

Dual-Reality Objects

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We have of course created a new universe. Our agglomeration of networked computers enables us to move, copy, modify, and store away documents, spreadsheets, images, or other wads of data treating them somewhat as we treat physical objects.

As we design “off the desktop” systems, we increasingly manipulate physical as well as virtual objects. A particularly effective technology here is the radio frequency identity tag (RFID tag). An RFID tag enables a physical object to be marked with a unique number, and RFID readers can detect the presence of the tag even without line of sight access. Thus a carton can be noted as it arrives at a warehouse, and tracked as it gets moved from shelf to shelf. RFID tag readers refer to databases in the virtual world to query or modify virtual data objects that correspond to the carton. The carton has a physical *and* a virtual existence. (See the “passenger” concept in [1]).

Still, the virtual universe and the physical universe seem rather separated. Except perhaps in science fiction, we don’t find objects leaving the physical world to take up residence in the virtual, nor do we find instances of immigration from virtual to real. In almost all instances in which a virtual object creates a real world presence (e.g., as when printing a document), the virtual object stays behind. The same is true when a physical object approaches the boundary to create a virtual world counterpart (e.g.: scanning a document). The membrane between the virtual and the physi-

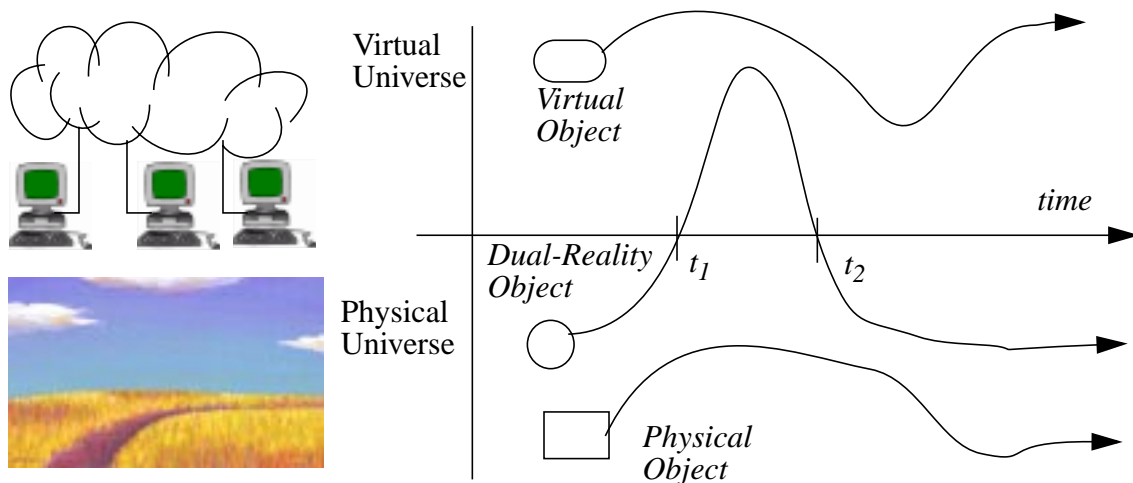


Figure 1. A physical object can exist and move about only in the physical universe, a virtual object only in the virtual universe. A dual-reality object is a new kind of thing that can leave one universe and enter the other. Here at time t_1 the dual-reality object moves into the virtual universe, but returns to physical reality later at time t_2 .

cal is thin enough to allow communication, but apparently too thick to allow penetration in either direction.

We propose to create a fundamentally new kind of object, the *dual-reality object*. The dual-reality object can live in either the physical universe *or* the virtual universe, can freely move between the two, but cannot be in both at the same time (Figure 1).

An implementation scheme is outlined in subsequent sections. The implementation employs special hardware and a distributed software system that enforces the character of physical object within the virtual world. Although one could actually make a bunch according to this approach, the dual-reality object is presented here more as a thought experiment, meant to elicit discussion and insight about the relation between the virtual and physical worlds. The dual-reality object is an extreme point in a design space of possibilities for working with physical and virtual objects in “off the desktop” systems, and as such is intended to highlight fundamental issues. This is not to say that there is no utility here. Applications are discussed in a later section.

What is an object?

The dual-reality object notion is predicated on a particular, pragmatic definition of the word “object.” When we look into the world, we perceive a wash of visual stimuli. Our brain learns to parse this flood of sensory input into objects, a convenience that helps us deal with reality. Now the laws of physics do not ultimately support this object notion: everything is connected to everything else, what is an object in one context can be seen as a loose agglomeration of parts in another, and constituent elementary particles come and go. So any notion of object is a mental construct, a subjective judgement based on observation of emergent phenomena. For the purposes of this work then, I use a very practical meaning: as long as a reasonable human brain perceives an object, there is an object.

