TCL Abstract Lists

What Are They, and
Why Extension Authors Should Care

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Abstract Lists in TCL

Agenda

- Introduction
- What is a TCL List
- What is an Abstract List
- Why Abstract Lists
- How to Create an Abstract List
- Critical Things to Know! (even if you are not interested in Abstract Lists!)
- Q & A

Introduction

A quote from a recent post in TclChat:

mjanssen:

”I’ve worked with two tools that use TCL and implement the concept of "collections", which are basically sets of elements where each element has a very complex description. In one of them, collections had string representations so you could use them as lists, but <u>transforming them into lists had a high cost</u>. So my understanding is that ***the tool created versions of several commands (concat, lappend, lindex, etc) that bypassed TCL’s native implementation.***"

TCL List

```
0: [”One”  ]
1: [”Two”  ]
2: [”Three”]
3: [”Four” ]
```

- A collection of values stored in an C array.
- Access to values by indexing the array.
- Values stored in a Tcl_Obj struct
  - Tcl_Obj holds 2 representations, (called the ”stork” model)
    - Canonical string
    - Internal representation, such as an integer or a List.
- Access via commands in a script, or C API calls.
- List commands: lindex, lsearch, lsort, lrange, foreach, lset, etc, are tied to this data model.

Abstract List

- An Abstract List
  - Separates the data management from the access operations.
  - Access is via a set of protocol functions.
- How list values are stored or managed depends on the protocol functions.
  - Examples: RB-Tree, Hash Table, Directed Graph, f(x)
- Values can even be computed on demand
  - The value for a given index must be consistent with the string representation of an equivalent List.

Abstract List

continued

- The `[lseq]` command is implemented as an Abstract List.
- Generates a sequence of numbers based on a start, end, and step values.

```
[lseq 10 .. 15 by 3] -> {10 13 16 19 22 25}
```

- Values computed using math: *f*(index) = ($start `+ ($index * $step))`
- This allows for very large lists with O(1) create time.
  Just don't ask for a string of the entire list. 😉

WARNING!

Extension Maintainers — Take Note!

- A TCL List value holds a reference to an element Obj.
- `Tcl_ListObjIndex(interp, listPtr, index, &elemObj)`
  Returns an **Obj** with a **refCount** of **1** or greater.
- With an <u>Abstract List</u>, it is possible that the returned element can have a **refCount** of **0**.
- **lseq will return an element with a refCount of 0.**
- **The caller is responsible for freeing the Obj when it is no longer needed!**
- `Tcl_BumpObj(objPtr)` - new function used to free Obj with refCount==0
- Or use the practice of calling Tcl_IncrRefCount(), then Tcl_DecrRefCount()

Abstract List

continued

- In some cases, an Abstract List will be converted to a traditional list.
- This occurs when the Abstract List is incapable of honoring the protocol request.
- An example: using [lset] on an [lseq] sequence:

```
set s [lseq 8]
lset s 5 ”Hi”
```

- After the `lset`, the new value will be a traditional list:

```
0 1 2 3 4 Hi 6 7
```

Why Abstract Lists

- Optimize
  - Value storage space
  - Value access
  - Computation
- Eliminate the need to mimic List commands
- Reduce or eliminate ”shimmering”
  - In TCL, defined scalar value types have a Length function that always returns 1
  - This avoids the conversion to a List

```
set k [expr {6 + 7}]
set point {3 15}
…
if {[llength $k] > 1} {
    # Process a point
    …
} else {
    set x [expr {$k / 2}]
}
```

Why Abstract Lists

continued

- Example extensions that can benefit from Abstract Lists
  - tarray - https://wiki.tcl-lang.org/page/TArray
  - vectcl - http://auriocus.github.io/VecTcl/
    and http://auriocus.github.io/VecTcl/design/40.html
  - There are certainly many more …

Creating an Abstract List

List Protocol Functions

```
Tcl_Size (LengthProc)  (Tcl_Obj *listPtr);
int      (IndexProc)   (Tcl_Interp *interp, Tcl_Obj *listPtr, Tcl_Size index,
                        Tcl_Obj** elemObj);
int      (SliceProc)   (Tcl_Interp *interp, Tcl_Obj *listPtr, Tcl_Size fromIdx,
                        Tcl_Size toIdx, Tcl_Obj **newObjPtr);
int      (ReverseProc) (Tcl_Interp *interp, struct Tcl_Obj *listPtr,
                        Tcl_Obj **newObjPtr);
int      (GetElements) (Tcl_Interp *interp, struct Tcl_Obj *listPtr,
                        Tcl_Size *objcptr, Tcl_Obj ***objvptr);
Tcl_Obj* (SetElement)  (Tcl_Interp *interp, Tcl_Obj *listPtr, Tcl_Size indexCount,
                        Tcl_Obj *const indexArray[], Tcl_Obj *valueObj);
int      (ReplaceProc) (Tcl_Interp *interp, Tcl_Obj *listObj, Tcl_Size first,
                        Tcl_Size numToDelete, Tcl_Size numToInsert,
                        Tcl_Obj *const insertObjs[]);
```

