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To Universal Design Through Infusion IoC

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Abstract

Using the techniques of today, code and designs become "old" very quickly, often unmaintainable from the point of inception. Old code is brittle and hard to refactor, hard to press to new purposes, and hard to understand. Here we present a system aimed at creating a model for *scalable development*, addressing this and several other critical problems in software construction. Such an aim is far from new, and has resembled the aims of each generation of software methodologists over the last 50 years. It deserves comment why these aims have so signally failed to be achieved, and we will present arguments as to why the combination of techniques explained here could expect to lead to novel results.

Software products of today are notoriously unadaptable. An application which meets need A generally cannot be extended to meet apparently very similar need A' without something resembling "software engineering". Applications present users with a "take it or leave it" proposition — if the software doesn't happen to meet a user's needs or preferences, there's no way to change it without writing more code, which is out of reach for most users. Indeed, software regularly fails to be easily adaptable to meet the needs of users with differing needs, such as in the case of accessibility. These "precarious values" — accessibility and usability with different devices, languages, and personal needs — are typically left until the end or ignored, and represent a significant expense in traditional approaches to software development. Often these needs are met by developing a largely unrelated version of the application, requiring maintenance of additional, separate code bases.

Our aim is to enable *Universal Design*[3], a concept which, like the now popular use of "Design Patterns" in software technology, was originally taken from the field of architecture for buildings and spaces. With Universal Design, products are usable by all people to the greatest extent possible.

To address these problems of adaptability, we present a model for software construction, together with a base library, Fluid Infusion, implemented in the JavaScript language. This model features a notion of *context* as the basis for adaptability, resolved in a scope implemented neither lexically nor dynamically, but as a result of the topology of a data structure, a *component tree* expressing the computation to be performed. We will also work with a model of *transparent state* in which the total modifiable state within a tree is held in publicly visible locations, indexed by path strings. This model for state is isomorphic to that modeled by JSON[6], a well-known state model derived from, but not limited to, the JavaScript language. Instantiation in the model is handled by an *Inversion of Control* system extended from the model of similar system such as the Spring Framework or Pico first developed in the Java language.

We relate such systems to goal-directed resolution systems such as Prolog, and show that they have beneficial properties such as *homoiconicity*[2] which have not been seen in a strong or widespread form since the days of LISP. We exhibit some cases to show how the framework enables, through a simple declarative syntax, types of adaptation and composition that are hard or impossible using traditional models of polymorphism. We conclude with some remarks on the applicability of the system to the parallelisation of irregular algorithms, and its relationship to upcoming developments in the ECMAScript 6 language specification.

Keywords JavaScript, Inversion of Control, Transparent State programming, Accessibility, JSON,

1. The Development and Need for Inversion of Control systems

The core of the system described here is an "Inversion of Control" system implemented in the JavaScript language. It constructs applications from trees of components expressed declaratively in JSON notation. Whilst the primary use of the system is in assembling user interface markup and operating logic for HTML web applications, these ideas can be adapted to other domains, illuminating broad issues of software construction. We begin by examining the history and motivation of similar systems, the relationship of our IoC system to other models of software construction, and then finish by describing some current applications, and planned future work.

1.1 The Crucial Nature of Dependency Structure in Software

In a pioneering work, John Lakos[1] identified the patterns of *dependency* of parts of a software system on other parts as key determinants of software quality. In his conception, a piece of code A has "knowledge of" or "dependency on" another, B, if names in B appear in A. To mark our technical uses of these concepts, we will qualify them by referring to "L-dependency" or equivalently "L-knowledge". In the C++ language in which Lakos was working, there are various gradations of knowledge, for example, whether the knowledge about B was sufficient to affect the memory layout of objects allocated in A, or merely required the compiler to have visibility of B names when compiling A code. Although the details differ, the core of this formulation is invariant across essentially all programming languages.

Lakos argued that code in a "dependency-correct" system should form a *directed acyclic graph* (DAG), when expressed in terms of the logical units into which it was divided and the L-dependencies among them. In the C++ language, these logical units were often classes, although he noted that this kind of boundary could be drawn at any level in a system.

Lakos observed that there were many significant consequences of constructing bodies of code with inappropriately arranged L-dependency, following on from his initial effort to control escalating build times in complex systems. Highly interdependent code was harder to understand, harder to test and maintain, and most importantly to our domain of end-users, tended to be extremely brittle over time. Such code imposes unexpectedly huge development costs to respond to seemingly innocuous feature requests.

1.1.1 Evaluating Physical Design Quality Through Dependence Graphs

L-dependency problems are easiest to see in cyclic cases, for example, when some part A of a system depends on part B, but part B also depends on A. Consider the problem of testing this system. One would like to find an order of testing for the parts of the system, such that all the parts that A (say) depends on have been tested before testing A. But when there is a cycle in the L-dependency structure, there just is no such order: in the example, B has to be tested before A, but A has to be tested before B.

Even when there are no L-dependency cycles, systems still differ in important ways, reflected in their L-dependency structure. Figure **??** contrasts a few different cases of dependency geometry. Each component is labelled with its **level number**, which is the count of all components (including itself) which have L-dependence on that component. At the left is a cylic structure of the sort we just described. In the centre is shown a system whose dependence graph forms a balanced binary tree, representing a typical reasonably-well factored system. At the right is a system with a horizontal graph, composed of components which have no mutual L-dependency. Lakos proposed a measurement of "quality" of such a dependence graph, which is the sum of all level numbers in the graph, known as the **cumulative component dependency** (CCD). This measure can be used to compare the quality of the dependence structure of graphs involving the same number of components. Lakos observes that arrangements showing lower CCD numbers are associated with beneficial properties of many kinds. These arrangements correspond to applications which are easier to test, easier to refactor, faster to build, and which offer better opportunities for reuse.

1.1.2 Consequences of Improving Dependence Structure in Static Languages

As it turns out, the problem raised by Lakos' recommendations on the organisation of dependencies cannot be fully resolved in C++, or other static languages, at all. We will consider a typical case, of a design where the majority of dependence arcs are caused by L-knowledge resulting from an *aggregation* relationship — in classical object-oriented terms, where, for example, object A "has-A" object B. Consider a hypothetical DAG of dependency-correct code, organised into units of these classes. Take two of these elements, A and B — in terms of C++, aggregation-derived L-knowledge of class A about class B, would translate into a requirement for objects of class A to bear responsibility for construction of objects of class B, and not vice versa. This knowledge may be pushed into a common ancestor, C — but wherever it resides, this constructional knowledge cumulates towards the root of the tree, creating a *fragile base* to the overall design.

Common attempted solutions to this kind of issue in non-dynamic languages involve constructional "design patterns", usually factories. These impose two kinds of penalties. Firstly, the family of products from the factory need to have a common signature, a serious restriction. Secondly, whilst *some* type information may be erased at this polymorphic boundary, remanent type information still naturally cumulates upwards in the DAG of knowledge in a way that prevents scaling. In the next section we will explain how a certain kind of framework, known as an *Inversion of Control* system, can resolve these kinds of issues, given a sufficiently dynamic base language.

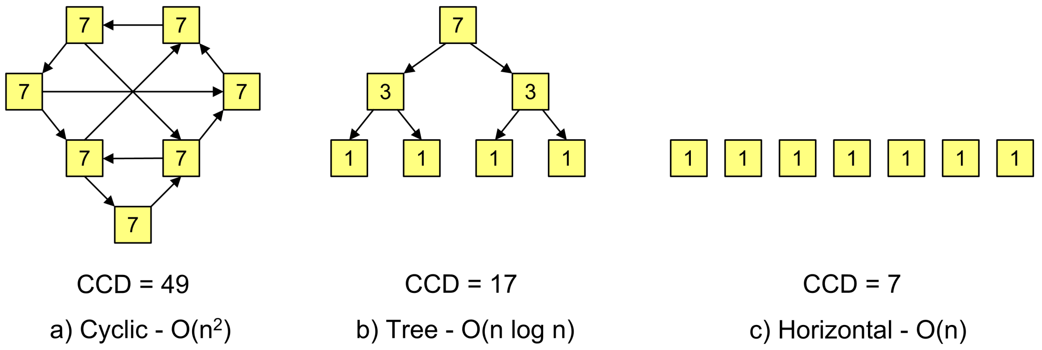


Figure 1: Comparison of Dependence Structures with Different Geometries for 7 components (following Lakos[1], pp.194-195)

1.2 Inversion of Control Systems

The Java language is not particularly dynamic, but enjoys enough of this quality through its reflection system and the possibility for bytecode manipulation that some workable solutions to the fragile base problem emerged, generically described as "Inversion of Control" (IoC). Martin Fowler outlines some of the variants of IoC framework in [4]; popular frameworks in Java include Pico, Avalon, and currently most popularly the Spring framework[14].