How to implement

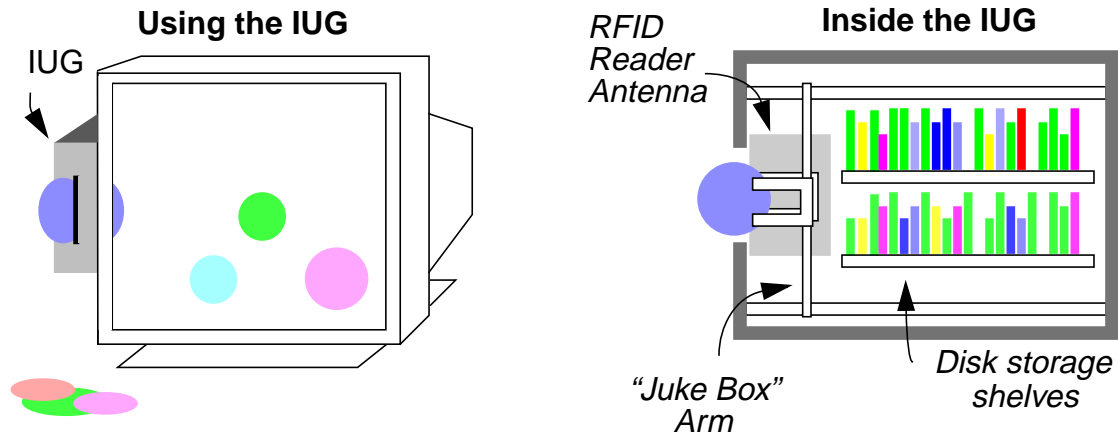
The key device is a Inter Universe Gateway. The IUG appears to “absorb” a software object and “emit” a physical object in such a way as to encourage the human brain to perceive the passing of a single object from the virtual to the physical domain. The IUG can go the other way as well, taking a physical object in to the software world.

The IUG needs associated software, called the IUG Management System, or IUGMS. The IUGMS is described in the next section.

As a first implementation, dual-reality objects might appear as plastic disks of various colors and sizes. Each disk has an RFID tag inside. Just inside the slot is an antenna for an RFID reader, so that as a disk is inserted it’s tag can be read (see Figure 2). The IUG appears simply as a box with a slot in it, but inside, the IUG looks rather like a juke box, with a large collection of disks of various sizes and colors waiting in case they need to be emitted into the physical world.

The IUG typically attaches to the side of a computer display, so that as a disk is inserted into the slot, it can appear on the computer screen.

Figure 2. The Inter Universe Gateway can move dual-reality objects between the physical and virtual universes. The IUG appears as a black box with a slot, and typically attaches to the side of a computer display so an object can be appropriately depicted on the screen as it moves into or out of the virtual world. The internals of the IUG are depicted at right: The RFID reader identifies the tag in each disk as it slides through the slot. A “juke box” arm carries disks between the slot and storage areas inside the IUG box.



Now one might argue that this is simply an illusion, as there are of course two objects involved, a real and a virtual. But in the spirit of the analysis of the previous section, I assert that this illusion is only apparent if you look inside the system. After all, what we perceive to be one object, say a snowflake, can also be considered an illusion created by its constituent molecules. The bottom line is if the everyday human brain perceives something as one object, then it is one object.