Creating an Abstract List

continued

```
typedef struct Tcl_ObjType {
    const char *name;
    Tcl_FreeInternalRepProc *freeIntRepProc;
    Tcl_DupInternalRepProc *dupIntRepProc;
    Tcl_UpdateStringProc *updateStringProc;
    Tcl_SetFromAnyProc *setFromAnyProc;

    size_t version;

    /* List emulation functions - ObjType Version 2 */
    Tcl_ObjTypeLengthProc *lengthProc;       /* Return the [llength] */
    Tcl_ObjTypeIndexProc *indexProc;         /* Return [lindex $al $index] */
    Tcl_ObjTypeSliceProc *sliceProc;         /* Return [lrange $al $start $end] */
    Tcl_ObjTypeReverseProc *reverseProc;     /* Return [lreverse $al] */
    Tcl_ObjTypeGetElements *getElementsProc; /* Return an objv[] of all elements */
    Tcl_ObjTypeSetElement *setElementProc;   /* Replace element, as in [lset al $val] */
    Tcl_ObjTypeReplaceProc *replaceProc;     /* Replace subset with subset, e.g. [lreplace] */
} Tcl_ObjType;
```

Original ObjType

Version

Abstraction Functions

Creating an Abstract List

continued

- Set version field using a macro
    - TCL_OBJTYPE_V0 // Used for existing definitions (pre 9.0)
    - TCL_OBJTYPE_V1(a) // Used for scalar values.
      // ”a” is an length function that returns 1
    - TCL_OBJTYPE_V2(a,b,c,d,e,f,g) // Used for Abstract Lists
      // a-g are the set of List functions

Creating an Abstract List

continued

- Abstract List protocol functions are counterparts to the C API functions that perform the same action.
- List protocol functions are optional*.
- In the absence of a function, TCL will revert back to internal List behavior.
  - For example, without a SetElement function, TCL will first convert the list to a traditional TCL list, then complete the [lset] operation as usual.
- *The Length function is required for any Abstract List.
  Without it, none of the other functions will be invoked.

Creating an Abstract List

Examples

- Example ”toy” implementations of Abstract Lists can be found:
  - https://github.com/bgriffinfortytwo/abstractlist-toys
- An Abstract List adaptation of VecTcl
  - https://github.com/bgriffinfortytwo/VecTcl9/tree/abstractlist

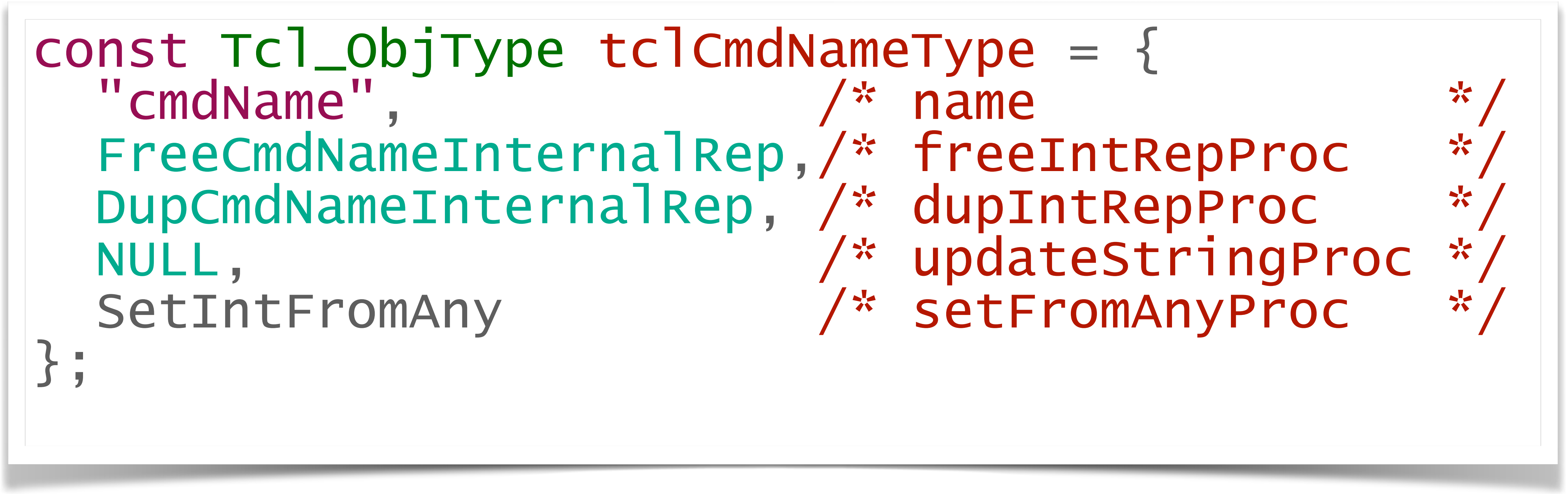
WARNING!