The defining activity of such an IoC system, specifically named by Fowler as "dependency injection" is as follows: If an object of class A needs an object of another class B at construction time, rather than A's code calling a constructor for B, A's need for a B is registered in some kind of declarative format with the IoC system. The IoC system then **injects** an instance of B into the object that needs it. The "inversion" is that "asking for an object" is replaced by "being given an object". The operation of such a system relies intrinsically on dynamic properties of the target language. In fact, rather than "constructing itself" as is the case in static languages, the entire tree containing A, B and all neighbouring dependencies is constructed by the framework, informing the target code of lifecycle points in a model similar to that of event-driven frameworks. The IoC framework, in this model, takes the place of the brittle constructional code otherwise placed in class C.

Users of these frameworks get increased agility in the face of end-user requests and variability in environment. That is, important environmental decisions (in the concrete terms of workaday developers, issues such as transaction management, database dialect, message resolution etc.) are taken out of the code and replaced by declarative configuration.

As well as resolving the "fragile base" problem, IoC frameworks improve the L-dependence structure of a design in a number of ways. Firstly, a choice may be made not to support designs with cyclic dependencies (use of Infusion IoC mandates and assists this, whilst it is a configuration option available with Spring IoC). Secondly, the facilities of the IoC system may "flatten" the dependence graph of a design by removing a number of arcs, which represent dependencies that would otherwise be manifest in the application design but instead are subsumed into basic framework facilities. More powerful IoC frameworks can remove progressively more dependence arcs from the application design, depending on their idiom and capabilities. We will return to this point in section 4.1.2.

1.3 Limitations and Extensions to the IoC model

A significant lack in existing IoC systems is a suitably flexible concept of *context*. To a Java IoC system, the context is a **container**. A configuration file is entered into the system as a global specification and if users or developers require changes in resolution based on recognition of a new context or requirement, they need to change the file. Even organising such files hierarchically does not permit decisions to be made based on dynamic considerations. But we can extend the notion of IoC to allow contexts as well as tasks to shape what a system will do.

The Fluid IoC system supervises the matching of names of functions to implementations. What we speak of as a **function name** is more generalised than the traditional notion of a "function" in that it does not necessarily correspond to a function as implemented directly in the programming language. All names of such functions could, however, if registered globally serve as "function names" if required. Instead a "function name" corresponds to the notion of a "task to be performed" in the world of a user. There are generally different classes of "users", operating at different levels in a the tower of abstractions, where the definition of a task at the level of one user, say an end user, decomposes it into subtasks that make sense only to a user at another level, say an application designer.

An implementation provider — and even unrelated third parties — can provide a set of directives to the IoC system, which specify under which conditions a given implementation is an appropriate one to deliver to an end user. These directives are named **demands blocks**, matching conditions which are represented by supplying one or more **context**

names. These names are also simple strings, like function names.

The power of the system to proceed in a contextually aware way is significantly enhanced by allowing the names of *products* of the system to serve as names of *contexts* guiding the construction of future products. Some names may serve as both function names and context names. The name of a user interface widget, for example, may be used sometimes to specify needed functionality, and sometimes to specify a context in which a subsidiary widget might be embedded.

2. Relation to other Programming Paradigms

2.1 Link to Goal-Directed Programming

One way of understanding the cascade of instantiations performed by an IoC system in pursuit of constructing a particular "object", is as related to the "resolution" process performed by knowledge-oriented systems such as Prolog. Prolog casts knowledge in the from of **relations**, connecting one term with another. The input from the user proceeds "forwards" in their world, expressing the dependence of one proposition (or alternatively seen, "goal") on another. Each "rule" of this kind is entered into a database of such rules progressively, building up an unbounded network linking these propositions. A "run" of the system takes the form of requesting the status of a particular proposition - execution then cascades "backwards" (in the view of the developer) through the set of dependent rules until an answer can be determined.

Recursive resolution of dependent components by an IoC system can be seen as a model of a similar process as the cascade of Prolog relation resolution. Important differences are that whilst this IoC system currently operates no form of "backtracking", on the other hand, we add a concept of **context** to the resolution system. Absence of contextual awareness was historically a weakness of Prolog, which, for example, provided no straightforward means for dealing with situations which changed over time.

2.2 Link to Aspect-Oriented Programming

A popular approach for dealing what it terms "cross-cutting aspects of a design" which has grown up alongside and in some cases intertwined with the use of IoC is known as "Aspect-oriented programming". In this model, the implementation domain of a codebase is stratified, forming a higher "meta-level" of design comprising units of code (in a related, but usually distinct syntax) which consists of directives which *advise* the operation of the remaining base level of code which can usually enjoy some kind of simplified implementation.

AOP systems are often extremely powerful, and have the ability to issue *advice* which modifies the execution of the base code at the level of individual method calls or property access - either modifying this dispatch or replacing it entirely. However, this power of oversight, whilst broad, can often be "blind" or at least short-sighted — the specification of a "cutpoint", the environment in which an advice matches, is made in quite low-level terms, and with the data-hiding mentality which goes together with object-orientation (OO), usually has quite limited insight into the contextual situation which has been matched. As a result of the very broad power of cutpoints to match, but limited power to act, AOP designs can become very hard to understand without custom tools and the temptation to use advices extensively is strong.

The "redispatch" formed by the matching of Infusion IoC demands blocks has a similar kind of power, but is at the same time limited in its scope for matching, as it is broadened in its ability to interpret context. A demands block can only act at points in a design where the IoC system is already instantiating a subcomponent in the tree, or else where the user has explicitly requested its operation by use of an *invoker* or *boiled event*. However, when it does act, the dispatch modification may make use of the same contextual resolution system which guided its own matching, to stably discover relevant pieces of state over the entire component tree in scope, rather than just those located close to the advice site as in traditional AOP. This tradeoff of increased formality of matching against increased contextual understanding should produce designs which are much easier to understand as a whole, although we still anticipate a very important role for assistive tools. However, since these tools only require parsing of a simple dialect of JSON rather than the free-form mixture of advice syntax with the base language as seen in AOP, we anticipate them being much easier to write.

2.3 Relation to Domain-Specific Languages

Domain-Specific Languages (DSLs) have grown up in many fields served by software engineering, as concise forms of syntax tailored to kinds of tasks and entities frequently handled in a particular domain[5]. Examples are statistical scripting languages such as S, R, and SPSS, the MATLAB mathematical programming language embedded in the MATLAB system, or hardware specification languages such as Verilog and VHDL. It is illuminating to examine different ways in which the Infusion IoC system conforms to the DSL pattern or fails to fit it.

One important variance from the traditional DSL concept is that Infusion IoC configuration requires no special *parser* beyond the simple rules required to interpret JSON structures. While unusual, reusing existing syntax is seen elsewhere in the DSL field — for example, XML, a more complex state-oriented language, has been used to build DSLs such as the application language XAML, the chemical language CML and many others. This choice makes it very much easier to work with and build a tool chain for the resulting DSL, since the need to port the parsing and lexing layers of interpretation to each new environment has been removed.

However, the most key difference to a traditional DSL is the presence of the crucial property of *homoiconicity*, to be addressed in the next section. This makes it extremely easy to produce tools which **transform** "programs" written in this "language" into other forms. This could be termed the introduction of **machine-readable code**, which at first blush sounds paradoxical — since surely *all* code, by definition, is machine-readable. The crucial ability here is for the code to be read, in the sense of actually being *semantically interpreted*, as opposed to merely being *interpreted for execution* which is virtually all that can be done by code written in non-homoiconic dialects.