The IUG Management System

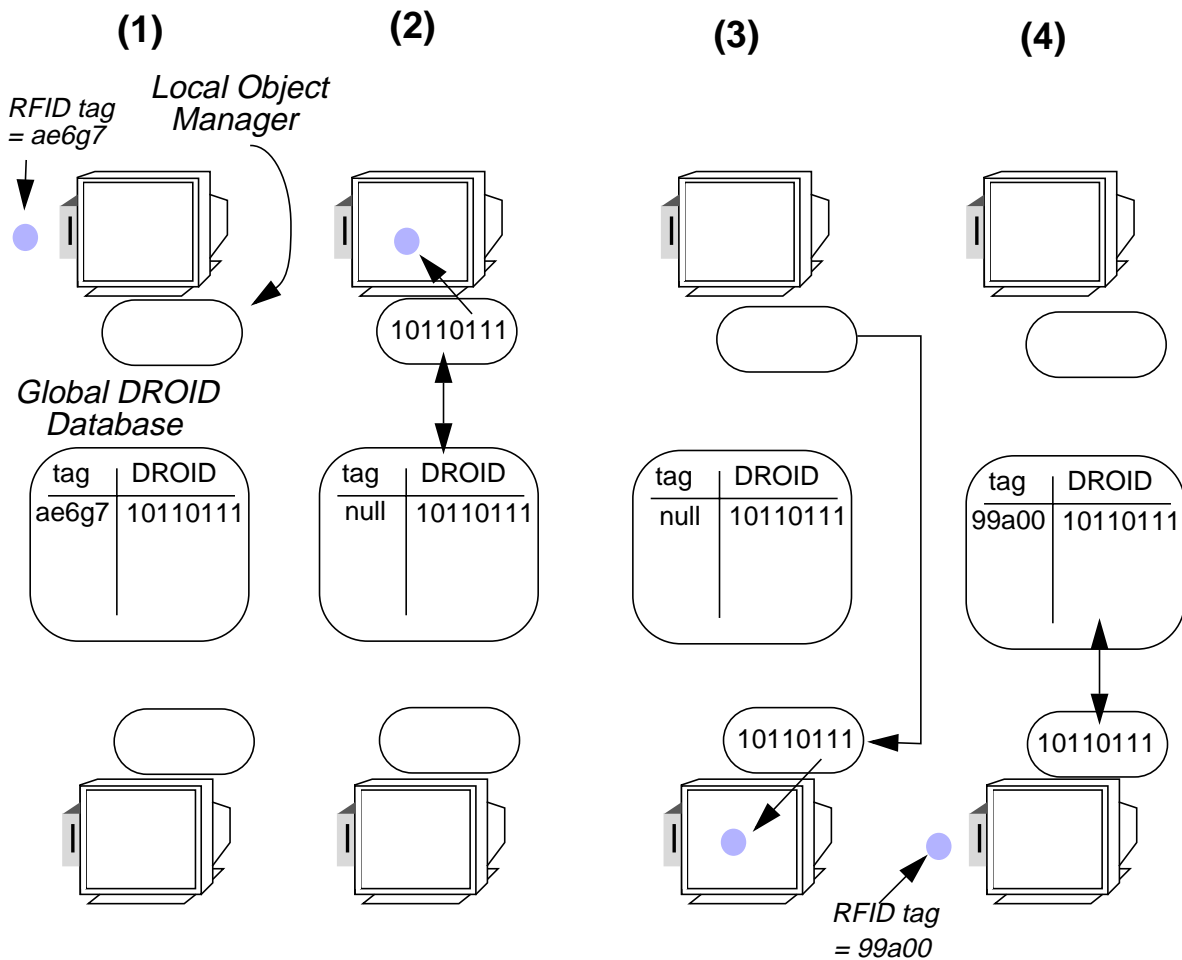
Every dual-reality object has a globally unique ID number called the DROID. It is very important to note that the DROID is *not* the same as the RFID tag value on a plastic disk! This is because throughout the lifetime of a dual-reality object, the object may be implemented as one disk at one time and some other disk at another. Indeed, part of the IUGMS is a global service which stores an association between the DROID and the currently associated plastic disk’s RFID tag value. If the object is not currently in the physical universe, the association is between the DROID and a special symbol, *null*, indicating the object is currently virtual.

The IUGMS is a globally distributed service in combination with the “Local Object Manager” applications associated with each IUG. To move dual-reality object *A* into the virtual world, the IUG notifies the LOM of the RFID tag value on *A*’s disk, read as it passes through the slot. The IUG then stores the disk away in its juke box. The LOM retrieves the DROID for *A*, and the Database removes the association between the DROID and the now irrelevant RFID tag value. The LOM is also responsible for depicting object *A* on the screen.

Once the LOM has *A*’s DROID, it can pass the DROID across the network to another LOM. When this occurs, it is sensible to say that the originating LOM no longer has object *A*, and that the destination LOM has acquired it. The LOM’s cooperate to create this single object illusion, so, for

Figure 3. The Inter-Universe Gateway management system consists of a Global dual-reality object ID Database plus all the Local Object Managers (or “LOMs,” one LOM per IUG box) in cooperation. All communications amongst the LOMS and the Global DROID Database are authenticated. This figure illustrates how to transfer a dual-reality object from one location to another. The disk is inserted into the IUG (1), where the Local Object Manager reads the RFID tag and looks up the DROID from the Global DROID Database (2), which in turn removes the association between that DROID and that RFID tag value. Ownership of the object is passed directly from the originating LOM to the destination LOM (3). The object is made real (4) when the destination IUG causes a disk of the proper size and color to be emitted from its slot. The LOM informs the Global DROID Database of the new RFID tag value.

