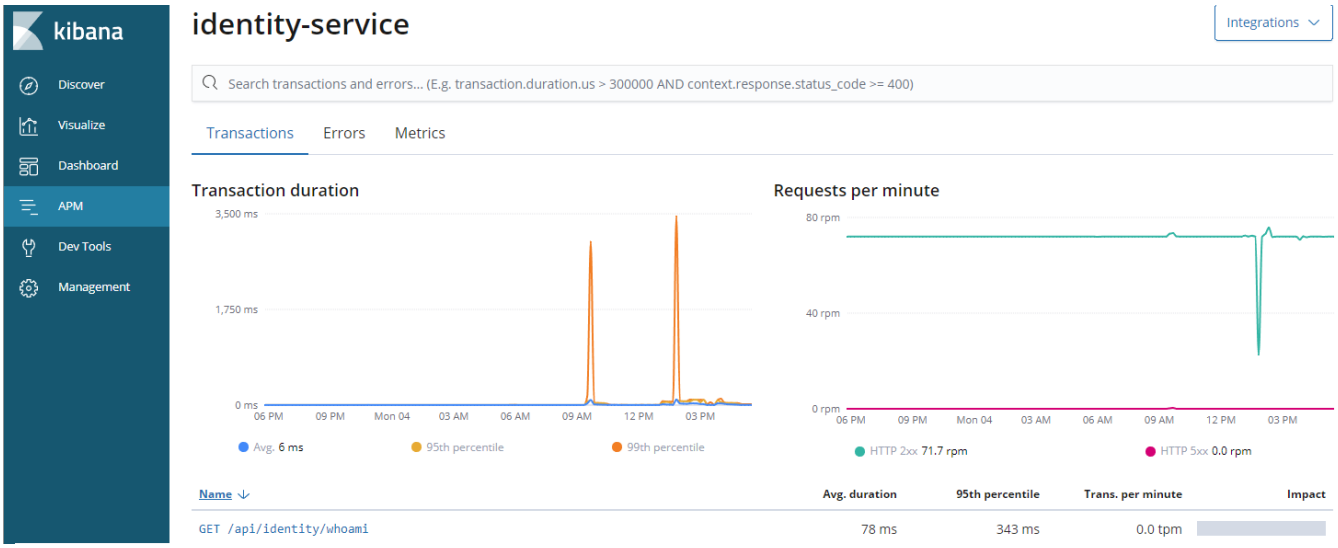
OpenTracing is a open, vendor-neutral API for tracing similar to SLF4J for logging. The project is a member of the Cloud Native Foundation. Jeager and Elastic APM are two implementation providing support for it. `crnk-monitor-opentracing` features an `OpenTracingServerModule`. The module sets a human-readable name to any span tracing a JSON:API call, for example:

- `GET /api/users`
- `PATCH /api/users/{id}`

Notice the `{id}` that will prevent dynamic parts of the URL from polluting the tracing data stores.

INFORMATION: The module does not start spans on its own. It is the duty of the underlying HTTP layer to do so. This way the HTTP layer can cover all kinds of calls, not just JSON_API ones.

In Kibana together with Elastic APM it looks like:



WARNING	Distributed tracing is still an evolving topic. Most notably W3C Trace Context will provide a standard for header propagation that hopefully will allow various systems to better work together on a protocol-level.

13.2. Tracing with Zipkin/Brave

WARNING	This module is deprecated. The use of OpenTracing is recommended instead.

A `BraveClientModule` and `BraveServletModule` provided by `io.crnk:crnk-monitor-brave4` provides integration into Zipkin/Brave to implement tracing for your repositories. The module is applicable to both a Crnk client or server.

The Crnk client can make use of either HttpClient or OkHttp to issue HTTP requests. Accordingly, a matching brave integration must be added to the classpath:

- `io.zipkin.brave:brave-instrumentation-okhttp3`
- `io.zipkin.brave:brave-instrumentation-httpclient`

The `BraveClientModule` then takes care of the integration and will create a client span for each request.

