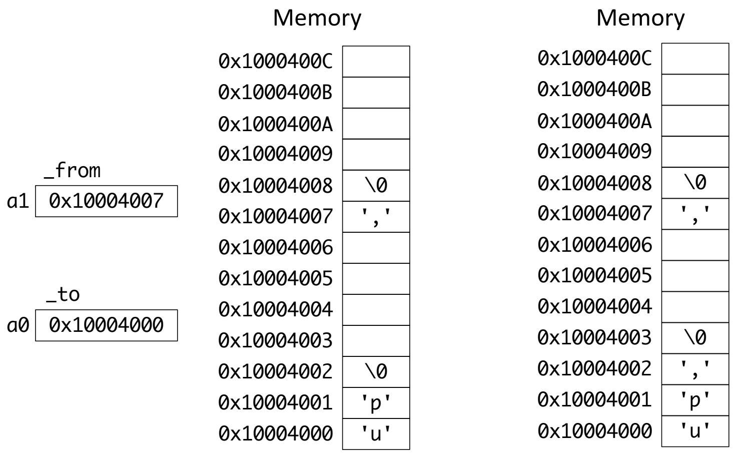
You are developing a new App where you can record the movement of a ball in a real-life shuffle board game and then convert it into movements of a blinking ball in a grid on the screen. Unfortunately the trajectory-capturing software records the movement of the real ball into a binary representation and the image-rendering library that you are using was written in JavaScript and expects a string of word commands. An important mobile device in the target market is based on a RISC-V microcontroller that uses RISC-V assembly, but there is no compiler available for this controller yet. Thus you will have to write RISC-V assembly routines to do this conversion. To make the task easier, you have divided the functionality that you need into two separate routines.

Question 4 (20 points): In this question you will write `concatenate`, a subroutine that receives two pointers to null-terminated strings: `a0` receives the `_to` pointer, which is the address of the string that will be grown by the concatenation; `a1` receives the `_from` pointer, which is the address of the string that is to be concatenated into the string pointed by `_to`. Figure 1 illustrates the effect of one call to the subroutine concatenate. You can assume that there is enough memory allocated for the `_to` string to enable the concatenation of the `_from` string without overwriting to other data structures in the program. You must follow all the subroutine invocation conventions of RISC-V.



(a) before `concatenate` (b) after `concatenate`

Figure 1: Example of execution of a concatenate function.

Figure 2 shows an implementation of `concatenate`

```
# concatenate
# receives two pointers to null-terminated strings (_to and _from)
# and concatenates the string pointed by the pointer _from
# into the string pointed to by the pointer _to
# example: if _from points to the string "set"
#             and _to points to the string "up"
#          then after concatenate, _to will point to the string "upset"
# arguments:
#   a0: _to is the address of the string to be grown
#   a1: _from is the address of the string to be appended to _to
# register usage:
#   a0: p_to is a pointer to _to array
#   a1: p_from is a pointer to _from array
concatenate:
    lb      t0, 0(a0)         # t0 <- first character of _to
    beq     t0, zero, append  # if t0 == null found the end of _to
nextchar:
    addi    a0, a0, 1         # p_to++
    lb      t0, 0(a0)         # t0 <- next character in _to
    bne     t0, zero, nextchar    # if t0 != null get next _from character
append:
    # a0 contains the position where _from should be placed into _to
    lb      t1, 0(a1)         # t1 <- next character in _from
    sb      t1, 0(a0)         # *p_to <- t1
    addi    a0, a0, 1         # p_to++
    addi    a1, a1, 1         # p_from++
    bne     t1, zero, append  # if t1 != null append next _from character into _to
    jr      ra
```

Figure 2: A solution for `concatenate`.