2.4 The Crucial Important of Homoiconicity

The "curse" of code manifests itself most concretely in its traditionally concreted-in position in a processing pipeline. By the "central dogma of programming languages", code progresses unidirectionally from its form in a text file produced by someone resembling a "developer", through to lexing and parsing stages, to representation of an AST which through various further transformations and optimisations results in object code which is linked to become executable. Although many erosions and shortcuts exist in various environments, this is the basic workflow in which most software practitioners live their everyday lives. All of these stages are completely disconnected from the way users conceive of their tasks in the real world. Some environments try to bridge this gap between users and code by either producing interfaces that synthesise source code, or producing libraries that allow some limited domain of problem be handled by a de facto "domain specific language" represented in data structures held by the program. In neither case do these results produced by end users have any helpful or reversible relationship with the method of choice that would be adopted by a software professional addressing the same task.

In our aim of building bridges between the worlds of software professionals and people who want work done, we argue it is essential to have a bidirectional transfer of artefacts between developers and "end users" who work with the finished product. This set of transfers should not be "mutually blind" but allow some form of harmonised understanding of the transferred abstraction. The system should exhibit a "homogeneous tower of abstractions", stretching from the low levels out into the world of users.

A crucial element of such a software system is "self-understanding" of the syntactic structure of the language. This allows the process of "software operating on software", such as an authoring tool or preferences wizard, working on behalf of a user to proceed as part of such a homogeneous system. This property has been given the name of *homoiconicity*[2] — whilst many languages lay some form of claim to this property, few approach even closely the level enjoyed by one of the earliest of computer languages, LISP. In LISP, a "program" consists of an "S-expression" which may be viewed equally as an executable element of the language, or else as a data structure known as a *list*. In LISP, programs known as *macros* may operate on lists, interpreted as programs, and transform them into new programs. Many subsystems, such as CLOS, Flavors, LOOPS, etc. were built upon the base of LISP, but the basic homoiconic structure was never built on or expanded. LISP contains the foundation of the "homogeneous tower" we mention, but it does not stretch out very far due to the limited primitives of the language — just one structure-forming primitive, the list — which impedes interpretability and readability of the language.

Our system builds upon this conceptual heritage by defining several dialects of the state-oriented subset of the ubiquitous JavaScript language, JSON, which may be viewed as direct representations of ASTs of a hypothetical language. The power of LISP macros, then, to reflect on and transform program material, is in the hands of standard Javascript programs operating on these structures. At the end of the paper, we will appeal to the design of a future, strongly homoiconic language in which these representations will directly be interpreted as syntax trees, and may operate on themselves without the visible intercession of a JavaScript-like language.

3. Domain of Validity and Other Configurable Systems

3.1 Domain of Validity

It is useful to try to draw out the domain of software tasks for which this approach may be relevant, against a background of tasks for which it may be less helpful. There is a traditional dichotomy drawn between problems which could be named as "deep" — those limited by problem complexity, such as design of a compiler, operating system or database, and others which could be termed "broad" — those limited by problem change and definition, such as the interfaces and implementations of user-facing systems on the web and elsewhere. The system described here is most applicable to the latter type of problem.

However, this dichotomy itself deserves some comment. Software engineers, and computer scientists, as they are for the most part working surrounded by their peers, tend to arrive at a disproportionate focus on the former, "deep" category of problem, the form of problem which they create for themselves and each other. This focus leads to an exaggerated respect both for the particular kinds of difficulties which these problems pose, and also for their real value in the world. The overwhelming majority of consumers for software artifacts are not programmers — consisting in the most part of normal human beings wanting some work done — in the most part of some orderly and idiomatic access to some form of shared state in the world. It is actually the norm, rather than the anomaly which software professionals can sometimes take it, for problem definitions to be vague, constantly shifting, and even to themselves comprise a huge domain of variation with respect to the "market" — comprised, ultimately, of the entirety of humanity, rather than simply software professionals only. We contend that this self-focus by the community has led to the prevalence and disproportionate value attached to approaches such as the "data hiding" strand of the object-oriented philosophy which are actively counterproductive when applied to the vast majority of programming tasks as laid out in our presentation of this dichotomy. Below we will explain how the antithesis of this approach, which we name *transparent state*, is crucial to our formulation of IoC and also to addressing these kinds of tasks in general.

3.2 Existing Configurable Systems

It is worth examining the most configurable kinds of systems which the industry has so far produced, and explain the kinds of variation which we aspire to express, and why they are essential to any conception of Universal Design, beyond the traditional conception of "accessibility".

Some highly configurable products are intricate desktop applications, such as Microsoft's Visual Studio or IBM's Eclipse, aimed at developers, and Microsoft Word, a word processing application ostensibly aimed at normal human beings. These offer configurations including the following kinds:

- Configuration of keyboard bindings used to invoke functions of the application
- Reorganisation and customization of "toolbars" holding icons invoking application functions
- Alteration of layout and positioning of panes holding working documents, indexes of these documents, menus and toolbars
- Installation and configuration of "plugins" offering extensions to the application's function (for example, the ability to work with different kinds of document, or integrate with a particular kind of remote service)
- Others

Whilst this is a form of "high water-mark" in terms of configurable systems, it falls short of what is required. Also, even this level of configuration is achieved at considerable development expense — i) each form of configuration must be explicitly planned for in the application design, ii) the UI supplied for the configuration itself is separately developed and is not itself configurable, and iii) not obviously related visually or in function to the target UI, and iv) the worst of all, the resulting configuration system is a "stovepipe", only valid for the particular application it is designed for. It would be inconceivable to take a "plugin" or customisation option, for example, from Visual Studio, and apply it to Word — still less to transport it to an application written in an entirely different language such as Eclipse.

In addition to these drawbacks to the configuration system, the reach of the system itself falls short. Here are some kinds of configuration which are desirable, and also capable of expression in a system such as Infusion IoC:

- Replacing application-wide, a control with a particular function by one with the same data binding function but different presentation and mode of operation — for example, a numeric bounded range presented with spin buttons replaced by a linear slider
- Changing interaction idioms over domains with a particular geometry — for example, items displayed in a linear list which are navigable by means of arrow keys might be customized to allow navigation to wrap from the top to the bottom of the list, or else to "stick" at the extremes of the list
- Reformulating the workflow of portions of an application so that multiple controls displayed in a single, complex dialog are replaced by a linear sequence of simpler steps

In addition, the customization we are seeking also aims at some "meta-values" —

- To make it as easy as possible to transport customisations from one environment or "application" to another whilst preserving as much semantic meaning and function as possible[1]
- To allow as much customisation as possible to proceed by *direct manipulation in context* — that is, by a modal interaction or otherwise, to allow the customization of a UI element to be achievable by an operation directly performed on the element itself, rather than in a distant and separately developed part of the UI
- To achieve this level of configurability with no extra effort on the part of developers — that is, without requiring them to plan up front for the specific axes of configurability which the resulting application offers[2]

These larger values are still distant, but we believe they are only achievable through development organised on the principles we have described for our system, relying on some key choices:

- Expression of customization as well as application structure in a declarative form based on transparent state — for which a good model is the state-based JSON dialect of JavaScript, highly amenable to transformation and transmission

[1] This goal is a key goal of one of the major partners of the Fluid Project, the **Global Public Inclusive Infrastructure** (GPII)[9] which aims to deliver universal accessibility (and hence universal customization) for all applications, mediated by means of globally available personal profiles held in a cloud-based system

[2] This is a goal specifically defeated by "object-oriented" methodologies which typically cast amenability to a particular form of configuration in terms of derivation from a previously formulated *interface* or *base class*. New such axes cannot be introduced without rewriting existing code

- Interpretation of customization as well as application structure in a *context-aware* semantic — where each configuration item is not only *context-aware* but also *context-forming* — that is, forming a context guiding the interpretation of further items.