On the server-side, `BraveServletModule` creates a local span for each accessed repository. Every request triggers one or more repository accesses (depending on whether relations are included). Note however that `BraveServletModule` does not setup tracing for incoming requests. That is the purpose of the JAX-RS/servlet integration of Brave.

Have a look at the Spring boot example application to see the `BraveServletModule` in use together with a log reporter writing the output to console.

NOTE	`io.crnk:crnk-brave` is deprecated and makes use of the Brave 3.x API.

14. FAQ

How to do Cors with Crnk?

In most (if not all) cases Cors should be setup in the underlying integration, like with the Servlet-API or as JAX-RS filter and not within Crnk itself. This allows to make use of the native Cors mechanisms of an integration and to share Cors handling with the other parts of the application.

Is Swagger supported by Crnk?

Have a look at http://www.crnk.io/related/.

15. Advanced Customizations through Modules

Crnk has a module API that allows to extend the core functionality by third-party contributions. The mentioned JPA module in the next section is an example for that. The API is similar in spirit to the one of the https://github.com/FasterXML/jackson. The main interface is `Module` with a default implementation provided by `SimpleModule`. A module has access to a `ModuleContext` that allows to register all kinds of extensions like new `ResourceInformationBuilder`, `ResourceLookup`, `Filter`, `ExceptionMapper` and Jackson modules. It also gives access to the `ResourceRegistry` holding information about all the repositories registered to crnk. The `JpaModule` in `crnk-data-jpa` provides a good, more advanced example of using the module API.

15.1. Request Filtering

Crnk provides three different, complementing mechanisms to hook into the request processing.

The `DocumentFilter` interface allows to intercept incoming requests and do any kind of validation, changes, monitoring, transaction handling, etc. `DocumentFilter` can be hooked into Crnk by setting up a module and registering the filter to the `ModuleContext`. Not that for every request, this interface is called exactly once.

A request may span multiple repository accesses. To intercept the actual repository requests, implement the `RepositoryFilter` interface. `RepositoryFilter` has a number of methods that allow two intercept the repository request at different stages. Like `Filter` it can be hooked into Crnk by setting up a module and registering the filter to the `ModuleContext`.

Similar to `RepositoryFilter` it is possible to decorate a repository with another repository implementing the same Crnk repository interfaces. The decorated repository instead of the actual repository will get called and it is up to the decorated repository of how to proceed with the request, usually by calling the actual repository. `RepositoryDecoratorFactory` can be registered with `ModuleContext.addRepositoryDecoratorFactory`. The factory gets notified about every repository registration and is then free do decorate it or not.

15.2. Filter Modifications

Changes to attributes and relationships can be tracked by implementing `ResourceModificationFilter`. The filter is invoked upon an incoming request while setting up the resource objects; before the actual repository is called. Such filters are useful, for example, to implement auditing functionality.

15.3. Filter Priority

`DocumentFilter`, `RepositoryFilter` and `ResourceModificationFilter` can implement `Prioritizable` to introduce a priority among multiple filters.

15.4. Access to HTTP layer

`HttpRequestContext` resp. `HttpRequestContextProvider` provides access to the HTTP requests. Most notably to get and set HTTP request and response headers. In many cases, the underlying implementation like JAXRS or Servlet provides that access as well. With `HttpRequestContext` there is an implementation that is independent of that implementation. As such it is well suited for module development, in particular for request filtering. A typical use case is to set and access security headers.

`HttpRequestContextProvider.getRequestContext` returns the request context for the currently active request. Modules have access to `HttpRequestContextProvider` trough the `ModuleContext`. Repositories, filters and modules can implement `HttpRequestContextAware` to get access to `HttpRequestContextProvider`.