IUGMS in a real — virtual — real transition.



example, they do not support copying of the DROID. All communication between the Global DROID Database and a LOM is authenticated and encrypted, as is the communication between two LOMs.

The DROID for object A might be implemented as a public/private key pair. The private key would be kept within the IUGMS, but if the public key was given out to a local application (such

as a web browser or media player) then the application can use it to query the local LOM. The LOM could reliably demonstrate whether or not it has object *A*. Thus *A* can act as an unforgeable access right.

The IUGMS obviously shares concerns with digital rights management systems, and there are parallels between the DROID and other identifiers such as the URL [2], DOI [3], and EPC [4], to name surely just a few. The relatively simple implementation described here is intended to convey the basic idea, but many features from existing systems could likely be utilized in a more robust and fully featured design.

Applications

Dual-reality objects might be used anywhere possession of a physical object gives authority, while offering the convenience of being virtualizeable. For example, today, RFID tags are routinely used to give access to doorways. The door system could look up the DROID and utilized it as the enabling key. In this case, a dual-reality “key” could be sent across the network and emitted at the far end. New employees could get their door access tokens by e-mail, absentee landlords could send a key to new tenants, and vacationing homeowners could send their key to neighbors or visiting relatives, without having to anticipate their need for access. This method does not require the duplication of keys and the attendant need to invalidate copies. Rather, the key is returned, so loss of authority is visible to the possessor.

A dual reality object could be used as a kind of virtual CD or DVD token. Customers who buy music over the web (or rent a DVD) are issued a dual reality object. If the disk is inserted into the IUG so that it becomes held by their computer’s LOM, user’s can play the music over the computer’s speakers, or watch the DVD on the screen. But as a physician token, the disk can be carried between computers or loaned to a friend by physical or virtual transfer. While your friend has the object, you can no longer play the music or watch the video. This recaptures our current model of access right as enforced by possessing physical media.

Conversely, dual-reality objects can be used anywhere a virtual object is used, but then moved into the real world should that be convenient. The DROID might be used as a virtual access right. Removing a DROID into the physical world effectively removes the access right from the virtual world. Having a document in one’s pocket might offer a sense of increased security, plus enables one to pass it along to a friend or colleague at a meeting or informal encounter.

Dual-reality objects support “delegation” (by physically passing or by e-mailing the object). Delegation has the advantage of being transitive: if you send me your house key while on vacation so I can feed the cat, then I can send it (or simply hand it) to someone I trust if I find I am temporarily unable to feed the cat. You do not need to anticipate who I may wish to authorize.

Extensions

For maximal utility, the RFID tag value should also be unforgeable. Putting cryptographic calculations on the RFID tag is beyond the reach of current technology for passive (unpowered) tags, but certain elliptic curve cryptographic calculations may soon be installed in battery powered tags.

It would be nice if any marks made on a plastic disk could be scanned as it passes into the IUG, and so printed on a new disk as it “becomes real.” Rather than plastic disks, one could of course use 3D scanners and 3D printers. Then the IUG could take in any 3D shape, and cause it to appear later at any remote location.

It is natural to start thinking about revoking the rights associated with a dual reality object, or allowing copies, or otherwise enhancing the functionality, but this paper purposely leaves out such discussions in order to retain focus on the basics.

Some Conclusions

The dual-reality object is a fundamentally new kind of thing. An object that can live in either our physical or virtual universe. It could be a building block in many “off the desktop” systems. The route taken in the current design favors the flavor of physical object, enforcing a single location, a single holder of the true thing. But this is not necessarily the character of the physics underlying software objects. Virtual physics is in fact malleable, and so in this design the virtual side of the equation was forced into mimicking physical reality, to enforce a coherent physics across both domains. It might be interesting to consider the implications of relaxing this uniformity.

Acknowledgement

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References

[1] N. Streitz, T. Prante, C. Muller-Tomfelde, P. Tandler, and C. Magerkurth, “Roomware(R) - The Second Generation,” in *Proc. CHI 2002* (Minneapolis, Minnesota, April 2002), pp 506 - 508, ACM 2002.

[2]<http://www.w3.org/Addressing/>

[3] <http://www.doi.org/hb.html>

[4] http://www.autoidcenter.org/aboutthetech_indepthlook.asp