The conjunction of *customization* with *application structure* in these two goals suggests, as we believe, that a further key element in achieving the goals is the specification of what we call application structure *in the same terms as* those we cast what we have called customization. This conjunction has been seen already in configuration-based IoC systems such as Spring and Guice, but so far only in "thin layers" representing the outermost and grossest layers of application function (and hence those of less immediate interest to end users) and not in a suitably context-aware way.

4. How Infusion IoC is Used

The configuration for our IoC system is issued in two kinds of JSON structures, known as **defaults** and **demands blocks**. This configuration is *static*, in that it is issued directly upon loading of the containing JavaScript files, and does not change over the lifetime of the application. A different value for defaults/demands constitutes a different version of the application or framework in question. Defaults and demands blocks are governed by a well-defined grammar, although at various points in the "syntax", the content is unconstrained, to allow arbitrary application structure to be expressed. The named units of composition described by the grammar are named "components" although these need not correspond to the traditional concept of a "UI component" or "widget".

The examples presented here show the syntax supported by the version 1.4 release of Fluid Infusion, of July 2011. Since the Infusion IoC system is still under development, future versions of Infusion will feature different support, although the basic syntax presented here is expected to remain essentially stable.

4.1 Defaults and Components

A **defaults block** sets up a default set of options for a component, as well as defining its immediate composition structure in terms of subcomponents and other non-component material. A "run of the system" consists of a call to a concrete JavaScript function which directly or indirectly instantiates one or more components in accordance with this configuration, creating a *component tree*. Components are *instances*, analogous to object instances in an OO system but differing in a number of ways. Points of similarity are that components are packages of related data and functions (*methods*) — differences are that components are considered freely addressible as JSON structures, and are not derived from either classes (in the OO sense) or a prototype hierarchy (in the JavaScript sense).

Some roles for components in our system are as follows:

```
fluid.defaults("fluid.uploader.multiFileUploader", {
    gradeNames: "fluid.viewComponent",
    queueSettings: {
        fileSizeLimit: 20480,
    },
    ...
    components: {
        strategy: {
            type: "fluid.uploader.progressiveStrategy"
        },

        fileQueueView: {
            type: "fluid.uploader.fileQueueView",
            options: {
                model: "{multiFileUploader}.queue.files",
                uploaderContainer: "{multiFileUploader}.container"
            }
        },
   ...
   }
}
```

Figure 2: Sample of a defaults block

- A generalised "unit of computational work"
- An actual "widget on the screen"
- The result of a decision about an implementation strategy
- A context for further such decisions
- A named unit of scoping where state may be looked up

Figure 2 shows part of the defaults structure for a component `fluid.uploader.multiFileUploader` implementing the UI of a progressively enhanceable Uploader widget. Parts of the configuration similar in nature to that shown are omitted with ellipses. Note that the names of components are qualified names held in a (single) global namespace. Whilst this top-level component is a "view component" in the MVC sense, subcomponents further down the tree will in general have more abstract functions and not be bound to the view.

4.1.1 Grades

Firstly, the component announces its **grade** — grades are forms of *types* but a specific conception based around *composition of JSON documents* rather than having a focus on runtime data structure or substitutability as in OO. The primary purposes of Infusion Grades are to i) fix the signature of the component's creator function, and ii) to set up any special semantics to be applied when building up component specification through merging of JSON structures. This latter amounts to a light *schema* applied to the JSON structure of the component's options which is otherwise free-form (e.g. in this case, the `queueSettings` section). There are currently only 5 grades in the Infusion system itself, named `littleComponent`, `modelComponent`, `eventedComponent`, `viewComponent` and `rendererComponent`, although in fact any component may act as a grade through its `defaults` structure.

In this way, we create a model for **types as documents** which is crucial to the reduction of all application structure to a declarative form. New types can be created by simply supplying new documents to the system, and the effect of *combining types*, often so problematic in the OO world as an unclear pattern of *multiple inheritance* can simply be understood in terms of *combining documents*. The way is paved for end users to engineer the effect of creating their own "types" using straightforward authoring tools, bypassing the traditional "gatekeepers of state", the developers.

4.1.2 Subcomponents

The view in Figure 2 shows 2 subcomponents configured for the top-level component, which are named `strategy` and `fileQueueView`. When the component is instantiated, the subcomponents will be constructed by the system and assigned as top-level members of the overall component with these names. An important aspect of this aggregation system is that, since the subcomponents are resolved and instantiated by the framework, there is no necessary induction of L-dependency (see section 1.1) of a supercomponent on a subcomponent by this form of "has-A" relationship as there is in classical OO systems. In classical OO, this dependency is induced by constructional responsibility for the subcomponent by the supercomponent, which here is absent. Indeed, third parties may freely contribute additional subcomponents, or modify or resolve away the subcomponents drawn up in defaults blocks, without necessarily disturbing the operation of the supercomponent, as we will show in section 4.2 on *demands blocks*.

The subcomponents here are described by **type names** — these are **function names** in the same space as the supercomponent name `"fluid.uploader.multiFileUploader"`. Note that these **need not** correspond to the names of actual functions globally registered into the system. In this case, `"fluid.uploader.fileQueueView"` does indeed correspond to such a concrete function, whereas `"fluid.uploader.progressiveStrategy"` does not. The latter name is supplied as a function name which will enter **function resolution** as described in section 4.2. This contrast may be compared to the contrast between *interface names* and *concrete class names* in a classical OO system, in that the latter are expected to be directly instantiated, and the former are not — the situation is not directly analogous since in Infusion IoC there is no necessarily induced "is-A" relationship between a function name entering resolution and the concretely resolved name used for instantiation. This is a consequence of the fact mentioned in the previous paragraph, that a subcomponent need not, and in most cases does not, impose any direct contract on its supercomponent.

The typical absence of this upward contract in component hierarchies driven by Infusion IoC is one of the crucial ways in which our system improves the L-dependence structure of a design. By removing these "dependence arcs" from the graph, its geometry is pushed further towards the right-hand end of the diagram in Figure **??**, representing designs with a flatter, more scalable dependence structure.

4.1.3 Context Expressions and Scoping

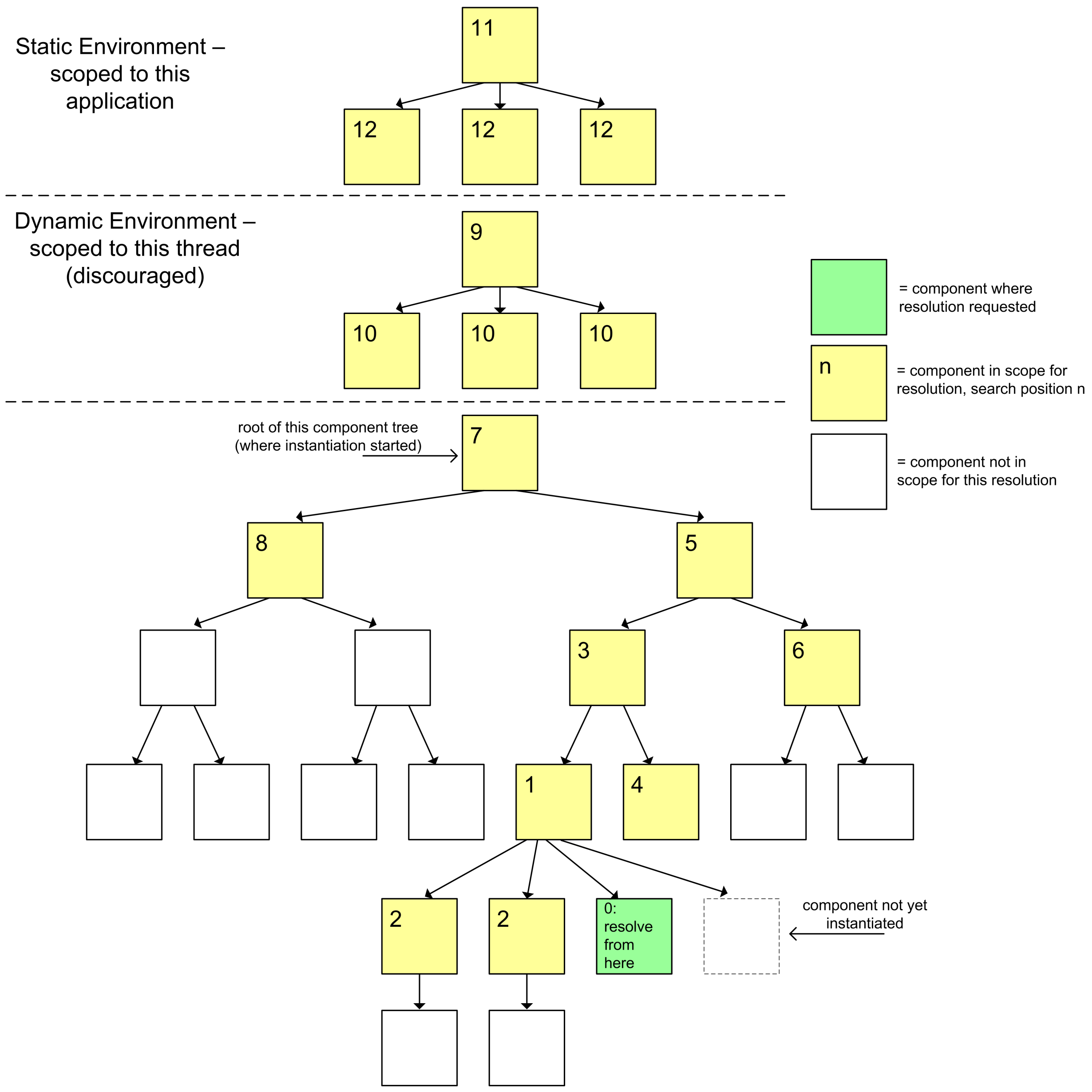
The subcomponent `fileQueueView` which is more concretely defined in Figure 2 includes some configuration using a special syntax, e.g. the string `"{multiFileUploader}.container"`. This type of expression is used extensively within IoC, referred to as **contextualised EL expression** or **path expression**[3]. The initial section within braces refers to the name of a **context**, actually resolving onto a particular component in the tree that will instantiate, and the remainder of the expression is interpreted as a path within that component.