15.5. Module Extensions and dependencies

ModuleExtension is an interface can can be implemented by modules to specify a contract how others can extend it. The interface has two mandator properties: targetModule and optional. targetModule specifies the module consuming those extensions (and providing the implementation for it). optional specifies whether the target module must be registered or not. In case of an optional extension without the module being registered, the extension is simply ignored. The implementing module is free to add any further, custom methods to provide extension hooks to other modules. To get access to this extensions, the module can implement ModuleExtensionAware. Extensions must be registered during Module.setupModule(...) and will be available to the target module when Module.init() is called.

For an example have a look at MetaModuleExtension and the JpaModule making use of it. The ModuleExtension was introduced with Crnk 2.0 and its use is expected to grow heavily over time.

15.6. Integrate third-party data stores

The core of Crnk is quite flexible when it comes to implementing repositories. As such, it is not mandatory to make use of the Crnk annotations and conventions. Instead, it is also (likely) possible to integrate an existing data store setup like JPA, JDBC, ElasticSearch, etc. into Crnk. For this purpose a module can provide custom implementations of `ResourceInformationBuilder` and `RepositoryInformationBuilder` trough `ModuleContext.addResourceInformationBuilder` and `ModuleContext.addRepositoryInformationBuilder`. For example, the JpaModule of `crnk-data-jpa`

makes use of that to read JPA instead of Crnk annotations. Such a module can then register additional (usually dynamic) repositories with `ModuleContext.addRepository`.

15.7. Implement a custom discovery mechanism

Crnk comes with out-of-the-box support for Spring and CDI. Both of them implement `ServiceDiscovery`. You may provide your own implementation which can be hooked into the various Crnk integrations, like the CrnkFeature. Alternatively, it can be auto-detected through the Java service mechanism. For example, `crnk-cdi` makes use of:

META-INF/services/io.crnk.core.module.discovery.ServiceDiscovery

```
io.crnk.cdi.internal.CdiServiceDiscovery
```

Modules have access to that `ServiceDiscovery` trough the `ModuleContext.getServiceDiscovery()`.

15.8. Let a module hook into the Crnk HTTP client implementation

Modules for the Crnk client can additionally implement `HttpAdapterAware`. It gives the module access to the underlying HTTP client implementation and allows arbitrary customizations of it. Have a look at the Crnk client documentation for more information.

15.9. Implement a custom integration

Adding a new integration has become quite simple in recent times. Have a look at `crnk-servlet` and `crnk-rs`. Most functionality necessary is already be provided by `crnk-core`. The steps include:

- implement `HttpRequestContextBase`.
- instantiate `CrnkBoot` to setup crnk.
- get the `RequestDispatcher` from `CrnkBoot`.
- invoke the `RequestDispatcher` for each incoming request with the implemented `HttpRequestContextBase`.
- you may want to further implement `SecurityProvider`, `TransactionRunner` and `PropertiesProvider` to interface with that particular systems.

15.10. Create repositories at runtime

Repositories are usually created at compile-time, either by making use of the various annotations or

a module such as the ´JpaModule´. However, the module API also allows the creation of repositories at runtime. There are two complementary mechanisms in place to achieve this and outlined in the next two sections.

NOTE	this feature is in incubation, more refinements are expected in upcoming releases.

15.10.1. Implementing repositories dynamically at runtime

There are different possibilities to implement a repository at runtime:

- Create a matching resource class at runtime with a library like http://bytebuddy.net/#/ to follow the same pattern as for any compile-time repository.
- Make use of the `Resource` class. It is the generic JSON:API resource presentation within the Crnk engine.
- Make use of an arbitrary dynamic object like a `java.util.Map` and provide a `ResourceFieldAccessor` for each `ResourceField` to specify how to read and write attributes (see below for `ResourceField` examples).

