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PROOF OF A CONJECTURE OF CHAN, ROBBINS, AND YUEN *

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Abstract. Using the celebrated Morris Constant Term Identity, we deduce a recent conjecture of Chan, Robbins, and Yuen (math.CO/9810154), that asserts that the volume of a certain $n(n-1)/2$-dimensional polytope is given in terms of the product of the first $n-1$ Catalan numbers.

Key words. combinatorics, Catalan numbers, polytope.

AMS subject classifications. 05-XX, 52B05.

1. Main Result. Chan, Robbins, and Yuen [1] conjectured that the cardinality of a certain set of triangular arrays $\mathcal{A}_n$ defined in pp. 6-7 of [1] equals the product of the first $n-1$ Catalan numbers. It is easy to see that their conjecture is equivalent to the following *constant term identity* (for any rational function $f(z)$ of a variable z, $CT_z f(z)$ is the coeff. of z^0 in the formal Laurent expansion of $f(z)$ (that always exists)):

$$CT_{x_n} \dots CT_{x_1} \prod_{i=1}^{n} (1-x_i)^{-2} \prod_{1 \le i < j \le n} (x_j - x_i)^{-1} = \prod_{i=1}^{n} \frac{1}{i+1} \binom{2i}{i}. \tag{1.1}$$

But this is just the special case $a = 2$, $b = 0$, $c = 1/2$, of the *Morris Identity* [2] (where we made some trivial changes of discrete variables, and 'shadowed' it)

$$\begin{gathered} CT_{x_n} \dots CT_{x_1} \prod_{i=1}^{n} (1-x_i)^{-a} \prod_{i=1}^{n} x_i^{-b} \prod_{1 \le i < j \le n} (x_j - x_i)^{-2c} = \\ \frac{1}{n!} \prod_{j=0}^{n-1} \frac{\Gamma(a+b+(n-1+j)c)\Gamma(c)}{\Gamma(a+jc)\Gamma(c+jc)\Gamma(b+jc+1)} \, . \end{gathered} \tag{1.2}$$

To show that the right side of (1.2) reduces to the right side of (1.1) upon the specialization $a = 2, b = 0, c = 1/2$, do the plugging in the former and call it M_n. Then manipulate the products to simplify M_n/M_{n-1}, and *then* use *Legendre's duplication formula* $\Gamma(z)\Gamma(z+1/2) = \Gamma(2z)\Gamma(1/2)/2^{2z-1}$ three times, and *voilà*, up pops the Catalan number $\binom{2n}{n}/(n+1)$. ☐

REMARK 1.1. *By converting the left side of (1.2) into a contour integral, we get the same integrand as in the Selberg integral (with $a \to -a$, $b \to -b-1$, $c \to -c$). Aomoto's proof of the Selberg integral (SIAM J. Math. Anal.* **18***(1987), 545-549) goes verbatim.*

REMARK 1.2. *Conjecture 2 in [1] follows in the same way, from (the obvious contour-integral analog of) Aomoto's extension of Selberg's integral. Introduce a new variable t, stick $CT_t t^{-k}$ in front of (1.1), and replace $(1-x_i)^{-2}$ by $(1-x_i)^{-1}(t + x_i/(1-x_i))$.*

REMARK 1.3. *Conjecture 3 follows in the same way from another specialization of (1.2).*

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