A component can be matched via the *context* portion of such an expression through three routes — that is, a component, once instantiated in a component tree, gives rise to either two or three *context names* which can match against such a name name within braces, e.g. `multiFileUploader` in this case. Considering as an example, the context names formed by the subcomponent `fileQueueView` above are as follows:

- The fully qualified name of the concrete component as instantiated (in the above case, `fluid.uploader.fileQueueView`)
- The final segment of the fully qualified name (e.g. `fileQueueView`)
- The subcomponent's name within its parent, if any (in this case, *also* `fileQueueView`).

Such context names are considered *in scope* from a site of resolution, for example, the instantiating `fileQueueView` component above, if they match a component which is either an ancestor (container) of the component holding the resolution site, or if they are a sibling of such a component. Therefore, in the simple case above showing just three components, *every* component in the tree is a potential site which may match the context name `multiFileUploader` demanded from the configuration of `fileQueueView` — although this name in practice clearly matches the root component. Figure 3 shows the components in scope in a more general case — the most darkly shaded component, numbered 0, is the resolution site and the component currently being instantiated by the system, and the more lightly shaded components, with higher numbers, are the components which are considered in scope for forming context names, with the number indicating the priority order. Components with lower numbers will "hide" scopes formed by components with higher numbers, as in the traditional rules for operating nested scopes in programming languages.

[3] The use of *expression* here is slightly misleading since in fact no expression elements (operators, variables, etc.) are permitted in these strings. The usage of "expression" has been inherited from other environments, such as JSPs, ASPs, etc. where a full *expression language* was provided for such string-encoded value references.



Static Environment – scoped to this application
11
12
12
12
Dynamic Environment – scoped to this thread (discouraged)
9
10
10
10
root of this component tree (where instantiation started)
7
8
5
3
6
1
4
2
2
0: resolve from here
component not yet instantiated
= component where resolution requested
n
= component in scope for resolution, search position n
= component not in scope for this resolution

Figure 3: Scope Visibility and Priority for Context Resolution

4.2 Demands Blocks

Function names such as `fluid.uploader.progressiveStrategy` and `fluid.uploader.fileQueueView` that appear as subcomponent type names in Figure 2 ultimately give rise to concrete function invocations by the Infusion IoC system. The crucial capability of the system to meet the kinds of configuration needs we described in section 3.2 is achieved through the **function resolution** process — the designation of the particular function invocation required, as appearing in subcomponent definitions and in several other places in the framework is *transformed* by the intercession of rules which transform the function invocation from one form into another. This transformation is specified by issuing JSON structures known as "demands blocks", a partner to the defaults blocks of the previous sections.

Whereas defaults blocks specify the basic skeleton of the component tree geometry, demands blocks intercede in a *context–aware way* to transform the elements of this geometry to meet the particular needs of the user in a particular context. This intercession is the analogous of the *advice* action of Aspect-Oriented Programming that we considered in section 2.2.

4.2.1 Simple Use of a Demands Block

A very simple example of a demands block is shown in figure 4. This shows an "advice" applied to the subcomponent `strategy` of type `fluid.uploader.progressiveStrategy` that we saw in diagram 2. The function `fluid.demands` takes three arguments:

- **demandedName** — a string, the original function name demanded by the configuration site being resolved
- **contextNames** — a string or array of strings, the *context names* which must be visible for this demands block to be activated in order to resolve the demanded function names
- **disposition** — a JSON structure describing the resolution to be performed ("advice") — this as well as resolving the demanded function name, this may also describe rules for transforming the function arguments.

In this case, the disposition simply replaces the demanded function name (which as we mentioned in section 4.1.2 in fact had no implementation) with another. In a context where the context name `fluid.uploader.html5` can be seen, this demands block directs that the function name `fluid.uploader.html5Strategy` be used in place of the original name `fluid.uploader.progressiveStrategy`. The rules for scoping are the same as those shown for *value resolution* in Figure 3 — components which do not fall in the numbered, lightly shaded region of the component tree relative to the resolution site are not considered for the purposes of forming contexts for function resolution by demands blocks.

```
fluid.demands("fluid.uploader.progressiveStrategy",
              "fluid.uploader.html5", {
    funcName: "fluid.uploader.html5Strategy"
});
```

Figure 4: A simple demands block

4.2.2 A More Complex Demands Block

As well as the ability to redirect the dispatch of the required function name held in the demands block, the arguments to the function call may also be freely interspersed, replaced, or merged with material drawn from elsewhere in the tree.

```
fluid.demands("fluid.uploader.local", "fluid.uploader.html5Strategy", {
    funcName: "fluid.uploader.html5Strategy.local",
    args: [
        "{multiFileUploader}.queue",
        "{html5Strategy}.options.legacyBrowserFileLimit",
        "{options}"
    ]
});
```

Figure 5: Sample of a demands block

In Figure 5, the *disposition* entry now contains an entry `args` in addition to `funcName`. This block directs that in addition to resolving the demanded function name onto a particular concrete implementation `fluid.uploader.html5Strategy.local`, its argument list is also to be replaced. The syntax used for argument lists, in addition to allowing literal JavaScript constants, also allows any combination of values using the *value resolution syntax* that we saw in section 4.1, using the same resolution rules.

This adds a new capability to programming. Facing a function with a signature actually unknown to the calling site, three argument values are "fished out of the air" in order to meet its contract. This adds a capability for loose coupling that was not previously available — a completely unrelated third party may now intercede between any function call site, and any other function implementation site, and cause the caller and callee to be conformed together, irrespective of any mismatch between the actual function name *as well as any mismatch in the function signature*.

This ability to "fish values out of the air" in order to meet unanticipated (by the caller) function contracts requires a different model for how state is made available in a program design. In particular, it argues against the "data hiding" paradigm that is recommended by object-orientation. In the next section, we will see how the antithesis to this approach, one that we name the use of *transparent state*, can be made the basis of a workable progamming model, whilst still meeting the goals which originally seemed to motivate the use of data hiding.