In the following example we make use of the second option:

DynamicResourceRepository.java

```
public class DynamicResourceRepository extends ResourceRepositoryBase<Resource,
String> implements UntypedResourceRepository<Resource, String> {

    private static Map<String, Resource> RESOURCES = new HashMap<>();

    private final String resourceType;

    public DynamicResourceRepository(String resourceType) {
        super(Resource.class);
        this.resourceType = resourceType;
    }

    @Override
    public String getResourceType() {
        return resourceType;
    }

    @Override
    public Class<Resource> getResourceClass() {
        return Resource.class;
    }

    @Override
    public DefaultResourceList<Resource> findAll(QuerySpec querySpec) {
        return querySpec.apply(RESOURCES.values());
    }
...
}
```

This new repository can be registered to Crnk with a module:

DynamicModule

```
public class DynamicModule implements InitializingModule {

    private ModuleContext context;

    @Override
    public String getModuleName() {
        return "dynamic";
    }

    @Override
    public void setupModule(ModuleContext context) {
        this.context = context;
    }

    @Override
```

```
    public void init() {
        for (int i = 0; i < 2; i++) {
            RegistryEntryBuilder builder = context.newRegistryEntryBuilder();

            String resourceType = "dynamic" + i;
            RegistryEntryBuilder.ResourceRepositoryEntryBuilder resourceRepository =
builder.resourceRepository();
            resourceRepository.instance(new DynamicResourceRepository(resourceType));

            RegistryEntryBuilder.RelationshipRepositoryEntryBuilder parentRepository =
builder.relationshipRepositoryForField("parent");
            parentRepository.instance(new
DynamicRelationshipRepository(resourceType));
            RegistryEntryBuilder.RelationshipRepositoryEntryBuilder childrenRepository
= builder.relationshipRepositoryForField("children");
            childrenRepository.instance(new
DynamicRelationshipRepository(resourceType));

            InformationBuilder.ResourceInformationBuilder resource =
builder.resource();
            resource.resourceType(resourceType);
            resource.resourceClass(Resource.class);
            resource.addField("id", ResourceFieldType.ID, String.class);
            resource.addField("value", ResourceFieldType.ATTRIBUTE, String.class);
            resource.addField("parent", ResourceFieldType.RELATIONSHIP,
Resource.class).oppositeResourceType(resourceType)
                    .oppositeName("children");
            resource.addField("children", ResourceFieldType.RELATIONSHIP,
List.class).oppositeResourceType(resourceType)
                    .oppositeName("parent");

            context.addRegistryEntry(builder.build());
        }
    }
}
```

A new `RegistryEntry` is created and registered with Crnk. It provides information about:

- the resource and all its fields.
- the repositories and instances thereof.

Have a look at the complete example in `crnk-client` and `crnk-test` There is a further example test case and relationship repository.

15.10.2. Registering repositories at runtime

There are two possibilities to register a new repository at runtime:

- by using a `Module` and invoking `ModuleContext.addRegistryEntry` as done in the previous section.
- by implementing a `ResourceRegistryPart` and invoking `ModuleContext.addResourceRegistry`.

The first is well suited if there is a predefined set of repositories that need to be registered (like a fixed set of JPA entities in the `JpaModule`). The later is suited for fully dynamic use cases where the set of repositories can change over time (like tables in a database or tasks in an activiti instance). In this case the repositories no longer need registration. Instead the custom `ResourceRegistryPart` implementation always provides an up-to-date set of repositories that is used by the Crnk engine.

An example can be found at CustomResourceRegistryTest.java

15.11. Discovery of Modules by CrnkClient

If a module does not need configuration, it can provide a `ClientModuleFactory` implementation and register it to the `java.util.ServiceLoader` by adding a 'META-INF/services/io.crnk.client.module.ClientModuleFactory` file with the implementation class name. This lets `CrnkClient` discover the module automatically when calling `CrnkClient.findModules()`. An example looks like:

ValidationClientModuleFactory

```
package io.crnk.validation.internal;

import io.crnk.client.module.ClientModuleFactory;
import io.crnk.validation.ValidationModule;

public class ValidationClientModuleFactory implements ClientModuleFactory {

    @Override
    public ValidationModule create() {
        return ValidationModule.create();
    }
}
```

and

META-INF/services/io.crnk.client.module.ClientModuleFactory

```
io.crnk.validation.internal.ValidationClientModuleFactory
```