- A TCL List value always hold a reference to an element Obj.
- There is code out there that relies on calls to Tcl_ListObjIndex(…) to **return** an **Obj** with a **refCount** of **1** or greater.
- The caller then does not bother with refCount management if it does not hold a reference directly. — This can result in a memory leak in TCL9.0!
- **[lseq] will return an element with a refCount of 0. The caller is responsible for freeing the Obj when it is no longer needed!**
- **Tcl_BumpObj(***objPtr***)** - new function used to free Obj with refCount==0

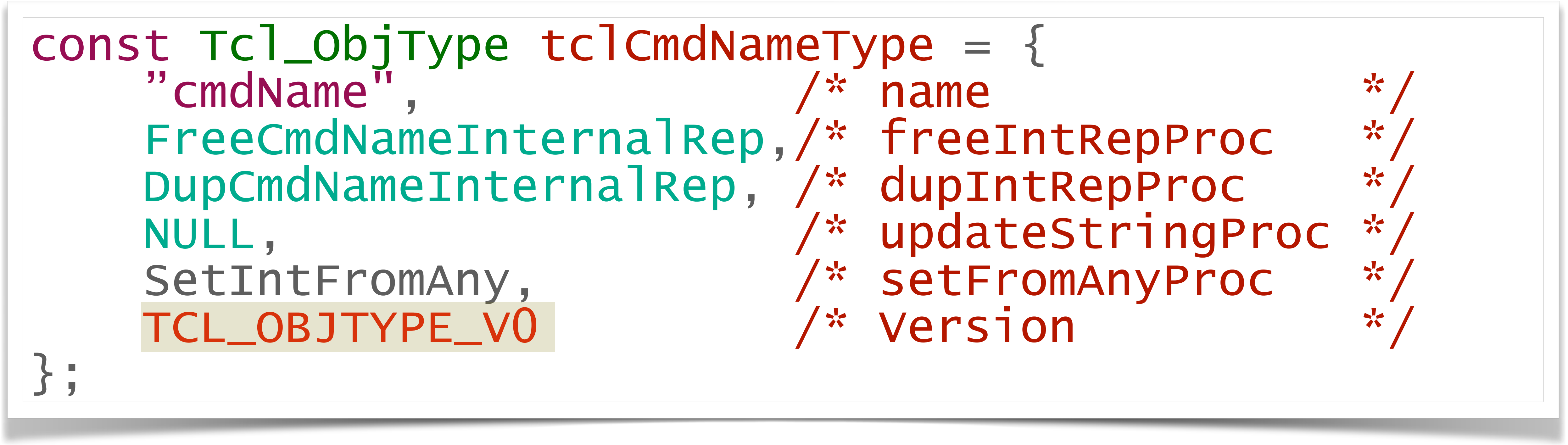
Critical Things to Know for 9.0

continued

- The Tcl_ObjType struct has new fields.
- Code that uses Tcl_ObjType will likely receive a compile warning or error.
- Use the macro **TCL_OBJTYPE_V0** to correct the warning.
  No other changes will be needed.



```
const Tcl_ObjType tclCmdNameType = {
   "cmdName",                /* name              */
   FreeCmdNameInternalRep,/* freeIntRepProc    */
   DupCmdNameInternalRep, /* dupIntRepProc     */
   NULL,                     /* updateStringProc */
   SetIntFromAny             /* setFromAnyProc   */
};
```



```
const Tcl_ObjType tclCmdNameType = {
    "cmdName",                /* name              */
    FreeCmdNameInternalRep,/* freeIntRepProc    */
    DupCmdNameInternalRep, /* dupIntRepProc     */
    NULL,                     /* updateStringProc */
    SetIntFromAny,            /* setFromAnyProc   */
    TCL_OBJTYPE_V0            /* Version           */
};
```

Precursors of Abstract Lists

- TIP 192: Lazy Lists (https://core.tcl-lang.org/tips/doc/trunk/tip/192.md)
- TIP 225: Arithmetic Series with Optimized Space Complexity
- TIP 629: Add a lseq (formally "range") command

- The original authors of the Abstract Lists concept (and some code) are: Alexandre Ferrieux, Salvatore Sanfilippo, and Miguel Sofer

Q & A