4.3 The ChangeApplier and the conception of *transparent state*

It is a key requirement to operate demands blocks, that the component tree is defined in terms of what we call **transparent state**. The meaning of this is something similar to the prescription of *RESTfulness*[10] for web applications — that the state of the system is indexed by path-segmented strings in a public and stable namespace. This feature arises simply and naturally when JSON-encoded data is accessed from the JavaScript language, but tends to be obscured when the traditional recommendations in favour of data hiding are followed.

4.3.1 The "State API"

One way of viewing the adoption of transparent state, is in terms of a "moral API" which is considered to be always in operation when state is being addressed. In terms of our analogy with the HTTP REST verbs, which in the HTTP protocol are named `POST`, `GET`, `PUT`, and `DELETE`, the members of this API can be considered as representatives of the CRUD (Create, Read, Update, Delete) paradigm, original proposed by James Martin[11] as an approach towards the management of persistent state. The extra element which REST adds to the original conception of CRUD is the insistence that the data items addressed by the state operations are indexed by stable, public, path-segmented strings.

We argue that this idiom is appropriate for the management of all mutable state (and access to immutable state) *within* an application, rather than just operated across process or machine boundaries as part of the original conception of CRUD/REST. Certainly, the JavaScript language, by providing the native idiom for addressing freely-formed JSON structures as a language primitive, makes this conception extremely natural — the path-segmented stable strings we mentioned are simply the natural (applied recursively) member access operators provided by the language.

Using this "RESTful" approach to *all* application state, however, implies that all of this state be made available *"as if"* represented by a single, giant (most likely lazily loaded) JSON structure. Whilst future developments in the JavaScript language (proxies, arriving in ECMAScript Harmony[7]) do promise to make this a practical possibility, the constraints of the current JavaScript language imply that access to state which is *not* directly embodied by a concrete and directly available JSON structure of the right kind needs to be mediated by the use of an old-fashioned API.

This API is present in Fluid Infusion, as part of a package of data binding primitives in the core framework as well as a particular implementation known as the **ChangeApplier** which mediates mutation of state. Figure 6 shows the equivalence between actions performed directly in the core language, the ChangeApplier, and HTTP REST as a point of comparison.

4.3.2 Addressing the goals which appeared to motivate data hiding

Data access policies We argue that adoption of the transparent state model makes many of the goals which appeared to motivate data hiding, paradoxically, *easier* rather than harder to meet. An interesting representative of these goals is secured access to data. Many applications operate a *security model*, defining rules and predicates which specify which users of the application should be permitted to read, modify, or perform other operations with respect to which data that the application manages.

A very popular framework for managing such security assertions is *Spring Security*[15], a subproject of the Spring IoC framework mentioned earlier as the foremost popular embodiment of IoC ideas in the Java community. Spring Security gains a great measure of its power through reducing security assertions about access of principals to data and implementations to a declarative form — just the same reduction that motivates our own work. However, the power of Spring Security and similar frameworks to express policy is seriously hampered by a necessary lack of insight into the *identity of data* which is a consequence of the OO model.

Here is a real-world example of a desired security policy that arose in the context of work on one of our partner projects, the CollectionSpace Project[8]. This project operates a relational model, connecting together data seen as *records* connected by *relations*. The required security policy expressed that permission for a principal to modify the relation between two records should be derived from the permission held on the records which it related. Specifically, a principal should only have permission to modify a relation between two records if they already held permission to modify the contents of both records separately.

It's clear that without a stable and global identity (expressed, preferably, as a string) addressing each record in the system, it is impossible for such a security policy to be expressed in any declarative form — and since Spring Security and suchlike frameworks have no place for such an addressing scheme, they cannot express such a policy at all. This requires such a policy to fall back to non-declarative schemes and be expressed literally in application code, therefore putting it out of reach of end users of the system to inspect and modify.

This example shows a case where the adoption of a transparent state scheme positively assists rather than hinders the expression of policies controlling capabilities by users of a system to access or modify state.

Maintaining invariants and Serialization Another important category of goals motivating data hiding is maintaining **data integrity**. Often, state comes together with a set of *invariants* or *validation rules* which must be checked and maintained whenever state modification is attempted. In the OO paradigm, these invariants are traditionally maintained by logic embedded in application code packaged as *methods* (private or public) of the objects holding the state to which the invariant refers.

Having such rules locked up in application code carries similar risks to those just mentioned. A particular difficulty this creates is providing the application function of *serialization* — taking the set of application state and writing it to a serial form such a disk file or network stream, or this process in reverse. Serialization in an OO system always meets the design risk represented by the packing of an object's invariant protection as a direct part of the object's own API. During the deserialization process, this protection must be "somehow" suspended, this "somehow" being directly at odds with the OO philosophy. As the object tree is built up in memory, it is quite likely that the invariants protecting validity of the state will be violated at intermediate points where the object tree is incomplete — especially if these invariants relate to relations amongst objects. In semi-dynamic environments such as Java, object serialization needs to be a specialised platform/language facility, and is often hard to control. In static languages such as C++, serialization poses a double burden on developers — having designed an object hierarchy once, a separate design effort needs to be mounted to serialize it.

Invariants through ChangeApplier guards A system which separates state from behaviour, as we recommend, deals with such issues trivially — state serialization and deserialization are performed directly by the primitives provided by the base language, e.g. in JavaScript, the `JSON.stringify` and `JSON.parse`. Alternative serializations are also trivial,

	JavaScript native	Infusion API	HTTP REST
Read	`var x = root.path1.path2;`	`var x = accessor.get(root, "path1.path2")`	`GET root/path1/path2`
Write	`root.path1.path2 = "value";`	`accessor.set(root, "path1.path2", "value")` **OR** `applier.fireChangeRequest({type: "ADD", path: "path1.path2", value: "value"})`	`PUT root/path1/path2 value`
Delete	`delete root.path1.path2;`	`applier.fireChangeRequest({type: "DELETE", path: "path1.path2"})`	`DELETE root/path1/path2`

Figure 6: Comparison of syntaxes for direct access to mapped state

either through transforming the JSON tree, or by using the iteration primitives of the language to drive an alternative serialization. The capability to ensure invariants (or not, depending on whether they are required) is mediated by mechanisms held in the *State API* we described earlier. In particular, the machinery held within the *ChangeApplier* allows the registration of **guards**, listeners to the **change events** passing through the system attempting to honour the modification of state requested by the user. If an event violates the invariant embodied in a guard, it is *vetoed* — the event is discarded and the state modification does not occur.

The configuration of guards is defined in a further document, itself following the transparent state model, aligned with the primitive state. This document defines, or can be directly derived from a *schema* for the primary state. This continuation of the "types as documents" model which we touched on in section 4.1.1 on *grades* continues to put power in the hands of users to prescribe behaviour by modifying documents, rather than enfranchising developers by putting power in the hands of authors of application code.

Transactionality A closely related issue to maintaining of invariants for data integrity, is the requirement for *transactional updates* to state. In a system with transactional updates, it is not possible to observe the effects of partially updated state during a long sequence of coordinated updates — instead, "outside the transaction", the updates appear to be applied atomically. This is the kind of issue that is not typically handled at the language level in an OO system, but instead arises as part of a particular object-relational mapping (ORM) technology which maps the state of objects in a running system onto persistent state held in some form of database layer.

By adopting a transparent state model, in conjunction with "change application" machinery such as the ChangeApplier, transactional semantics can be supplied in a standard way for in-memory objects, matching the semantics of their persistent analogues in the database layer. In figure 6, the argument to the method `fireChangeRequest` can be seen to be a piece of transparent state in itself — in fact, a *change request object* which is the natural form of entries in system following the transaction log pattern. The implementation of the ChangeApplier is capable of applying grouping to this stream of events, ensuring that units of change represented by a group forming a transaction are either seen to be applied completely (atomically) or not at all, in the case of a guard (invariant) failure.

4.3.3 New capabilities through transparent, mapped state

The transparency provided by stable addressing of state allows more powerful reorganisations of data and the operations performed on it. Examples include the *bidirectional programming* framework of Pierce et al.[12], in which state is "lensed" through information–preserving transformations. The greatest difficulty with these schemes in practice is the *alignment* of this state before and after the transformation — a transparent state model performs this alignment intrinsically and naturally. Another example is work involving parallelisation of irregular algorithms[13]. An important prerequisite for this kind of task transformation is that units of work are divided up into stably named elements embedded in a graph, without "distant side-effects". This is just the partitioning of work units presented by the IoC component tree and its indexing model.

4.3.4 Transparency applied to component trees

Since component trees are not in general considered mutable, this potential for global reference raises few problems during the instantiation process itself. The parts of the component trees which hold state which is considered mutable after instantiation are designated as **models** and access to them is mediated by a companion component known as a **change applier**. This, whilst preserving the transparency of addressing through path strings, restores the virtues which encapsulation and data hiding are intended to achieve in the "object–oriented" model — atomicity of update, consistency through verification of invariants, and a publish/subscribe model for notification of changes. A feature known as **proxies** which is upcoming in the ECMAScript 6 specification[7] will enable this package of guarded access to be applied to state accessed through the natural semantics of the language.

5. Case Studies in Implementation

5.1 Case study — Progressively enhanced Uploader component

Whilst the Infusion IoC system to some extent allows us to get beyond traditional conceptions of "component–oriented" or "object–oriented" applications, it is an important stepping–stone in providing value to both users and developers of the system alike to develop packages of functionality that fill well-defined, though flexible functions.

5.1.1 Goals for the Uploader Widget

An application that we have worked on recently and present here is that of a Uploader "widget". This widget assists users to select one or more files from their local filesystem, and to supervise the process, with feedback, of transmitting them via HTTP to a web server. This implementation is a challenge due to the broad range of technologies potentially available in the browser environment to meet this need, stretching from the very latest versions of HTML5 interactions delivered in this year's Firefox 4 browser, back to the extremely basic support for uploading single files provided by HTML 4 in the 1990s. A crucial goal of the uploader is to provide a single, concrete entry point to the developer/integrator, whilst automatically sensing the capabilities of the environment, registering the user's preferences and selecting an appropriate implementation strategy in a transparent way, in accordance with the goals of progressive enhancement.

Whilst the Uploader presents a straightforward and stable entry point to users as a simple function call, under the surface it uses IoC to intelligently adapt to the combination of the capabilities of the user's browser and their expressed preferences. At the same time, this implementation can be extended to deal with unanticipated technologies and environments, without modification of either the implementation or user code.

5.1.2 From the integrator's point of view

In its simplest possible form, the widget can be used as shown in Figure 7 (assuming inclusion of appropriate Fluid and jQuery[16] JavaScript files).

In this simple form, a call to a concretely named JavaScript function is targetted at a block of markup holding a standard (HTML4-style) file upload form. Since no further configuration is supplied, the IoC machinery behind the function call will detect whether a Flash version 9, Flash version 10, HTML5 (Firefox 3.6-style) or Binary XHR-compliant HTML5 style (Firefox 4 or Chrome) uploader is the most appropriate form, inject appropriate markup, and construct

```
<html>
 ....
   <form method="post" enctype="multipart/form-data" class="myUploader">
       <input name="fileData" type="file" />
       <input type="submit" value="Save"/>
   </form>
   <script type="text/javascript">
       fluid.uploader(".myUploader");
   </script>
</html>
```

Figure 7: Sample instantiation of an uploader component

a suitable implementation. Should none of these choices be workable, or if JavaScript is not enabled in the browser, the markup will be left as it is and still provide basic functionality for selectioning and uploading a file.

5.1.3 Benefits provided by Infusion IoC

The variant enriched implementations all present a common interface, allowing selection of multiple files, feedback of individual and overall progress as well as pausing or cancellation of operations. Due to the power of IoC, this implementation code, as well as several other sections of the implementation are reused across the variants as "invariant sections" of the component tree. Even this relatively compact problem would have been hard to address through standard "object–oriented" techniques — assembling a class hierarchy mapping this area would have run into two principal hazards:

Firstly, the pattern of code reuse, with multiple, mutually–overlapping pieces of implementation shared between the configurations would have been hard to map onto a traditional inheritance hierarchy. Even were this done, it would be hard to be assured that in the face of future variation, the mapping would remain stable. In Infusion's IoC implementation, since essentially all implementation which is in code is packaged in a form equivalent to that of "free", context-less functions, it is easy to be assured that it can be recomposed by means of demands blocks into a new and suitable arrangement where implementation can be common.

Secondly, the simple point of entry in terms of a stable, context-less function `fluid.uploader` would have been harder to achieve. Given the delivered implementation is polymorphically variable, this would either have required concrete type-names to be mentioned in a "constructor", or the use of some suitable "factory method" on an already existing source of implementations... whose construction would represent the same problem, pushed back one level.

Say that, for example, despite the now obsolescence of Google's "Gears" technology for native browser functions, a user wanted to extend this Uploader implementation set to support it. This could be done without modification of either the user entry point `fluid.uploader` or the implementation files. In fact, all the demands blocks and implementation functions required for, say Gears, or some unanticipated future technology could be scoped to a JavaScript file which is not even delivered to users with user agents not supporting this technology. This kind of “file inclusion-based polymorphism” is hard to package with object–oriented techniques where constructors delivering implementations typically need to appear within the delivering code.

5.1.4 Use of demands blocks in Uploader implementation

Figure 8 shows schematically the structure of some of the demands blocks implementing the Uploader widget. Each arrow linked with a circle along its length represents a *contextual resolution* — a choice made by the instantiation system based on the context provided by constructions which have already concluded. At the top of the diagram are raw **context tags** decoded by a direct inspection of the capabilities of the user agent — `fluid.browser.supportsBinaryXHR`, etc. Below this level in the tree is the point at which user configured material may be used to guide resolution, for a particular instantiation of the uploader, onto a particular strategy to be used. In the absence of this, the default demands structure will proceed by a default algorithm onto the uploader strategy tags, `fluid.uploader.html5` etc. Below this level, the resolution continues to cascade onto particular elements of the uploader implementation, guided by the strategy tags. At each level of demands resolution, there is scope for further demands blocks contributed at the user’s request, or an integrator or other party, to intercede, or in AOP terminology to “advise” the construction of subcomponents, by fetching data or implementation sourced from other parts of the uploader’s tree — or even, from other parts of a wider component tree. Whilst the uploader is packaged in such a way that it is usable by standard JavaScript citizens as a simple function tree, the full power of the IoC system together with the uploader is only realised when the entire implementation of an application is delivered as a single, giant interconnected series of demands blocks — with demands resolution given the power to roam freely and fetch contextualised data to be delivered anywhere within or among elements which would formerly have been seen to be opaque, monolithic “components”.

Whilst Figure 8 resembles a standard UML diagram in some respects, the meaning is somewhat different. This diagram shows a schematic for data structures which *might* exist in certain histories of the system, rather than those which will or do exist, statically. It is this contextual awareness at each point of the system that allows it to be easily extended for new cases, with instantiation guided along new paths, made visible by new demands blocks being brought into scope.

5.2 Wider case study - The CollectionSpace Collections Management System

The CollectionSpace project[8], led by the Museum of the Moving Image in New York, is producing collections management software for the use of museum curators and other staff. The project is using the current version of the Infusion IoC system, as described here. This project is proving an excellent ground for exploring the benefits in adaptible and declarative software that the IoC approach can offer. The user interface for this application consists of few but very detailed pages, containing many hundreds of widgets, reflecting the level of detail of the specialised knowledge operated in the domain of exhibit curation. As suggested in the previous section, the entire UI for this application is implemented as a giant, single-rooted tree of components governed by the underlying graph of demands blocks. This tree comprises components such as the Uploader and numerous others, instantiated by IoC. One immediate benefit of this approach for users is the easy adaptibility of the interface in a schema-driven way. Rather than relying on development support to orchestrate changes required by local institutions which may have very widely differing requirements, these can instead be enacted by editing simply-structured JSON files or in many cases can be inferred automatically from a description of the application’s schema.

Component markup, similar to component state, is not locked up in implementation files but “out in the open” in unpolluted and standard HTML files, reskinning of the application similarly can be performed without development support, using standard HTML editing tools. These kinds of reskinning comprise, but go beyond that possible through simple CSS effects. Directly editing HTML enables widespread reorganisation of the layout and content of the markup operated either by individual components or entire pages. This composition of markup is performed by the **Fluid Renderer**, an engine described in more detail in the full version of this paper.

6. Status of the implementation and framework

The Fluid group are currently working towards the 1.4 release of the Infusion system, which is targetted for the beginning of July 2011. This will be the first public release in which the described implementation of the IoC system (as well as the Uploader widget and other components not described here) will be available. Readers are invited to come along and inspect our progress, and even join in, at our github repository held at `https://github.com/fluid-project/infusion`. Overall documentation for the Infusion system, including the IoC implementation, is held at `http://wiki.fluidproject.org/display/fluid/Infusion+Documentation`. Future versions of Infusion are roadmapped at `http://wiki.fluidproject.org/display/fluid/Fluid+Community+Roadmaps` — we will continue to stabilise and expand the capabilities of the IoC system as well as evolving previously implemented components to defer to it more for implementation. A crucially important, but still very early–stage work package involves our server-side implementation, Fluid **Kettle**, an IoC-driven JavaScript implementation based on the rapidly

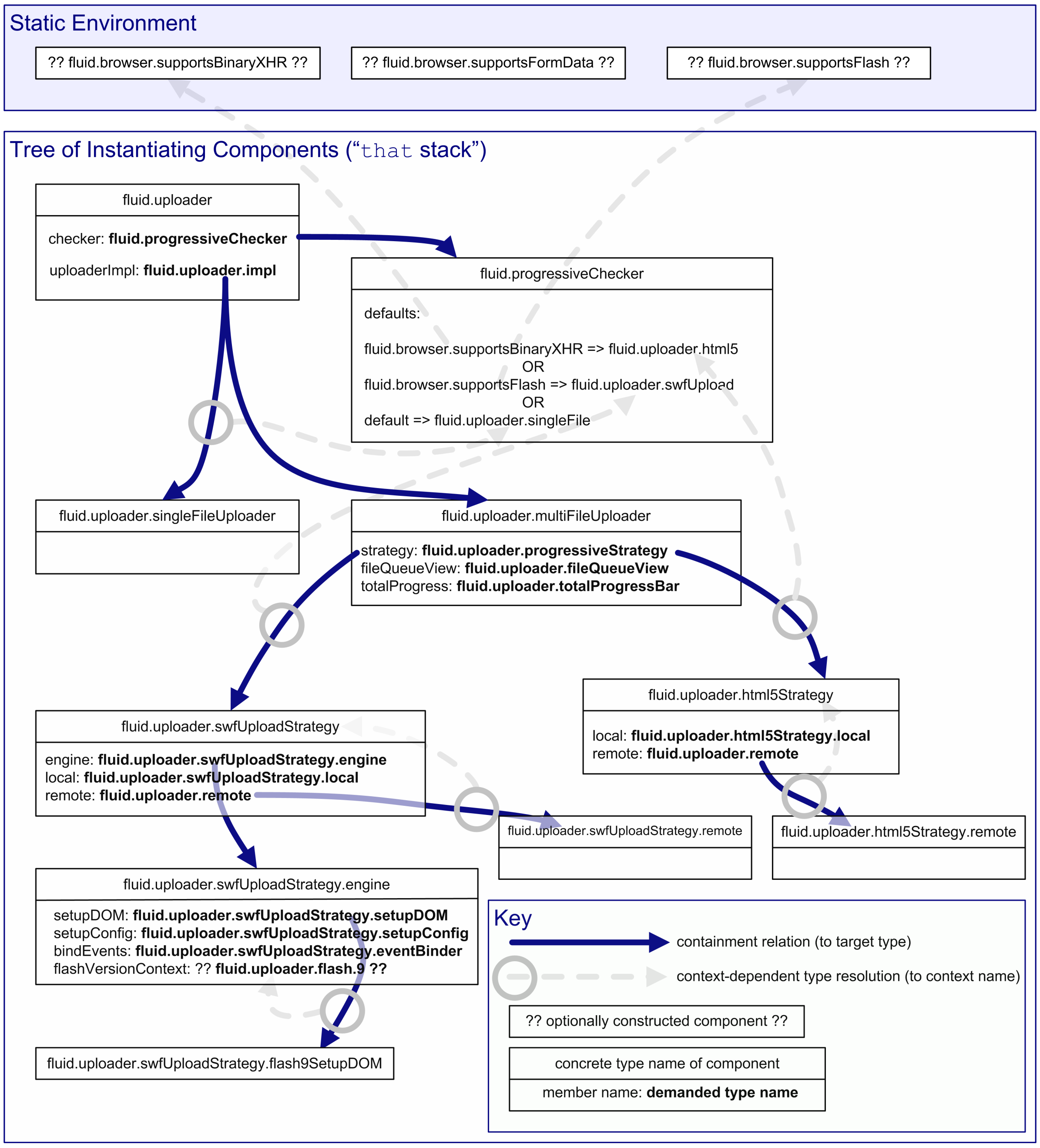

Static Environment
?? fluid.browser.supportsBinaryXHR ??
?? fluid.browser.supportsFormData ??
?? fluid.browser.supportsFlash ??
Tree of Instantiating Components ("that stack")
fluid.uploader
checker: fluid.progressiveChecker
uploaderImpl: fluid.uploader.impl
fluid.progressiveChecker
defaults:
fluid.browser.supportsBinaryXHR => fluid.uploader.html5
OR
fluid.browser.supportsFlash => fluid.uploader.swfUpload
OR
default => fluid.uploader.singleFile
fluid.uploader.singleFileUploader
fluid.uploader.multiFileUploader
strategy: fluid.uploader.progressiveStrategy
fileQueueView: fluid.uploader.fileQueueView
totalProgress: fluid.uploader.totalProgressBar
fluid.uploader.html5Strategy
local: fluid.uploader.html5Strategy.local
remote: fluid.uploader.remote
fluid.uploader.swfUploadStrategy
engine: fluid.uploader.swfUploadStrategy.engine
local: fluid.uploader.swfUploadStrategy.local
remote: fluid.uploader.remote
fluid.uploader.swfUploadStrategy.remote
fluid.uploader.html5Strategy.remote
fluid.uploader.swfUploadStrategy.engine
setupDOM: fluid.uploader.swfUploadStrategy.setupDOM
setupConfig: fluid.uploader.swfUploadStrategy.setupConfig
bindEvents: fluid.uploader.swfUploadStrategy.eventBinder
flashVersionContext: ?? fluid.uploader.flash.9 ??
fluid.uploader.swfUploadStrategy.flash9SetupDOM
Key
containment relation (to target type)
context-dependent type resolution (to context name)
?? optionally constructed component ??
concrete type name of component
member name: demanded type name

Figure 8: Illustration of component tree instantiation for Uploader widget

developing `Node.js` framework based on an asynchronous I/O model. A back-end based on Apache's CouchDB persistence technology using JavaScript as a query language will enable a homogeneous development model operating JavaScript at all tiers of the web application, which is hoped to bring developments of lowered barrier to entry by new developers as well as increased mobility of code and implementation algorithms between the layers.

7. Conclusion

We have made a case arguing that the longevity of application code, as well as the reach of its design space, is greatly increased by reducing as much of its volume as possible to a declarative form. A promising model for such a form are the JSON blocks we have described here, forming the demands and defaults blocks interpreted by the IoC-driven component system. As platforms and technologies change, new demands blocks can weave together with the old to meet new needs, without fragility in existing implementations. Should JavaScript and the web themselves cease to become current, this declarative form is easier to mechanically transform (following the mentality of LISP "macros") into forthcoming idioms, than implementations specified in imperative, sequential code. Such code that *is* written is packaged in global functions which are more or less "free", maximising the chance that it can be reused in fresh contexts without the worry of assumptions embodied in hazardous shared state such as that found in base classes or object instances. Finally, where expectations and contracts do change over time, old implementations may be adapted to new clients, and vice versa, by the interposition of suitable demands blocks, providing the appearance of new contracts for old.

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